# GENERAL BOARD OF HEALTH.

MINUTES

OF

# INFORMATION

COLLECTED WITH REFERENCE TO WORKS

FOR THE

## REMOVAL OF SOIL WATER OR DRAINAGE OF DWELLING HOUSES AND PUBLIC EDIFICES

AND FOR THE

## SEWERAGE AND CLEANSING OF THE SITES OF TOWNS.

**Ordered to be printed for the use of Local Boards and their Officers, engaged in the Administration of the Public Health Act, and of the Nuisances Removal and Diseases Prevention Act.**

JULY 1852.

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# GENERAL BOARD OF HEALTH.

MINUTES of INFORMATION on the DRAINAGE and CLEANSING of HOUSES and PUBLIC and PRIVATE EDIFICES, and the SITES of TOWNS.

THE testimony of such medical men as have duly observed the antecedents of disease is now unanimous to the effect, that no population living amidst cesspool-emanations, or in air rendered impure by such causes, can continue to be healthy. The strong may withstand these noxious influences for a time, but even their general health is eventually lowered, and their constitutions undermined by continued exposure to such emanations, while the effect, especially when concentrated upon the weakly and susceptible, is, in certain atmospheric conditions, extensively and rapidly fatal.

The presence of atmospheric impurity produced by the decomposition of animal and vegetable matter is now established as a constant concomitant of the excessive ravages of typhus and other epidemic diseases in towns; and a proportionate exemption from such maladies has marked the removal of the sources of aërial pollution. In proportion as perfect cleanliness has been obtained in prisons, the gaol fever has ceased to exist; and a comparative exemption from the entire class of zymotic * diseases has followed the progress of purification in every description of habitations.

These sanitary views are in conformity with great primitive religious ordinances, both for household and personal purification. For instance, by the law of Moses it was forbidden that even the open camp should be defiled with human ordure, which it was expressly ordained should be deposited at a distance, and immediately covered with soil. Many of the positive observances directed by the Mosaic law had a similar sanitary purpose. The ultimate object of the chief engineering appliances for the sanitary improvement of towns is precisely the same as that of

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* The term zymotic (from ζυμόω, I ferment, *zymosis*, fermentation), is applied to designate that class of diseases which are conceived to owe their origin to causes which act upon the system in a manner analogous to the action of yeast upon the gluten of flour; (not that there is any evidence that this is a real operation, but the idea may be admitted as a convenient means of classification); the class includes the diseases usually considered to be epidemic, endemic, or contagious.

the Mosaic ordinances for the preservation of the camp from defilement; and the result of those engineering operations will be the practical fulfilment of the Mosaic regulations for the cleanliness of the person, and for the cure or removal of the "leprous house."*

The habits of a people with respect to cleanliness, and more especially with respect to their care to protect their habitations from pollution by excrementitious matter, are a clear indication of their progress in civilization.† Archdeacon Paley was accustomed to direct the particular attention of travellers in foreign countries to the mode in which the people dealt with their excreta, stating that from this single fact a greater insight might be gained into their habits of cleanliness, decency, self-respect, and industry, and in general into their moral and social condition, than from facts of any other class.

It is a deplorable proof of the want of information and of due appreciation of the circumstances on which the improvement of the moral as well as the physical condition of the population depends, that the existence of filth in houses and towns, the prevalence of filthy habits among the people, and the efforts to remedy or mitigate the attendant evils, are often treated with

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* *Vide* Lev. xiv. 33—48; and the commentaries of Michaelis on the Mosaic ordinances.

† In a state of nature animals will not, when at liberty, remain near or sleep over their own droppings. Some animals are endowed with instincts to cover them up. When attention is paid to the proper keeping of animals, it is found to be injurious to allow them to lie amidst the fumes of their own dung. Formerly the Zoological Society suffered heavy losses among the animals kept at Regent's Park from neglect of this law, as, *e.g.*, in the case of the carnivora, which were originally confined in a roofed and enclosed building, the atmosphere of which, during a single night, became strongly impregnated with ammoniacal exhalations. A marked improvement has followed the keeping of the same order of animals in dens exposed to the open air, together with the practice of immediate removal of the excrement. Skilful trainers of horses for hunting and racing have their stables carefully cleansed, and all dung as well as the urine removed, three times a day, to such a distance that no fumes from them may reach the animals. But the common practice in towns is to keep the dung in the stables for weeks, during which time not only the animals, but the neighbourhood, are subjected to insalubrious effluvia, the effects of which are strikingly visible in the pallid countenances and inferior stamina of the grooms and stable boys. On an investigation of the disease among hunting dogs called "kennel lameness," it was found that mere change of the sites of kennels did not avert it; and eventually its cause was ascertained to be defective cleansing, including the want of a due supply of pure water, and of effectual drainage. A person having much experience on the subject lays it down as an axiom, that the removal of all foul matters from within or beneath the kennels, must not only be constant and complete, but distant; and that no opening of a drain should be allowed within at least 100 yards of the kennel.

unconcern, as if the subject was of no consequence, or fitted only to excite disgust. It may not be needful that persons on whom no duties in this behalf devolve should enter closely into the details in question, but it is incumbent on the local administrators of the law for improving the sanitary condition of the people to show by their manner of dealing with its provisions that they regard them as the means of fulfilling, and as being, in fact, when completed, the practical fulfilment of the primitive ordinances for personal and household purification; and it is important that they should treat even the minutest and most repulsive details with the like scrupulous and anxious care with which physicians deal with the most offensive particulars attendant upon sickness, suffering, and mortal disease.

### *Superior Economy of the Removal of Refuse by Water.*

Apart from all social, moral, and sanitary considerations, requiring the *immediate* removal of all excrementitious matters from the neighbourhood of dwelling-houses, assuming merely that all such matter must eventually be taken away, the arrangements should be at least made on the basis of the most economical and convenient means of removal.

Early in the progress of these investigations, the proposed system of cleansing, by the removal of ordure in suspension in water, was objected to on the ground of the supposed loss of manure which it would occasion. To this it was and still may be replied, that if there were a total loss of the money now received, or which might reasonably be expected, for manure, that loss would be trivial as compared with the expense entailed by the retention of ordure amidst habitations during the usual intervals between its removals by the common means. Where the householders, instead of paying for the removal of ordure, receive money from the farmers, for the accumulations, as in some of the provincial towns they do, the utmost payment does not cover the increased expenses occasioned by excessive sickness, apart from the bodily disability, the loss of work, and premature decay and death, inevitably occasioned by constantly breathing the impure air diffused over the premises. *Vide Sanitary Report*, 1842, p. 226, and *Supplement*, 1843, p. 72.

Professor Liebig objected to water-closets, (which he supposed to be peculiarly English,*) on the alleged ground that they necessitated the entire loss of the most valuable manure, assuming as an unavoidable consequence, that the whole of the manure must be poured, as at present, into the rivers on which

* The water-closet apparatus has been found at Herculaneum.

towns are seated. All such waste is, however, unnecessary. Except under extreme circumstances the alternative of polluting natural streams may be prevented. In the Minutes of Information on the Application of the Refuse of Towns to Agriculture, it is shown that in no mode can the refuse be so well received, so completely preserved, and so productively applied, as in suspension in water; while the greater expense of cesspools is shown in a Report which Mr. Rammell, one of the inspectors of the Board, was requested to make of the "Cesspool System of Paris," in which metropolis it is developed on the largest scale, under the most systematic management. The facts set forth in that report prove that by the adoption of the soil-pan or water-closet principle, and the tubular mode of drainage in the course of introduction into English towns, a saving might be effected in Paris of a million francs per annum. In the Minutes on the Application of the Refuse of Towns to Agricultural production, it is further shown that the fertilising power of the excrementitious matters would by the same means be enormously augmented.

But if, on the contrary, the substitution of water-closets for cesspools would necessarily involve the loss of the manure, the change would nevertheless be economical, since the annual cost of a cesspool, including interest, depreciation, repairs, and expenses of emptying and carrying away the refuse, considerably exceeds the annual cost of a water-closet, on the assumption that the first cost is repaid by an annual charge, and that the water is supplied at a fair price, that is, at a price proportionate to the expense of obtaining the water.

It appears that the quantity of cesspool refuse, including ordure and other animal and vegetable matter, is from one to two cubic yards per house per annum;* and the cost of its removal in London (including openings, and making good the cesspool, and cartage out of town) was stated by contractors, and proved upon a house-to-house inquiry, to be, on an average, about 20*s.* per annum.† The annual cost of the construction of a cesspool (including interest and depreciation), is estimated

* There are various estimates which give the night-soil and urine at one cubic yard and half per family of five persons; but other refuse, washings, animal and vegetable matter, thrown down water-closets or into cesspools make up the larger quantity.

† In many country towns, where night-soil is kept in shallow uncovered pits (called midden-holes), the cost of emptying is less than where deep cesspools are used, but although the emanations as being more diluted may be less noxious than those arising from covered cesspools, the sight of the exposed ordure is offensive and degrading, and the open midden-steads are in other respects serious nuisances.

to average not less than 10*s*. per house. When cheap cesspools are made, from which percolation is not prevented, the injury to the foundations of the houses would more than make up the difference.

This annual cost of 30*s*. per house is moreover the balance of loss above the value of the manure which those who take it away may retain for use if they please ; and in country towns, farmers often pay a small sum for liberty to take the night-soil away ; which, however, diminishes but in a small degree the cost of retaining it. The fœtid smell caused by the disturbance of night-soil in the vicinity of houses has led to the extensive use of apparatus for artificial dilution with water, so that it can be pumped through moveable pipes to the nearest sewer or stream. Though in addition to the expense of the operation, there is in this mode of removal a sacrifice of the entire agricultural value of the matter removed, the alternative is gladly adopted to avoid the nuisance of emptying by hand labour ; and it is therefore fair to add the intrinsic value of the manure thus sacrificed to the necessary expenses of the cesspool practice.

This sacrifice is carried to such an extent that often where there is sufficient open ground, a pit is dug and the contents of the cesspool are at once buried ; and in London it requires much vigilance by the police to prevent the men who are paid for removing ordure, from discharging it surreptitiously into the sewers through the gully-shoots, where, in its undiluted and highly concentrated state, it is a very dangerous nuisance. These facts prove that the value of the manure as now dealt with does not equal the cost of its removal, though that value, if the refuse were removed and applied in the most economical and efficient manner, would as to cottages be often equal to a moiety of the rent.

To obviate the nuisance and danger of cleansing cesspools, the use of moveable receptacles has been extensively adopted in Paris and other continental cities, and the expedient has been proposed for this purpose, and also for the saving of manure, in this country. But although the nuisance of emptying cesspools is prevented by the use of these receptacles, they are not found to arrest decomposition, or to prevent the loss of the most valuable part of the manure, and they are found to be more expensive than properly-constructed water-closets.*

* M. de Piorry, a French writer on Hygiene, whilst admitting the failure of the moveable cesspools to confine the noxious emanations, and the fact that they had been reported against as having proved injurious to the health of the inhabitants and the public, shows, nevertheless, that they are less expensive than the old fixed cesspools ; and his statement as to

The more expensive form of water-closet, and the connected drainage arrangements by which the constant removal of all excrementitious matter is effected, would not, as a distributed charge, usually exceed 6*s.* per annum; and the proper charge for the water consumed for the supply of an efficient water-closet should not be more than 6*d.* per annum; (*vide Report on Water Supply*, p. 293) for even when the water is supplied by a company, this, under public contract, would, almost without exception, be a remunerative price. No separate charge should be made for water-closets; the supply for such appurtenances being necessary for all, should be included in the general charge for the house.

Where a constant supply of water under pressure is given, of course no expense for a cistern need be incurred, the force of the water direct from the pipe being found abundantly sufficient for the removal of all the soil, &c. through a syphon of four inches diameter into the tubular drain. Where the shell of a closet, or a suitable privy, exists, all the apparatus necessary for perfecting this indispensable sanitary improvement will, therefore, be a service-pipe, a tap (self-acting or with lever handle), an earthenware basin, and a syphon-pipe, the cost of which, if distributed, need not exceed 3*s.* or 4*s.* a year. This is a rate of expense for the complete removal of refuse, with which no hand labour in emptying, and cartage in removal, can ever compete;* and it is very far below

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this economy will be available, and may be used as showing the yet greater economy of the water-closet connected with a tubular system of drainage. "A cesspool of the simplest construction costs from 39*l.* to 120*l.* as the first expense, according to the size and the nature of the soil. To repair a cesspool often costs much more. We will admit that the first cost is 43*l.*, which at 5 per cent. will be an annual expense of 2*l.* 7*s.* 6*d.* Moreover, according to the size of the receptacle, it will require to be emptied every two or three years, and this will cost from 3*l.* 19*s.* 2*d.* to 5*l.* 19*s.*, or 1*l.* 19*s.* 10*d.* a year, which, added to the 2*l.* 7*s.* 6*d.*, the interest on the first outlay, will amount to 4*l.* 7*s.* 1*d.* per annum. Moveable cesspools are let for 2*l.* 7*s.* 6*d.* or 3*l.* 3*s.* 4*d.* per annum; hence there is an economy of from 1*l.* 3*s.* 5*d.* to 1*l.* 19*s.* 10*d.* a year in the use of the latter. It must be further remarked, that when landlords have to repair old receptacles they will avoid by the use of the moveable cesspools, 1.—the risk to the foundations of the houses in forming a new cesspool; 2. the expense of future repairs; 3. the discolouration of the paint. Houses have sometimes been entirely destroyed by the repairing of a cesspool. Now, then, we have a case where the material interest of the proprietor coincides with the health of the inhabitants. It is to be hoped, therefore, that when this fact is more generally known, that the public health will gain immensely.'

* In Belgium, the estimated expense for carting the manure of a whole town to a depôt three miles and three quarters distant, was at

the expense of the keep of the men and horses required by the farmer, where he undertakes the labour of clearing and removal for the sake of the manure.

## *The Removal of all Cesspools from amidst Habitations the first Duty of Local Boards.*

As soon as a proper survey and system of levels (*vide* Minutes of Instructions on Surveys) have been obtained, the first duty of a Local Board of Health will be the prosecution of measures requisite for the entire abolition of all cesspools, and the prevention of their future formation, by the complete drainage of every house in the town.

All the available sources of water-supply having been examined, the most eligible finally determined upon, and works for its distribution arranged, means for the immediate removal of waste water will be next in order for consideration.

Waste water consists of house-sewage, *i. e.* foul water from house-drains and soil-pipes, and roof and surface drainage, with water from land-springs; and it will be a matter for special consideration in each case how much of these should be conveyed away in separate channels, or together.* It will be generally found

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the rate of 6*s.* per house per annum. *Vide* a Report made to the "Conseil de la salubrité publique de la province de Liège, sur des moyens de recueillir et d'utiliser les engrais, qui se perdent dans les grands centres de population, au detriment de la salubrité publique et de l'agriculture. Par J. P. Schmit, architecte, professeur agrégé à l'Université de Liège; Membre du Conseil de salubrité publique de la province, &c. Rapport, fait à la suite d'un circulaire adressé à M. les Gouverneurs des Provinces, sous date du 8 Avril 1846. Par M. Ch. Regier, Ministre de l'Interieur, 1850."

* In thoroughfares of considerable traffic in large towns, as in the main streets of the metropolis, as much ordure is dropped on the surface of the highway as is deposited in the cesspools of the corresponding houses. Thus it is reported that the quantity of dung removed daily from a space of 68 acres of paved roadway surface, including the bye streets of little traffic, as well as the crowded streets of the city of London, varied from 505 to 596 loads per week, or was on the average 92½ loads per diem, nearly all of horse-dung. To strangers these streets often smell of dung like a stable-yard. The water collected from some of the streets after rain-falls has been analysed by Professor Way, from which it appeared that its addition to the sewage would enhance its value as liquid manure.—*Appendix* III. *to the Report on the Supply of Water to the Metropolis*, p. 142.

The soluble matter contained in the sewer-water with which the meadows near Edinburgh are irrigated, was found to contain, when put on, 82 grains of matter in the gallon in solution, and 244 of solid matter in suspension; whilst the rain-water running from one part of the paved surface in Oxford-street, London, contained 276 grains of matter in solution, and 537 of solid matter in suspension; and from another portion it contained 194 in solution and 390 in suspension; from Gower-street 126 most economical to construct the channels for sewage large enough to convey the drainage during moderate rain, and to have in the valley lines large conduits chiefly, if not exclusively for storm-water.

In the channels for sewage thus contracted, all solid or semi-fluid matter will be carried immediately away. House-drains or sewers which accumulate deposit are, in fact, extended cesspools giving off poisonous emanations, and to expend money in their construction is rather aggravating than removing the chief evil to be remedied.

Improved town-drainage then is twofold; 1st, the drainage of the sub-soils, from the surplus rain-water falling on the uncovered area, and from surplus spring-water, by arrangements of permeable drains, (which are treated of in separate Minutes of Information, and *post*, p. 82;) 2dly, the immediate removal through impermeable channels of foul water from the interior of houses and premises, as well as rain falling from roofs, yards, pavements, and roadways.

The main object of the present paper is to give heads of practical information, in relation to the arrangements by which the last-recited objects may be effected most economically and completely.

Works for the abolition of cesspools and the drainage of houses form the greater part, requiring usually two thirds of the outlay necessary for the drainage of a town. Until house-drains are provided for the removal of the waste water, the introduction of additional supplies of water may increase the dampness of the foundations, and of the floors and walls of the houses, to an extent greater than would be produced by an additional rain-fall, as the cause of dampness will be constantly

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grains in solution and 3 of matter in suspension; from Hampstead-road, above the canal, 96 of soluble and 84 of insoluble matter; and a general average of soluble matter above that of the sewer-water of Edinburgh, when it had passed through the irrigated meadows, and contained yet considerable irrigating power.

To the washings of the dung from roadways are added deposits of soot and birds' dung from roofs, and the dung of animals from yards, and the dried dust blown from the roadway, which contains much valuable matter available as manure. In the principal highways of provincial towns, where there is less traffic, there is less cleansing, and frequently much accumulation at the time of rain; and though the proportion of soluble road matter is less, yet with the deposit of soot and other matter, it is sufficient to be utilised as manure, and to justify conveyance away with the ordinary house-drainage through the common sewers. Where the interiors of sewers of deposit had been cleansed, foul smells were found to arise from the animal and vegetable matter discharged from the surface of the streets and roadway, but detained by ill-constructed traps, (*vide post*, p. 97,) or ill-cleansed cesspits.

in action. Until house-drains are constructed, and in action, main-drains are of little use, and the cost of their construction wasted. Moreover, if but a small proportion of the sewage they are constructed to convey is brought into them, the stream, instead of being deep and rapid, will be shallow and slow, and consequently there will be greater liability to deposit; for which reasons, as well as to prevent pollution of the air and percolations from cesspools, Local Boards should exercise the powers with which they are invested by the 49th section of the Public Health Act, and insist upon all houses being effectually drained at the same time that a street-drain is being constructed.

The whole plan should proceed upon the assumption that the systematic drainage of all the houses will be complete. Unless the main-drains or sewers are laid out upon this assumption, and receive the drainage from the whole of the houses, the flow in the drains will be diminished, the frictional areas, the times of discharge, and the chances of obstruction may be more than doubled, and the expense augmented three or fourfold. On these grounds, primary consideration should be given to the principles of constructing house-drains, which form, as it were, the capillaries of a system of improved town-drainage.

Systematic house-drainage includes arrangements—

First—for the constant removal of the waste or dirty water from chambers, as well as from kitchens, sculleries, and outer offices.

Secondly—for filling-up cesspools (in old houses), and for the constant removal of human excreta from, upon, beneath, or near, the premises.

Thirdly—for the discharge of rain-water from the roof or from the courts and surfaces outside of the house.

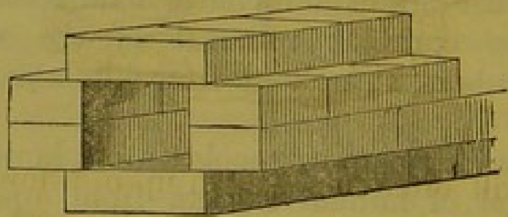
The consideration includes—

1. The construction of house-drains;
2. The materials of which they may be best made
3. Their shape;
4. Their size;
5. Their direction and fall;
6. Their connexion with the outfalls, through the branch sewers; from which will follow the consideration of the connexion and arrangement of the branch and main sewers for the clearance of the whole site.

It will be convenient for the elucidation of the subject, to state the course of investigation which led to the development of the chief settled principles of improved house and town drainage. This will be the more necessary, inasmuch as many of the objectionable practices are yet maintained, and are frequently introduced into new districts, where their attendant evils and expenses are unknown or disregarded.

*Materials and Construction of old House Drains.*

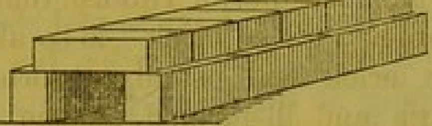
The materials of which house-drains are commonly constructed are burnt clay bricks; and of these bricks for the great majority of houses, (as with that portion of bricklayers work in general which is out of sight,) any inferior rubbish that can be put away is used. The common "place brick" is so absorbent and permeable, that each brick will usually absorb about a pint of water. It is rough and ill-formed on the surface, so as to impede the flow of the sewage. The bottoms of the drains of houses occupied by the poorer classes are not always formed of whole bricks, brick-bats being often used for the purpose; which are frequently put together dry, or the mortar used for their connexion is inferior, soluble, and permeable to water as well as to gases. The following are common forms of permeable brick-drains, which let out offensive liquid to spread beneath the premises, but detain, like sieves, the solid or less soluble matter:—



"These," say the Metropolitan Sanitary Commissioners, "and the flat brick house-drains, are generally put in 'dry' at the bottom, or without mortar, to let in the water of the land drainage, but they commonly let out at their bottoms or sides, instead of the ends, much of the sewer-water, which permeates the foundation and site of the house, leaving the solid refuse deposited in the surface of the drain to decompose, and ultimately choke it up. It is rare to find any house-drains of this description without deposit. They are, indeed, made on the hypothesis that they will accumulate deposit, and the construction of brick is preferred that the drains may be more readily opened, and the deposit from time to time removed. One of the surveyors of the Surrey and Kent sewers, the author of an 'Encyclopædia of Architecture,' prescribes a size of drain of 5 square feet for a moderate sized mansion, to enable a man to get at it to cleanse it from time to time. The Metropolitan Building Act prescribes that the *least* size of house-drains shall be 9 inches; the hypothesis being, that, inasmuch as even these drains accumulate deposit, drains still larger are desirable."

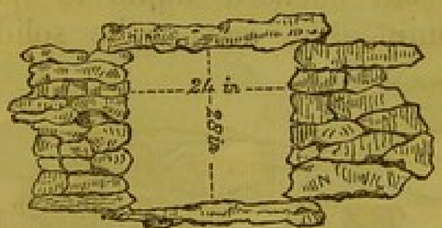
So thoroughly wet, spongy, and rotten do these descriptions of drains become in flat, low-lying, and wet districts, that the workmen find it necessary to be very careful when digging trenches near them, lest the sides should fall down, and let out the ordure detained and accumulated by them.

In many of the large provincial towns visited, still inferior drains are constructed. The following are two specimens:—



The first consists simply of two bad bricks placed edgewise on the bare ground and covered with other bricks.

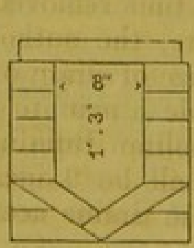
The next is constructed of rough stone without lime, and is of a size frequently used in the north of England for two or three cottages:—



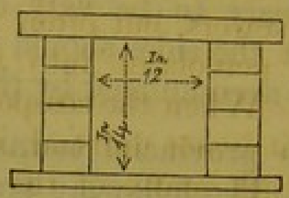

The former will often be choked up in a few months, especially if some other owner, as is often the case, drains into it. The latter, it must be obvious, will ultimately have the same fate, notwithstanding the supposed advantage of its large size,—should it not sooner collapse, and become a confused mass of rubble stone, and black stinking filth.

In some districts stone is used with lime, but generally of the like construction; in others wood is used.

The following is an example of a drain constructed of stone, or brick and stone, and one of the best forms of the kind:—

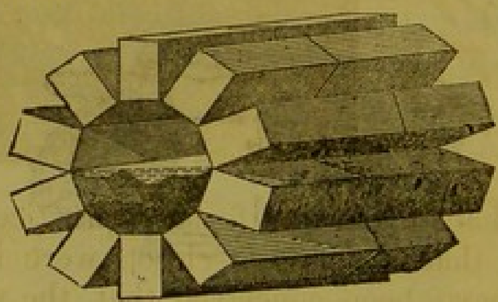


But for the poorer description of houses they are more commonly made with flat bottoms, like the following:—

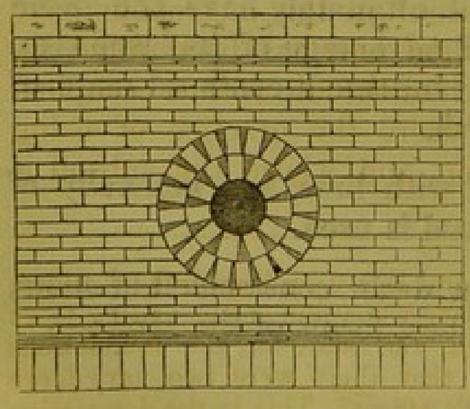


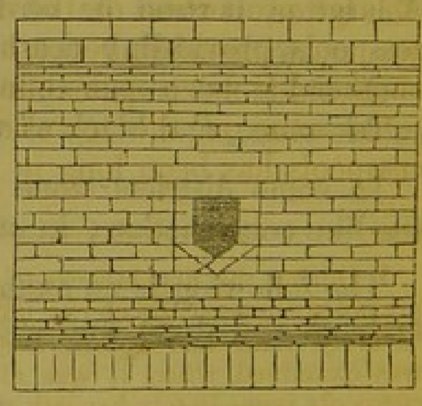

The drains for the higher class of houses are sometimes of a better construction, being lined with Roman cement to "keep out smells"; but still from their shape and size they accumulate deposit; for although the smells may be prevented by the cement from escaping at the sides, it escapes in greater quantity and intensity at the ends; and even if the entrance of the drain into the house is trapped, which it rarely is effectually, the products of decomposition find vent in the common sewer, and thence escape to the pollution of the air outside.

The following is a common form of construction of brick barrelled house-drains:*—



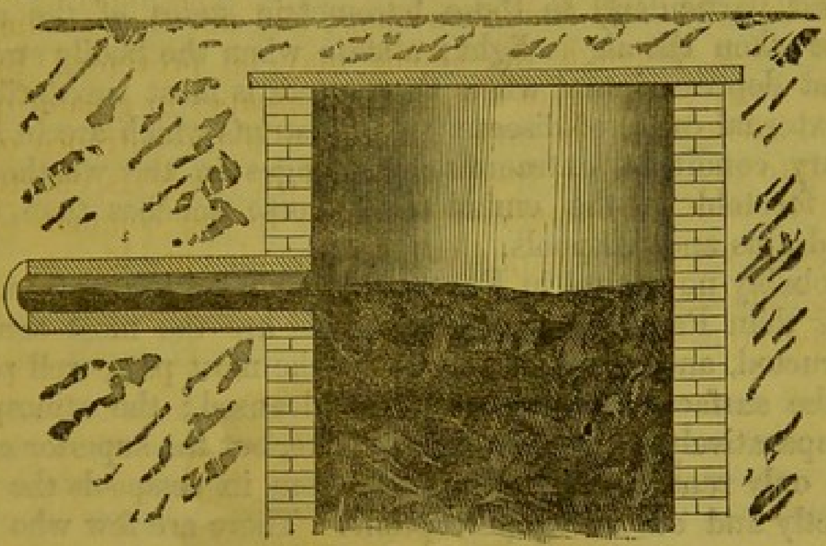
The following are views of the junctions of such drains with the larger sewers:—





* In some few provincial towns radiating bricks have been used for circular drains, but generally the use of flat bricks is continued in London, even for drains of small diameter. While the inner edges of the bricks are in contact, the outer edges are of course widely apart, and the wide gaping joints must be filled with mortar or other soft matter; a mode of construction necessarily defective and insecure.

House-drains, constructed as described, commonly convey the sewage into cesspools, from some of which the overflow is carried away into the sewers, but often there is no overflow-drain, and the liquid percolates into the soil beneath and adjoining the building. When the cesspool becomes filled with the solid filth detained, it is not unusual, instead of emptying it, to form another. Beneath many of the more moderate-sized houses as many as three cesspools have been found; their ordinary state is displayed in the following sketch:—



So perverse had been the former practice in respect to house-cleansing, that when water-closets were introduced, and when it might have been conceived that the ordure removed from sight would be immediately conveyed from the premises, it was only accumulated in a cesspool beneath them. A large proportion of the best houses * in this metropolis have cesspools provided beneath, and when one has been filled up another has been opened, until much of the site is thus occupied.

In some of the towns visited, where the practice of using cesspools has been long in operation, and where the subsoil is

* During the first labours of the General Board of Health much illness prevailed amongst the clerks, until on one occasion foul smells arising more severely than had before been noticed, the state of the foundations was examined, when it was discovered that there were two very large cesspools immediately beneath the Board's offices. This is the description of houses of which it is generally reported by house agents and others that they are well drained and in good condition; but it may be advised that it is absolutely unsafe to take any house without a thorough examination of the site beneath it, nor when any cases of fever, typhoid or gastric, have occurred amongst persons living in the lower offices of a house, is it safe for those who value their own health to remain in the premises without such an examination, nor until the cesspools are removed.

becoming wholly saturated with excrementitious matter, it has already become very difficult to find a spot of earth capable of receiving further percolations.*

In all these closed receptacles, whether fixed or moveable, decomposition is always in progress, commonly through all the stages of chemical change, and no effectual trap exists nor can reasonably be expected to succeed, in popular use, that will prevent the escape of the noxious gases.

From these magazines miasma are extensively liberated and diffused, particularly in those barometric states of the atmosphere when the air is light; a state when the bodily strength is most depressed, and when the system is most susceptible to any external cause of disease.† In districts which are in a low sanitary condition, extraordinary changes in the weather are often foretold by the emission of worse stenches than usual from drains and cesspools.

Probably no capital in Europe is cleaner on the surface of its streets than Paris, where the cesspools are the most carefully constructed, and covered. It is, for the most part, well paved, and the surface of the streets well cleansed; the atmosphere is comparatively free from visible smoke, but the superior cleanliness only renders the emanations from its cesspools the more distinctly and offensively perceptible. There are few who have

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* In Mr. Lee's Report on Reading (p. 48), Mr. Billing, the borough surveyor, says, "That is already the case in one or two instances that I know, where a whole garden is a cesspool. Ground cannot be found in some places from which the night-soil will be absorbed and pass away. I know several cases of actual death, and others of disease, arising from each of these causes."

† Mr. Charles Oldfield, a builder of the highest class of houses, at the west end of the metropolis, thus describes his practice in relation to them: "I am frequently called upon to examine houses where they say they are oppressed by unpleasant smells. Some time ago, I was called upon to examine a house in one of the principal streets in London, belonging to a gentleman of distinction, who was about to abandon it in consequence of the unpleasant smells which were continually arising. He was particularly annoyed, because this smell arose in the greatest strength whenever he had parties; the drains had been opened, and there was no lodgment of soil in them. People commonly imagine that when they get rid of the soil they have got rid of the stench; they do not see, and do not conceive the effect of the foul air, which is so much lighter than atmospheric air that it escapes where the atmospheric air would not. On examining the drains of his house I found that they were imperfect, and that the foul air filtered through them. Whenever he had a party there was a stronger fire in the kitchen, and stronger fires in other parts of the house, and the windows and the external doors being shut, and a greater draught created, larger quantities of the foul air from the sewers rose up. These stenches arise in the greatest strength in private houses when the doors and windows are closed, the fire and column of light air in the chimney being at work." *Vide Sanitary Report*, 1842.

visited that city who have not experienced, even in its finest streets and most sumptuous hotels, a peculiar and almost indescribable sensation from the offensive atmosphere around. It is felt in the court-yard, but it is produced in the greatest force on some staircase, passage, or landing leading from a common water-closet. It is caused by emanations from the foul cesspool into which all the refuse of the establishment is passed, and from which the dangerous gases of decomposition force their way through the whole atmospheric space around. To set open doors and windows is of little avail; that does not bring relief, the sensation remains. The refuse must be removed at once if there is to be safety to health; and such removal will be economical as well as healthful.

Houses occupied by the poorest classes in London often afford examples of the utmost perversity of construction in the lower offices. Mr. Lovick thus describes the condition of some tenements in a place called Tyndall's-buildings; a locality distinguished by the number and malignity of the cases removed from it to the Fever Hospital:—*

"'At No. 15, the privy is in the front vault; the vault flooded to a height of between 2 and 3 feet with soil and human fæces, ashes, ground, dead animals, green stuff, and other offal saturated with water, the privy (afterwards ascertained to be an open one) concealed

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* The 50th Report of the London Fever Hospital (for the year ending 31st December 1851) contains the following description of the principal fever localities:—

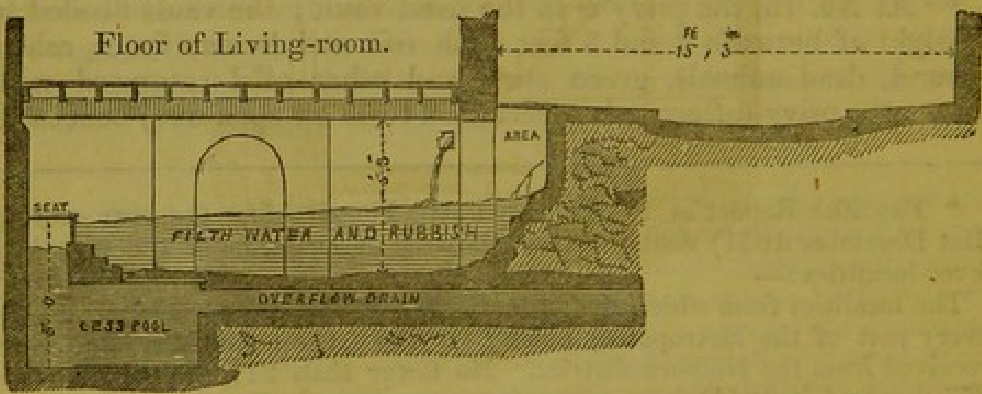
The localities from which the patients have been sent extend over nearly every part of the Metropolis; but by far the largest number have been received from the Holborn district. No fewer than 211 patients (out of 877 received in 1851) have come from courts and alleys on the eastern side of Gray's-inn-lane, such as Tyndall's buildings, Pheasant-court, &c. In several instances 10 or 12 of these have been received from a single house, and in one instance as many as 20. Thus it appears that one side of a single street, with the courts that branch off from it, have afforded nearly a fourth part of the total number of patients admitted during the year; but to this number should be added 50 more persons, who were removed to the hospital from the adjoining courts in Saffron-hill; so that, in fact, this circumscribed spot has supplied the hospital with nearly one third of its total number of patients. When the state of these fever nests is considered, this result will appear no matter of surprise; in Tyndall's-buildings and the adjoining courts, for example, the floors of the cellars are some feet beneath the main sewer, so that the drainage of the houses is impossible; the privy and the water-butt are commonly both together in the cellar; heaps of dust and decomposing matter are accumulated *within* the houses,—and in the whole of this locality overcrowding is carried to such an excess, that commonly three or four families occupy a single room, into which it is no unusual thing for 20 persons to be huddled together; one patient, indeed, stated, that, in the room in which he lived 27 persons lived by day, and slept at night.

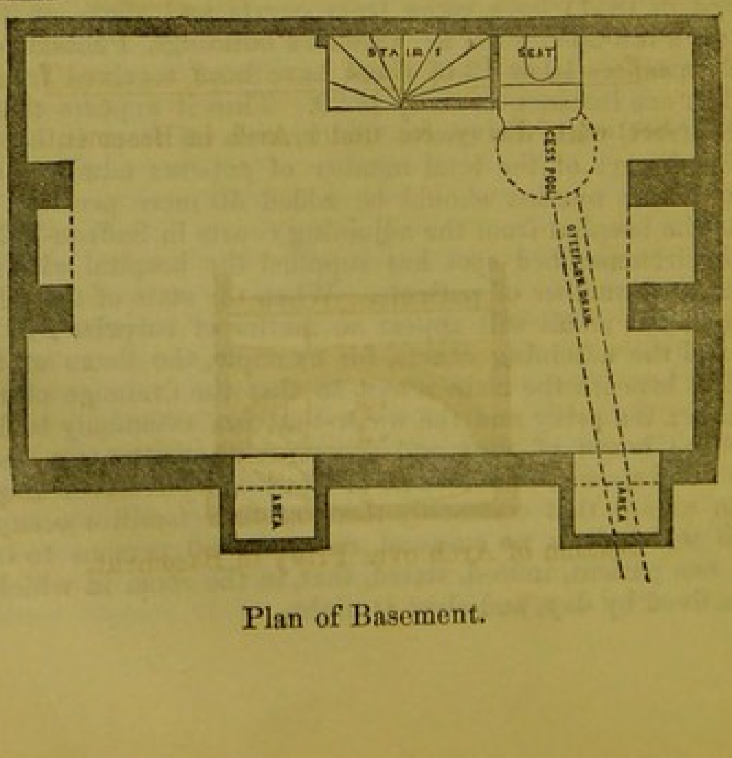
from view, and completely submerged by the noxious matter (the inmates, of course, cannot use it); the steps leading into the vault were covered with human fæces; the smell truly horrible.' The strongest terms I could employ would be inadequate to convey an idea of the exceedingly loathsome character of the emitted effluvia, or of the external appearance of the aggregated filth.

"'At No. 16, the privy, an open one in front vault, has a cesspool covered over with boards only, these can be shifted by any person; the cesspool is full: ashes, rubbish, human fæces, and offal of various kinds in great quantities in vault. Vault used apparently indiscriminately by all the inmates; condition most filthy; smells truly disgusting. Had there been an overflow of water in this vault, it would have scarcely been in a better condition than No. 15.'

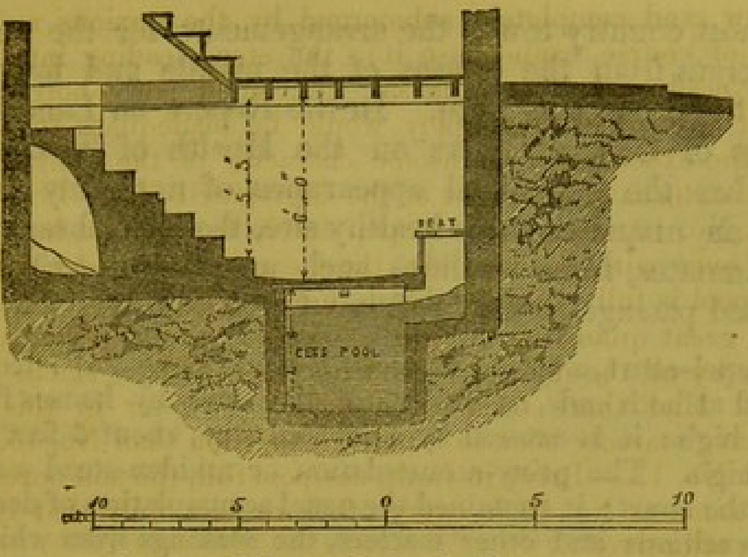
"'At No. 17.—Privy in vault, cesspool full, the soil oozes through ground, same as No. 16 in every other respect, only that it is a degree less offensive.'

"'At No. 18.—Privy in vault and at back of house, accessible only by trap-door, descending by wooden steps into vault, cesspool full—swarms of flies—very bad smells. There is a range of vaults; they are exceedingly close. The privies are quite open, being nothing more than seats; those using them are quite exposed to view.' The annexed are sketches of the basements Nos. 15, 16, 17."

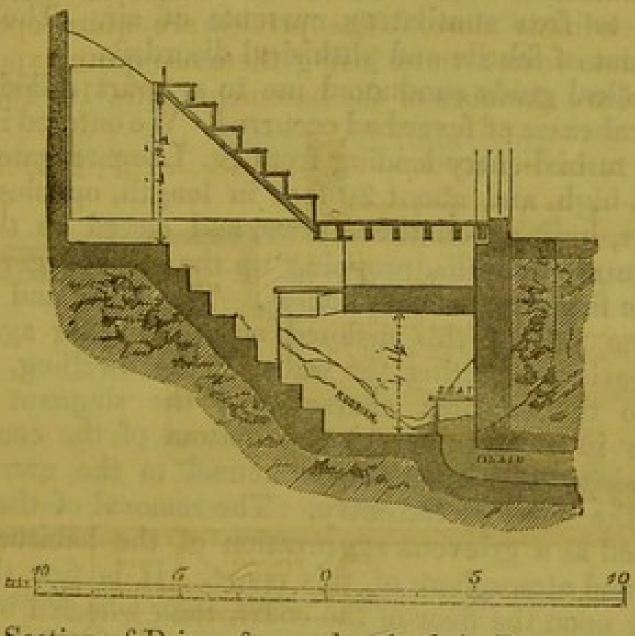


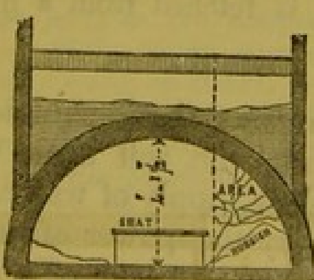

Plan of Basement.




Section of Cesspool, &c. in Basement.




Section of Privy, &c. under Arch in Basement.




Section of Arch over Privy in Basement.

In most country towns the arrangements for the removal of the excreta from the houses of the middle and lower classes are in the same bad state. In the Report on Lancaster, *e. g.* (Report of Commissioners on the Health of Towns, 1845), which has the superficial appearance of a cleanly town, and enjoys an unquestionably healthy site, the fever hospital rarely lacks inmates, from localities such as those described in the subjoined passages from Professor Owen's Report:—

"Chapel-court, a space about 60 feet in length and 7 feet wide, is enclosed at both ends, as well as at the sides, by houses from 20 to 30 feet high: it is entered by a covered way, about 3 feet wide and 7 feet high. The privy-accumulation or midden-stead was exposed within the court; it contained the usual accumulation of decomposing excrementitious and other matters, the soakings from which filled a stagnant kennel traversing the court, and slowly escaped by an untrapped gully-hole, near the entry, into the adjoining sewer. The noxious emanations from these sources are greatly aggravated by the obstruction to free ventilating currents of air. The court is the occasional seat of febrile and phthisical disorders.

"My medical guide conducted me to a court called Croft's-yard, where several cases of fever had occurred. We entered it by a covered passage, or tunnel-entry leading from St. Leonard-gate, 1 yard wide and 2 yards high, and about 20 feet in length, opening into a small square court, built up on three sides, and closed on the fourth, opposite the entry, by walls, propping up the soil of a garden above the level of the first floor of the houses. The privy and midden-stead occupied one side of this enclosed space, abutting against the first story; its oozings infecting the walls of the dwelling, and also contributing to the morbific character of the stagnant water which accumulates in wet weather at the bottom of the court, whence it drains off sluggishly by an open kennel to the untrapped grated opening of the sewer at the entry. The removal of the midden-heap was described as a grievous aggravation of the habitual noisomeness of the confined atmosphere of this court. It is first thrown out by hand labour upon the floor of the court, then wheeled by barrows-full down the narrow passage into the street, whence it is finally carted away. The farmer is willing to give 2*s.* in addition to the labour for this manure. The water for cleansing the court after this laborious and noisome operation is fetched from a public pump at some distance."

No one seemed aware of the inevitable effect of the percolation of liquid filth into the soil upon the wells, from which many houses derive their supply of water. The effect is indeed for a time disguised by the power of certain soils to absorb a portion of organic matter, and to effect the decomposition of much more, so that the result appears in the form of a nitrate of lime or other base. Nitrates are very commonly found in the well-water of towns, and doubtless owe their origin to the decomposition of organic liquid filtering through the soil.* As the soil becomes more completely saturated, the contamination of the water becomes more evident to the senses, till at last the wells are abandoned. In one district where many houses have been drained with tubular drains, and cesspools abolished, an evident improvement both in the appearance and taste of their well-water has been frequently noticed by the inhabitants with some surprise; it was a result, from the abolition of cesspools, for which they were not prepared.†

## *Of the Sizes of Mains and Sewers.*

The general practice with respect to the sizes of sewers constructed previous to the investigations made by the Commissioners, and even yet very commonly adhered to, is concisely given in the evidence of Mr. Kelsey, then surveyor of the City Sewers Commissioners, taken before the Commissioners for inquiring into the means of improving the Health of Towns:—

"For the ordinary purposes of one house an 18-inch main drain receiving collateral 9-inch drains may, with fair usage, last many years without cleansing, but when it has to be cleansed the trouble

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* *Vide* Report on Water Supply, p. 91. Dr. Angus Smith examined a number of wells both in Manchester and London, and found nitrates in nearly all. When in considerable quantity they give to the water a very unpleasant taste.

† On the subject of the pollution of wells from the permeation of the contents of cesspools, Mr. Quick made the following statement in evidence before the Health of Towns Commission:—

"Within a few days we have had an instance at Battersea of permeation of the cesspools in six new houses. They were supplied with water from springs sunk to the same level as the cesspools. As the springs were lowered by the consumption of the water, it was found, to the surprise of the inhabitants, instead of coming up clearer it was more discoloured, by the equalization of the water levels. One of the inhabitants, a baker, who drew harder than the rest, applied to the Company to lay on the water, giving me to understand that the people began to complain of the quality of his bread, the cause of which he could not make out, except it arose from the quality of the water, which somehow or other, was very bad; all his neighbours who drew from the same spring complained that the water was very bad. The cause was, on examination, undoubted."

and the cost of digging pits from the surface and raking out the filth will be considerable.

"But for the use of a line of houses in a public street, wherein some one or other will treat the drains unfairly, it may be laid down as a first principle that no common sewer should be so small that an ordinary-sized man could not get in to cleanse it; for if it were so small it would not only soon become choked up, but opening the surface to cleanse it would stop or more or less impede the traffic of the street.

"Taking a man of ordinary size, it will be found that a height of 1 foot 11 inches will just allow him to squeeze through on hands and knees, and 3 feet 3 inches will admit him crouching, and 4 feet stooping. To these must be added two or three inches to allow of the raising of the body when moving forward, and there should be some additional allowance for indurated soil in the bottom of the sewer.

"Taking these data, one can scarcely allow less than from 2 feet 4 inches to 2 feet 6 inches for a man to crawl through, and 3 feet 6 inches for a man to crouch through, and 4 feet 4 inches to 4 feet 6 inches for a man to stoop through; and as few men are less than 21 inches across the shoulders, it will not be unreasonable to say that 2 feet is the least width in which a man can work effectually although he may pass sideways through 14 inches.

"Applying these to the question of what is the best-sized sewer that ought to be built in any street, one is compelled to admit that it ought not to be less than 30 inches by 24 inches, and its depth not less than 12 feet in its shallowest part.

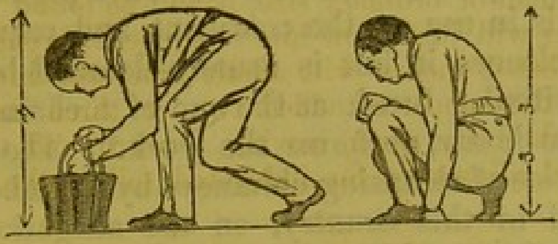
"The thickness of the brickwork cannot be less than 9 inches, nor would it be prudent to leave fewer than two tiers of strutting and planking in the ground.

"The cost of such a sewer would probably be about 9*s.* 9*d.* a foot, being somewhat less than half the cost of a sewer 4 feet 6 inches high, and 2 feet 6 inches wide.

"But this assumes that the work is done under the most favourable circumstances, and at the present low prices; and the calculation, of course, does not include gullies, man-holes, &c., nor securing the houses of a narrow street.

"The term 'common sewer' (as for more than one house) is used in contradistinction from public sewer (as unfit for more extended purposes), and taking the limited height of 20 inches from the bottom of a public sewer to the bottom of a drain, as a fair and reasonable allowance for the accumulation of soil in such sewer, before the private drains can be obstructed, and the sewer said to be foul; by adding 2 feet 6 inches to that, we shall find that 4 feet 2 inches is the least height which it is advisable to give a *public sewer*, but 4 feet 6 inches is better, as allowing freer space for cleansing."

In illustration of this evidence Mr. Kelsey put in the following sketches :—



Plans of works were generally found to be as destitute of sanitary considerations, both with reference to the nature of the effluvia generated from such deposit, and the operations for its removal, as indicated by the above-recited passage.

There are some descriptions of labour which it is improper for human beings to perform, and which ought to be forbidden, as being false in principle, and belonging to a low state of art, and as being ignorant or interested excuses for the avoidance of the trouble and expense of practicable and efficient substitutes. Putting men to crawl or creep through channels filled with foul ordure, and to breathe noxious gases, as above described, is one example of such labour. Putting children to crawl through channels, filled with soot, to cleanse them, is another. By a clumsy and inartificial construction of a chimney-flue in the form of a large parallelogram (which often follows an irregular course, with sharp bends and corners, always gathering soot,) the naturally circular current is widely spread and impeded, and additional deposits of soot occasioned. The chimney-flues are made, in England, additionally large to admit children to cleanse them, and this increased size, by increasing the quantity of cold air admitted, and by extending the surface which proportionally abstracts heat, and retards the ascent of the smoke, augments the quantity of foul deposit requiring removal. By these erroneous constructions the discharge (or flow) of the heated air is often so much impeded as to produce, besides the extra quantity of deposit, the evil of smoky chimneys. One means adopted of mitigating or remedying this evil, and occasionally of lifting the current of heated air out of descending currents or eddies of wind, is visible in almost every district, in additional lengths of flue of a more appropriate or circular form, contracted to one half the cubic capacity of the common parallelogram, or less. One architect bethought himself that if, instead of fixing the contracted length of tube at the top, he put it down the interior of the old chimney, it would answer as well, and that he should thus save the risk of its being blown over, and the expense of holdfasts. He tried, and he found it answer better; he would have found it answer completely if he had continued it down to the fire-place, when he would have produced a complete flue, such as is in use on the continent, and requires no climbing boys to cleanse it, but is usually cleansed by a heavy iron ball with a circular brush at the end of a chain, with which a servant of the house performs the work.* The cruel and degrading practice of cleansing chimneys by the labour of children was defended in this country, on the allegation that it was impossible to cleanse chimneys in any other mode. It was forbidden. It was then found to be practicable to cleanse even the chimneys of the old and vicious construction by machinery, without waiting for those improvements in heating by which it may be confidently predicted that the use of smokeless fuel will be found economical for towns.

It would be better that sewers of deposit, in their frequent condition, should be required to be opened to the surface, as house-drains of deposit are, for cleansing, rather than that it should be permitted to continue the practice of sending men to crawl up them amidst foul ordure, to the certain injury of their health, and at the hazard of their lives.† But it appeared upon investiga-

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* In Dresden circular chimneys of little more than five inches are found to serve well for coal fires for the great majority of buildings for which the large parallelograms were in use. By the better adaptation of size and form, with a better draught of air and better combustion, less coal is consumed as well as less soot deposited. Moreover, by the better draught, much of the heavier offensive and pernicious gases from the decomposition of coals, more particularly the inferior coals such as are used by the poorer classes, which escape and pervade the living rooms when the draught is sluggish or the chimney smokes, is cleared away. For the larger-sized houses flues of 8½ inches are used; and flues of 11¼ inches are found to answer for kitchen ranges and very large establishments.

† Instances occur of the death of men from the mephitic vapours encountered in this disgusting labour, which are made known to the public, but instances are numerous which are not heard of, where men are rescued in a state of insensibility, and sustain severe and permanent injuries. When the survey of the condition of the existing sewers in the metropolis, called the Subterranean Survey, had been determined upon, the members of the Board urged that special precautions should, for all such future labour, be taken, under the guidance of a competent medical officer, for the protection of the men employed; but this was

tion, as will be shown, that with properly-constructed sewers, combined with supplies of water, no deposit will be occasioned, and obstructions become so rare as to need no special provision for cleansing. Complete measures of sanitary improvement and

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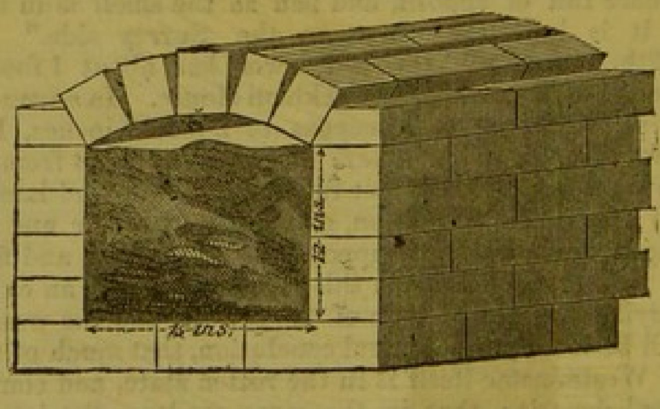
opposed by some of the old Commissioners on the ground of expense, and as wholly unnecessary, and lives were actually lost which the precautions recommended would certainly have saved. The following extracts from the reports made upon this survey show the nature of the gases generated in sewers of the vicious construction proposed directly with a view to the continuance of such labour :—

"69½ miles of sewers have been surveyed in the Surrey and Kent district." . . . . . "The surveyors find great difficulty in levelling the sewers of this district; for, in the first place, the deposit is usually about 2 feet in depth, and in some cases it amounts to nearly 5 feet of putrid matter. The smell is usually of the most horrible description, the air being so foul that explosion and choke-damp are very frequent. On the 12th January (1849), we were very nearly losing a whole party by choke-damp, the last man being dragged out on his back (through two feet of black fœtid deposit) in a state of insensibility. Another explosion took place on the 12th February in the Peckham and Camberwell-road sewer, and one on the 21st February in the Kennington-road sewer ; in both cases the men had the skin peeled off their faces and their hair singed. Two men of one party had also a narrow escape from drowning in the Alscot-road sewer, Rotherhithe, on the 24th instant; but, fortunately, none of the foregoing cases have been attended with serious damage. The sewers on the Surrey side are very irregular ; even where they are inverted they frequently have a number of steps and inclinations the reverse way, causing the deposit to accumulate in elongated cesspools. In must be considered very fortunate that the subterranean parties did not first commence on the Surrey side; for, if such had been the case, we should most undoubtedly have broken down. When compared with Westminster, the sewers are smaller and more full of deposit, and bad as the smell is in the sewers in Westminster, it is infinitely worse on the Surrey side." . . . . "February 12th. The Peckham-road sewer has about 1 foot 7 inches of deposit at side of entrance opposite Peckham House. In advancing towards Southampton-street the deposit deepens to 2 feet 9 inches, leaving only 1 foot 11 inches of space in the sewer. At about 400 feet from the entrance the first lamp went out, and 100 feet further on the second lamp (not being a safety one) created an explosion, and burnt the hair and face of the person holding it. The cause is supposed to be the foul and filthy state of the sewer." . . . . . "From this description, and an examination of the accompanying illustrated map of the sewers, and the weekly progress reports, it will be found, as a general conclusion, that much of the sewerage of the city of Westminster itself is in the rotten state, and contains a large amount of foul deposit ; that in the more modern district of Belgrave and Eaton squares, although the brick-work of the sewers is generally sound and good, they contain several faulty places and abound with noxious matter, in many cases stopping up the house-drains and smelling horribly ; that in the district of Grosvenor, Hanover, and Berkeley squares, as a rule, considerable deposit is found in the sewers, emitting much effluvia ; that the same remark may be made of the sewers in the neighbourhood of Clare-market, Covent Garden, Soho-square, and Fitzroy-square ; that much of the work north of Oxford-street, about Cavendish, Bryanstone, Manchester, cleansing by means of water will prevent the necessity of much injurious labour.

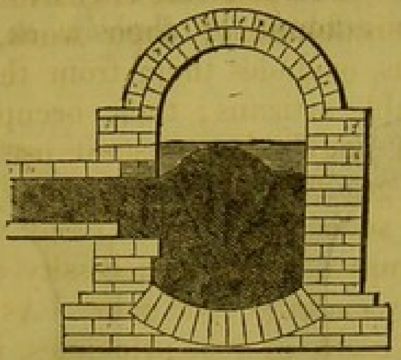
Those whose lot it is to perform offensive and filthy labour have their perceptions blunted; their work, rendering them filthy in their persons, excludes them from the society of more cleanly and respectable artizans; their occupation is supposed to necessitate and to justify the constant use of ardent spirits, and they become degraded in condition, and a separate caste. The prevention of such degradation, and the disuse of the degraded class, by superseding the necessity of such service, is of itself a matter of social and civic gain. As is usual, however, in the operation of really correct principles, it will be found to be attended also with pecuniary saving.

Main sewers were very generally found to be of larger sizes, with the certainty of containing greater accumulations than those in the circular form constructed for the city of London. For the convenience of working in them, they were commonly made with nearly flat segmental bottoms, and with upright sides, and spreading footings, in the manner displayed on the next page. Circular work, being more difficult or troublesome, it was found that the builders commonly preferred a similar construction for the smaller sewers, as the whole were built upon the hypothesis that deposit must accumulate; and except in the case of main sewers in valley lines, with considerable runs of water, it does so. The following sketch shows the condition of a flat-bottomed drain 15 inches wide, which drained 20 houses:—



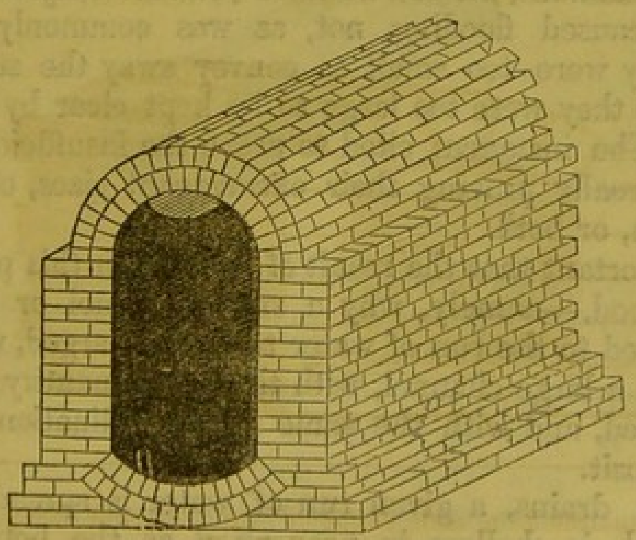
and Portman squares is in such a state of rottenness and decay that there is no security for its standing from day to day; that there is a large amount of the most loathsome deposit in these sewers, but the act of flushing might bring some of them down altogether; that even throughout the new Paddington district, the neighbourhood of Hyde-park-gardens, and the costly squares and streets adjacent, the sewers abound with the foulest deposit, from which the most disgusting effluvium arises."

The ordinary condition of sewers, in their connexion with house-drains, is shown in the sketch* subjoined :—



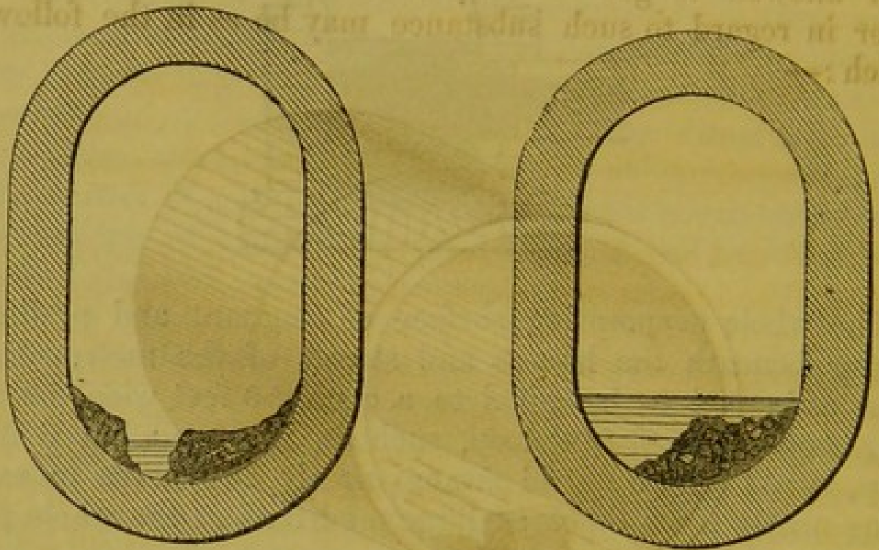
The whole evaporating surface of stagnant and pestilential matter beneath the houses and streets of the metropolis has been estimated to be equal to a canal 50 feet wide, 10 miles long, and above 6 feet deep, such as, if spread out 6 inches deep, would form a putrid swamp nearly 800 acres in extent, being nearly three times as large a surface as the whole population could lie down upon.

Sometimes large sewers as well as large drains are filled nearly to the top with deposit. The following cross section displays the condition in which one of them was found. The space occupied by the ordinary run of the sewerage to be removed, and the shape of the bed which it had worn for itself, are shown near the crown of the arch :—



* It may be mentioned, as a reason for the several illustrative cuts not being to one scale, that they originally appeared in different reports, from which they have been taken.

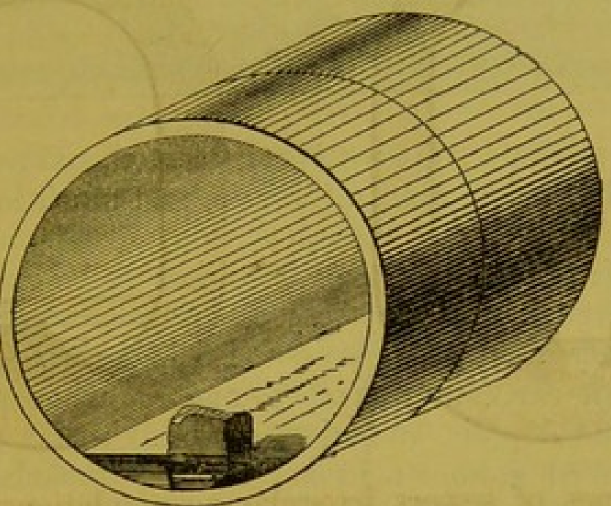
The actual space required for the removal of an ordinary run of sewer-water, and as far as the material will admit, somewhat of the shape of the channel formed by it, is often found displayed, in a lesser amount of deposit, as in the following examples:—



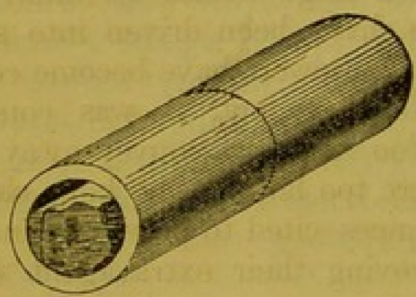
In many lines of sewers irregular accumulations were found to have been deposited in consequence of uneven bottoms, junctions at right angles, or other causes. (*Vide* Reports upon the Subterrenean Survey, directed under the Metropolitan Sewers Commission.) When large bodies of water, from sudden and extraordinary storms, have been driven into sewers containing such accumulations, the sewers have become completely choked, and have caused flooding, not, as was commonly supposed, because they were too small to convey away the storm-water, but because they were too large to be kept clear by their usual streams. The instances cited to prove the insufficient capacity of sewers, really proving their extravagant sizes, or their bad construction, or both.

It is important that the result of inquiry on this point should be understood,—namely, why a small channel or drain, properly adjusted to the run of water to be discharged, will be kept clear, while a large channel, with the same quantity of water to be discharged, and with the same fall or inclination, will accumulate deposit.

In large drains, a given run of water is spread in a thin sheet, which is shallow in proportion as the bottom of the drain is wide; hence friction is increased, the rate of flow retarded, and, according to a natural law, matters at first held in suspension, and which a quicker stream would have carried forward, are deposited. If there be any elevated substance, the shallow and slow stream, having less velocity and power of floating or propelling a solid body, passes by it. Thus, if by any neglect substances not intended to be received by a drain enter it, for instance, if a scrubbing-brush or hearth-stone has been allowed to get into, say a 15-inch drain, the height of water in regard to such substance may be as in the following sketch :—



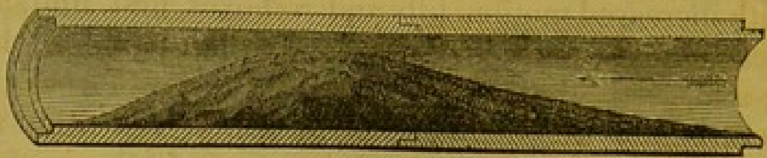
But if it were a 4-inch drain, the same quantity of water would assume a very different relative position, as in this smaller sketch :—



and it will be readily understood that the deeper stream of the contracted channel would be more powerful to remove any obstructing body.

Instead of concentrating the flow of small streams, and economising their force, the common practice is to spread them over uneven surfaces, which " deadens " and " kills " them.

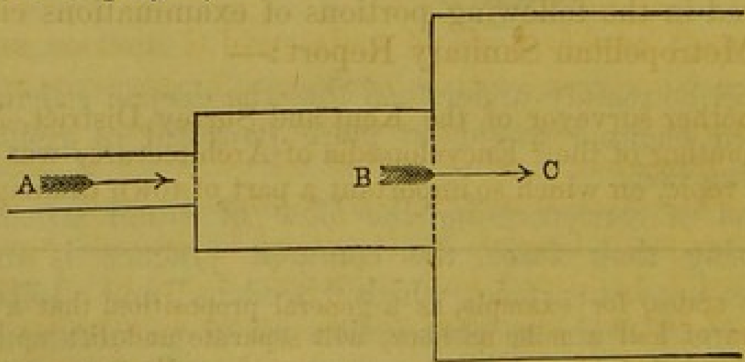
In a small drain an obstruction raises an accumulation of water immediately, which increases, according to the size of the obstruction, until four, five, or six times more hydraulic pressure is brought to bear for its removal than could by any possibility be the case in a large drain; for in a large drain of three or four times the same internal capacity, the water can only be dammed up to the same relative height by an accumulation of matter three or four times higher, and therefore 27 or 64 times greater, which will gradually lengthen out, as shown in the following sketch, and then be beyond the power of removal by the water :—



Earthenware pipes, if properly constructed, and non-absorbent, wear away less than brick drains do, and much less frequently want repair.

From their reduced size less earth has to be excavated from a narrower trench, and they may be laid more quickly and with more certainty than the common brick-drains. Rats cannot work through earthenware pipes, and as, when properly laid, they detain no deposit, and when smoothly made, give no foot-hold, they afford neither food nor shelter for such mischievous vermin.

In the course of investigating the primary and more important works, those within the house,—house-sinks for example,—the question was frequently put to architects, builders, and plumbers, "Why, to receive the water which passes through a 2 inch pipe, should you place a pitcher-drain of 9 or 16 inches square?" To this no satisfactory answer was received. In the following diagram Mr. Ranger illustrates the progressive increase at present given to pipes, drains, and sewers connected with each other, and used in the drainage of courts (where drainage is employed) :—




A, denotes a 3-inch drop or soil pipe.

B, the intermediate 9-inch drain between A and C., or 9 times the area of A.

C, being the common sewer, 2 feet 2 inches diameter, or $8\frac{1}{3}$ the area of B., and 75 times that of A.

The chief, if not the only reason assigned for making B, the intermediate drain, 9 inches diameter, is that of *preventing* its stopping or choking, an effect which its large size and sluggish flow almost inevitably occasions.

Observation of the laws of moving water, or the conditions under which water in slow motion deposits matter in suspension, and, with increased motion, lifts and removes, first, fine sand, then, with accelerated motion, coarser sand, then pebbles, then large stones, and, lastly, boulders and vast masses of rock; and the consideration of the inclinations by which velocities might be regulated, should have prevented the expensive errors which are displayed in the sewage arrangements for towns. But such investigations have yet to be made and recorded, at least as respects flows on the scale of rivers; though authentic and trustworthy experiments, made under varied circumstances would be a work of national importance. The data usually referred to as governing practical applications, were found upon inquiry to be wholly unsatisfactory, as for example, those in Professor Robison's Treatise on Rivers, which proved to be largely at variance with other observations.* Some of these discrepancies appear to have arisen, from partial investigations, from the omission to notice, amongst other things, that the power of water to suspend and to remove solids, along the same line of inclination or fall, is as the depth or head of water flowing. Thus a stream of water 4 feet wide and 1 inch deep, with a fall of 1 in 150, is sluggish; the same water, if passed through a pipe of 12 inches diameter, having the same rate of fall, would be comparatively a rapid stream. The one would deposit silt or sand, the other would certainly remove both.

The state of knowledge from which builders and common labourers derive instruction and guidance in their practice is displayed in the following portions of examinations cited in the First Metropolitan Sanitary Report:—

"Another surveyor of the Kent and Surrey District, Mr. Joseph Gwilt, author of the 'Encyclopædia of Architecture,' was questioned on this topic, on which so important a part of town drainage depends.

* He states, for example, as a general proposition, that a velocity of a stream of half a mile an hour, will separate and lift up particles of coarse sand, and of about three quarters of a mile fine gravel; whereas an instance was given of the velocity of water in the Bridgewater canal, towards the locks at Runcorn, of a velocity of about one mile an hour, at which silt is *deposited* by the water. Rivers in many parts of the world deposit silt so as to raise the surface of their waters above the adjoining land.

"'It appears that there were in the metropolis in the year 1841 270,000 houses. Now, if each were to have at the least a 9-inch drain, as you and other architects recommend, it appears that the area of the stream or river required to keep them full and flowing, would be a stream 1,132 feet in width by 105 feet in depth?—Yes.'

"'It is estimated that a supply of water for the whole of the metropolis, supposing each house to have a supply of 125 gallons per diem, or 25 gallons per head, would be given by a circular tunnel or aqueduct 12½ feet diameter. There are in the Kent and Surrey districts 55,000 houses, and the supply there would be given by an aqueduct of proportionate size to your number of houses, say one fourth. Such being estimated to be the size of conduits required to bring in water, it is presumed that the sectional areas of the drains and sewers would not be required of vastly greater size, supposing them to have as good a a fall, to carry away the same water. Can you prove any addition of rain-water, or even of extraordinary storm-water, requiring a system of drainage of a sectional area more than five times that of the Thames at Waterloo-bridge at high water, or nearly one thousand times the area of the aqueduct that would furnish the whole supply of water to the metropolis?—I apprehend, in providing drains for a house, you are to provide against accidents, therefore I should say it would be prudent always to have drains larger than are actually necessary, to guard against stoppages. A stoppage in a small drain stops up the whole orifice, a stoppage in a large one is partial. There may be most likely a means of its running off in some way or other.'

"'It has been stated that the smaller the pipe is, generally, the less likely will deposit be to accumulate, the greater will be the force of water concentrated upon the resisting medium, and the less likely is the resistance of that medium to be effectual. What is your opinion upon that subject?—My opinion is this; I will take the case of a washer to a sink being open, and the cook throwing down anything that comes to hand; it comes against a 4-inch pipe, and blocks it completely up; but the end of a cabbage-stalk will pass into a 9-inch drain, and there it will lie and decompose.'"

No more account is here taken by the architect, than by the engineer or surveyor, of the effects of the decomposition of that deposit, for the retention of which he provides. It will be seen, however, that it would be far better, were it necessary, for the inhabitants of many houses to pay for new tubular drains every year, and run the risk of having them stopped up every month, than to have large drains, detaining and spreading deposit, and facilitating decomposition within the walls and beneath the floors of their dwellings.

The necessity of the construction of house-drains with better materials and forms became immediately manifest upon the sanitary inquiry in 1842, but at that time nothing of the kind existing or being known in the house-building trades, Mr. Roe was requested to get some pipes made. Being afterwards asked to ascertain experimentally, for the immediate purposes in view, the difference of the run of water in an earthenware tubular drain, as compared with that through a tubular or barrelled brick drain, he found that the gain of velocity in favour of the better formed and less inexact surface was not less than one third; there would consequently be, with the same quantities of water, nearly a doubled power of cleansing. But the tubular drains, of the description tried, though the best that could then be obtained, were by no means perfectly true in shape, and they may still be rendered much more exact by a pressure applied by a machine when half dried. With this increase of exactness, and with but slight variation in diameter, it appears that they discharge one fourth more water in the same time even than the rude hand-made pipes first tried.

It appeared to be a common doctrine which governed the construction of such works, that it mattered little whether the surface of sewers or drains was smooth or rough; that even if they were made of rubble stone the only practical effect would be to diminish the diameter of the drain to the space between the points of the protuberances. Upon investigation this doctrine was found to be wholly erroneous, in respect to sewers as well as house-drains; Mr. Roe showed that brick sewers, whenever the surface was made comparatively smooth with cement, were kept clear of deposit, whilst the sewers having rough brick surfaces, with the same inclinations and the same quantities of sewerage, accumulated it.

Subsequently other trial works were directed to be made to ascertain the correctness of the existing hydraulic formulæ, and their applicability for determining the sizes of underground channels which might serve for town-drainage. The chief results as respects the house-drains are thus described in an examination of Mr. Medworth, the surveyor appointed to make the trials :—

"Among other things, were you not directed to try the flow of water from pipes of different constructions—some formed with pressure and some formed in the common way ?—I was.

"Did you not find that making the pipes smooth in the interior gave an increase of velocity of a third or fourth through a 3-inch pipe?—I did. These experiments were made with redware pipes, smooth, but not glazed.

"What quantity of water would be discharged through a 3-inch pipe on an inclination of 1 in 120?—Full at the head, it would discharge 100 gallons in three minutes, the pipe being 50 feet in length. This is with stoneware pipe, manufactured at Lambeth. This applies to a pipe receiving water only at the inlet, the water not being higher than the head of the pipe.

"What would be the rate of discharge supposing the whole 100 gallons to pass through the drain from the back to the front of the house, say some 60 feet, and how soon would the water be clear of the premises?—All that could be swept away by 100 gallons would be discharged clear of the house at the rate I have already stated.

"What would be the power of sweep?—Sufficient to remove any and even more than ordinary and usual semi-fluid deposit that is found in house-drains; that is, supposing the whole of the 100 gallons was to be discharged in the time stated.

"What water was this?—Sewage-water, of the full consistency, and it was discharged so completely, that the pipe was perfectly clean.

"At the same inclination what would a 4-inch pipe discharge with the same distances?—Twice the amount (that I found from experiment); or, in other words, 100 gallons would be discharged in half the time. This likewise applies to a pipe receiving water only at the inlet, and of not greater height than the head. In these cases the section of the stream is diminished at the outlet to about half the area of the pipe.

"Then a 4-inch pipe will discharge a 24 hours supply of sewage-water a distance of 50 feet in a minute and a half?—Yes; taking the 24 hours supply to be 100 gallons.

"Did you not try the force of this discharge with sand? and, if so, with what proportions?—Yes, with sand in proportion of from 1-16th to 1-40th the volume of the water, and the whole was entirely removed.

"But the different construction of the pipe with respect to smoothness will make full a fourth difference in the rate of velocity?—Yes; with the redware pipes formed by pressure, the accelerated velocity due to regularity of form and smoothness of surface was one fourth.

"What pipes did you use in these experiments?—In some experiments, including those previously referred to, we used redware pipes, but principally glazed stoneware pipes were used in the experiments at Greek-street.

"Have you not found that exactitude in the make is more important than the glaze?—Yes, the exactness of form and ACCURACY of JOINT are very important, so that the pipes may run into each other and form a complete cylinder. As an instance of the importance of exactness of joint, I had a case happen at one of my houses within the last few days. The tenant complained of the stoppage of the drain from the closet, &c. Upon sending a man to make an examination, it was found that the trap contained several oyster-shells, and one had been discharging into the drain, where it was arrested by an imperfectly formed joint.

"Then you found on experiment that this exactness of form expedited the discharge full one fourth?—Yes. As before stated in the case of the redware pipes.

"Before these experiments were made, were there not various hypothetical formulæ proposed for general use?—Yes.

"What would these formulæ have given with a 3-inch pipe, and at an inclination of 1 in 100? and what was the result of your experiments with the 3-inch pipe?—The formulæ would give 7 cubic feet, the actual experiment gave 11½ cubic feet; converting it into time, the discharge according to the formulæ, compared with the discharge found by actual practice, would be as 2 to 3.

"Or, putting it into another form, if there were a given quantity of detritus or fæces to be removed, it would, according to the formula, require nearly double the quantity of water that was found absolutely requisite in practice?—The proportionate discharges were found to be as 2 to 3, therefore the power required would be in those ratios.

"How would it be with a 4-inch pipe?—The formula would give about 14·7 cubic feet per minute, whereas practice gave 23 cubic feet per minute.

"Take the case of a 6-inch pipe of the same inclination?—The result, according to Mr. Hawkesley's formula, would be 40¼ cubic feet per minute; from experiment it was found to be 63½ cubic feet per minute.

"Will you convert that into time, and consider the 6-inch pipe as a small branch sewer? Within what time would 100 gallons be discharged at the same inclination over 50 feet?—It would be discharged in 15 seconds.

"That is to say, that the actual experiments prove how much less water can be made to suffice than these formulæ prescribe?—Precisely so.

"Then with respect to mains and drainage over a flat surface, the result of course becomes of much more value as the difference proved by actual practice increases with the diminution of the inclination?—Certainly, to a very great extent. For example, the tables give only 14·2 cubic feet per minute as the discharge from a pipe 6 inches diameter, with a fall of 1 in 800; practice shows that, under the same conditions, 47·2 cubic feet will be discharged.

"Will you give an example of the practical value of this when it is required to carry out drainage works over a very flat surface?—An inclination of 1 in 800 gives only 14 cubic feet per minute according to theory, while, according to actual experiment, and with the same inclination, 47 cubic feet are given.

"Then this difference may be converted either into a saving of water to effect the same object, or into power of water to remove feculent matter from beneath the site of any houses or town?—It may be so.

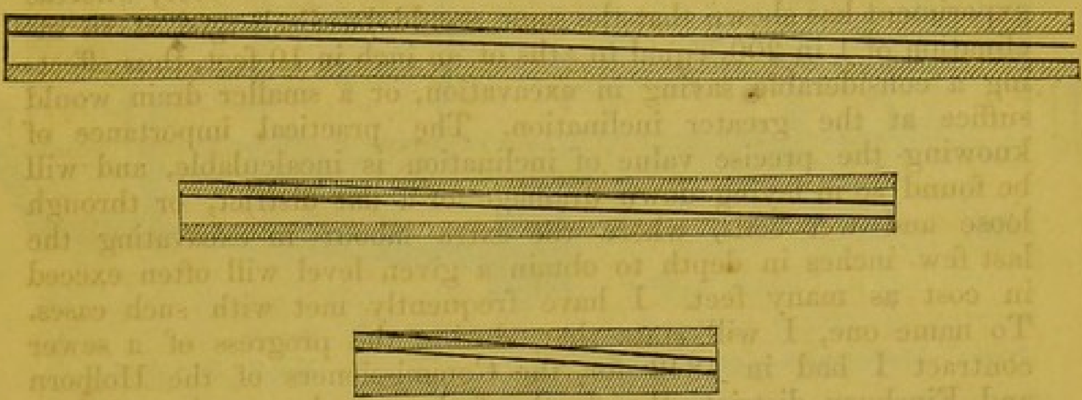
"And also the power of small inclinations properly managed?—Yes. For example, if it was required to construct a watercourse that should discharge say 200 cubic feet per minute, the formula would require an inclination of 1 in 60=2 inches in 10 feet; whereas experiment has shown that the same would be discharged at an inclination of 1 in 200, equal to $\frac{3}{5}$ths of an inch in 10 feet, thus effecting a considerable saving in excavation, or a smaller drain would suffice at the greater inclination. The practical importance of knowing the precise value of inclination is incalculable, and will be found so in laying down drainage for a flat district, or through loose and wet soils, where the extra labour in excavating the last few inches in depth to obtain a given level will often exceed in cost as many feet. I have frequently met with such cases. To name one, I will state that, during the progress of a sewer contract I had in 1842 for the Commissioners of the Holborn and Finsbury district, the depth of the trench was about 9 feet, and perfectly dry; the cost for labour was 8*d.* per cubic yard; the invert of the sewer, according to the levels given by the surveyor, required to be about 6 inches lower, and this proved to be in a running sand of the most troublesome nature, and cost me at the least 10*s.* per yard in the removal before the invert could be laid down."

## *Gain of Fall on the same Levels by small Tubular Drains.*

Besides so much gain in the force of sweep at similar inclinations, obtained by the use of tubular drains, gains in fall are obtainable from their reduced size, improved form, and smoother surface. In level districts this will frequently be a most important advantage.

The height from the top of a 9-inch barrel drain to the bottom of the opening is 13½ inches, while that of a 4-inch tube is only 5 inches, consequently, if the former must be level the latter may have a fall of 8 inches; this, in a drain of 90 feet in length, would give a fall of 1 in 135. If a brick drain 60 feet long must be level, a 4-inch pipe may be laid with a fall of 1 in 90; if 30 feet long, with a good working fall of 1 in 45; whilst with the shorter lengths of discharge available by means of back drainage, say of 10 feet, the fall would be 1 in 15. This is of great consequence, as the velocity of discharge and its cleansing power increase proportionately with the fall.

The following diagrams illustrate the gain of fall. The outer lines represent large brick drains laid level. The inner black lines show that from and to the same points small pipe-drains would have a considerable inclination : —



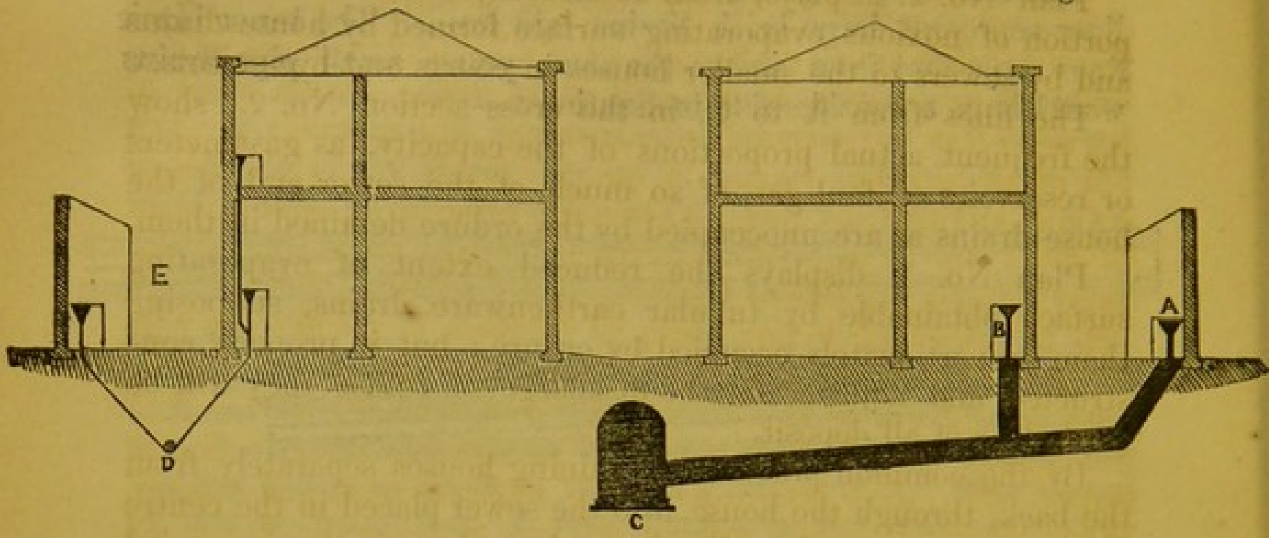
*Gain in Fall and diminished Friction of House Drains by Improvement in their Direction.*

Besides reducing the sizes of house-drains, it appeared upon investigation that great alterations were required to improve their inclinations, or fall, and also to reduce their length.

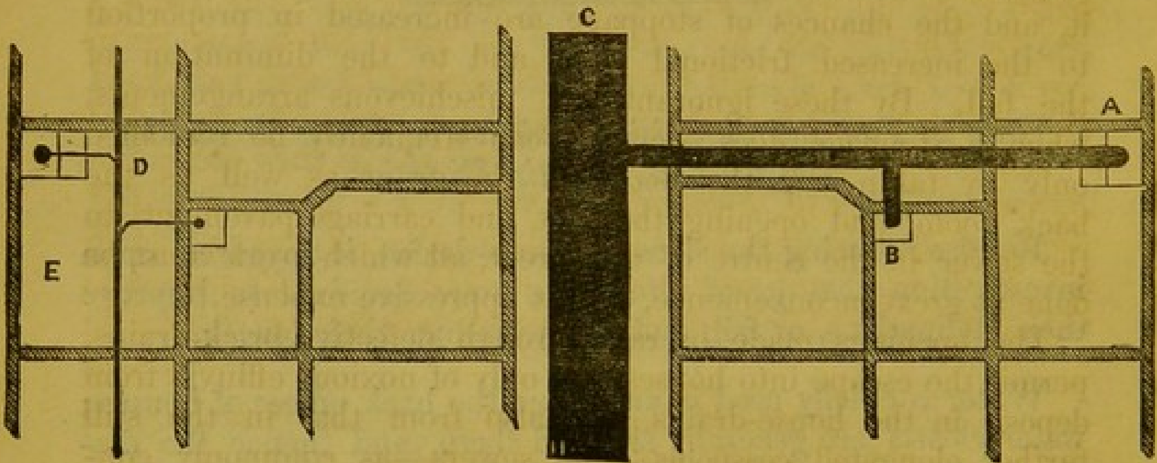
Water is chiefly used in and about the back offices of houses; water-closets are generally situated there, and thence the discharge of waste water will principally be.

The common or general practice has been to place sewers for the reception of house-drains so as to compel the passage of the refuse by a drain across the court-yard, underneath the back room or kitchen, underneath the front room, front pavement, and half the carriage pavement, to the centre of the street; whereas, if sewers had been laid at the back of the premises, frequently a house-drain of about one third the length would have sufficed, and by the same means more rapid falls would have been obtained. This is shown in the following plans and elevations, of a house with back premises on one side of the street, with the drainage from the privy A, to the sewer C, in front of the house, and of a similar house and premises on the opposite side of the street, with a main drain-pipe D, or pipe-sewer, brought to the back yard at E:—

Section No. 1. Back drainage. Section No. 2. Old drainage.




No. 1. House and yard drained. No. 2. Old drainage.




The water-closet or the scullery being situate at E, if the branch sewer were brought up from D, the length of the drain for the discharge of the fæcal matter would frequently not be more than one sixth of that which would be required if the house-drain were carried to the centre of the street, as at C, and the increase of inclination would be in the same proportion. The rapidity, however, with which the fæcal matter would be discharged from beneath the premises from E to D, by the back drainage, would be increased in much greater proportion; while with drains of the old construction, the increased friction, and the smaller flows of water, would frequently leave the more solid particles behind. The frictional area over which the refuse must be carried, by placing the sewers in the centre of the streets, will be many times greater than that which would occur in carrying the branch-drains to the back of the premises.

Plan No. 2. displays, from A and B to C, the actual proportion of noxious evaporating surface formed by house-drains and by sewers to the smaller houses in courts and bye-streets.

The lines from A to C, in the cross section No. 2., show the frequent actual proportions of the capacity, as gasometers or reservoirs of foul gas, of so much of the sewer and of the house-drains as are unoccupied by the ordure detained in them.

Plan No. 1. displays the reduced extent of evaporating surface obtainable by tubular earthenware drains, supposing them proportionately occupied by ordure; but if properly constructed and adjusted for the discharge of refuse they will be kept clear of all deposit.

By the common practice of draining houses separately from the back, through the house, into the sewer placed in the centre of the front street, the offensive and noxious matter is carried completely under the house, instead of directly away from it, and the chances of stoppage are increased in proportion to the increased frictional area, and to the diminution of the fall. By these ignorant and mischievous arrangements, when a stoppage does occur, it can frequently be remedied only by taking up the floors of the front as well as the back room, and opening the foot and carriage pavement to the sewer in the centre of the street, all which work must be done at great inconvenience, and at oppressive expense.

The openings made by rats, through defective brick-drains, permit the escape into houses, not only of noxious effluvia from deposit in the house-drains, but also from that in the still further elongated cesspools,—the sewers—as commonly constructed. A house-drain, as commonly constructed and arranged, acts as the neck of a retort, of which the sewer is the bulb, containing decomposing matter, which is discharged in the gaseous form into the premises. Medical men, who are called into houses to visit the sick at all hours of the night, have given strong testimony in relation to these offensive smells, and the excessive state of impurity in which they frequently find the air in dwelling-houses at that time.*

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* Almost innumerable instances are brought before the Board in the Reports of their Inspectors, similar to the following, stated by Mr. Lee, in the Report on Ashby-de-la-Zouch (p. 10):—

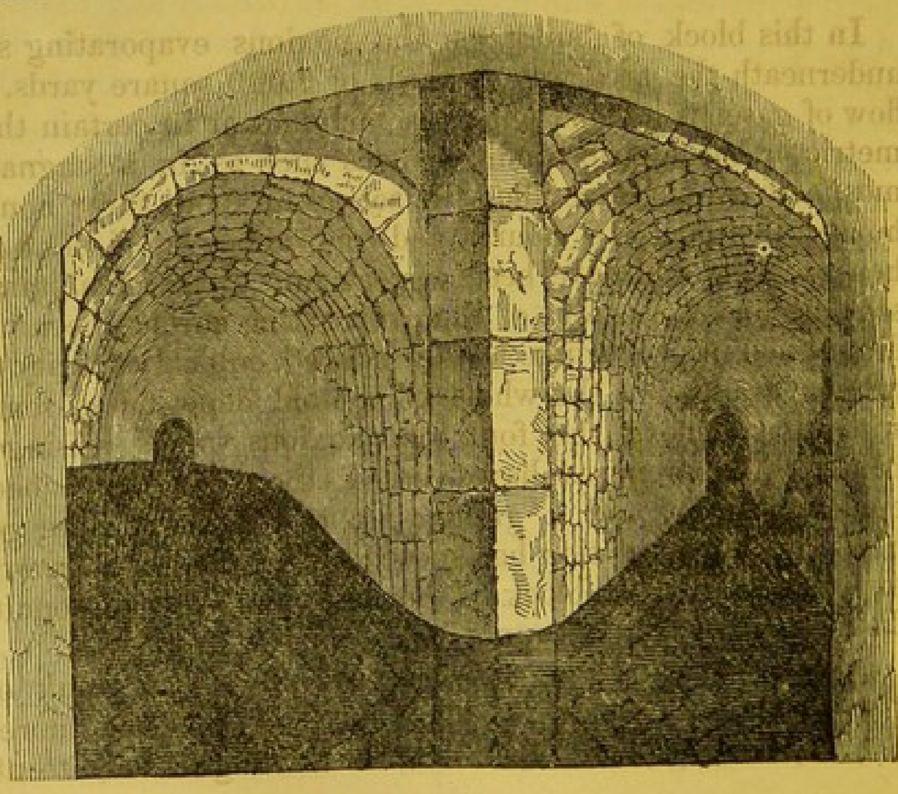
"A drain passes through many of the houses situate between Market-street and Ivanhoe-road; and I was informed that in a time of flood, the refuse frequently forces up the stones of the house-floors, and that the floors of the houses have to be taken up to cleanse the drain. It became choked in 1847, and Mr. Dalby, surgeon, informed me that he had three cases of typhus at the time, on the spot where the obstruction took place."

## *Trial of Tubular House Drains.*

The great majority of a town population do not differ so much in their habits, either as to the use of water,—or in other respects affecting this question,—to prevent the well-observed experience of an average group of houses sufficing, as to the main points, for general comparison; and the first trial works, which were made under the careful attention of the Dean of Westminster, were by him considered to afford a decisive proof of "the efficacy of draining by pipes, and of the facility of dispensing entirely with cesspools and brick sewers."

A severe epidemic fever had burst out in the houses connected with the cloisters at Westminster. Thirty scholars and inmates had been attacked, of whom several died. The houses had nearly all cesspools, and the inmates, during the variations of the weather, were beset with foul smells. On examination, it was found, that beneath the houses in which the fever raged there was a net-work of cesspools, old drains, and sewers. From beneath 15 houses which were the chief seats of fever, 150 loads of ordure were taken; and from drains and cesspools connected with the houses, upwards of 400 loads were taken.

The following is a view of the branches of a private sewer, under the schools. It usually contained several feet in depth of cesspool matter, which in one part was nine feet deep, and afforded a never-failing source of noxious exhalations into the school:—



These cesspools and old drains were all filled up, and an entire system of tubular house-drains with water-closets, substituted.

The changes in the sizes of the drains are thus stated:—

"At the outlet, the main sewer in the old works was 4 feet high, by 3 feet 6 inches wide, varying in width to 6 or 7 feet, and in height in one part to 17 feet. In the new drainage substituted there are two 9-inch stoneware mains, the united sectional area of which is but one sixtieth of the area of the smallest part of the old sewer, and not more than one half the area of the average of old single house-drains. We state that the secondary pipes are of 6 inches diameter, and the branches of 4 and 3 inches; 4-inch pipes were however used in many parts where 3-inch would have amply sufficed for all the requirements of the drainage, from an apprehension that the irregularity of the pipes would tend to create a certain amount of obstruction. This new drainage conveys the refuse and rain-water from 15 houses, the Westminster School Buildings, the Chapter House, and Cloisters of the Abbey, Little Dean's Yard, &c., comprising an area of about two acres. There is a total length of drain of upwards of 3,000 feet. The cubical capacity of the interior of the whole of the new main and branch drainage is about one thirty-second part of the cubical capacity of the interior of the old sewers; or the capacity of a portion of the old system is 32 times the capacity of the whole of the new system, exclusive of the old house-drains and cesspools; or the capacity of the old sewers is equal to a depth of water of more than two inches on the whole surface drained of about 87,120 square feet, or two acres; and they would have retained a rain-fall of this depth on the whole area."

In this block of buildings, the noxious evaporating surface underneath the area was upwards of 2,000 square yards. The flow of gaseous emanations from such matter in certain thermometric or barometric conditions was such as, in a stagnant atmosphere, would have filled the school in about three hours, the houses in about 16 hours, and the abbey itself in about 93 hours. It would have been a great gain to the inhabitants and scholars had the extent of the evaporating surface been merely diminished in proportion to the reduced cubical capacity of the tubular drains, but the whole of the old deposit was removed; with that deposit, the foul and noxious smells arising from beneath the premises have ceased, there has since been no epidemic fever, and a greater improvement in the general health of the population has succeeded than might be reasonably expected in a small block of houses, amidst an ill-conditioned district from which it cannot be completely isolated.

With respect to the action of the pipes, the result of this change, which has now (1852) been in operation more than three years, proves that, notwithstanding intermittent and ill-applied supplies of water, the force of the sweep in 4-inch tubular drains, properly laid, keeps them clear of all deposit, and also further proves that they require no extraordinary flushings.

An accumulation of noxious deposit under houses, appeared upon investigation to be often due even more to the vicious construction of house-drains than to the bad falls produced by the defective arrangement of the system of sewers.

One of the Inspectors states, that in Sheffield a difference of 10*s*. in one particular case, between the tender of a responsible contractor, and one upon whom no dependence could be placed, determined the drainage of some valuable buildings in favour of the latter. In six months, the whole length of drain was full of deposit, and had to be reconstructed, at his own price, by the more responsible person. The proposed saving was about 3 per cent.; the eventual loss was 106 per cent. The owner was wealthy, and a clever business man. Similar cases frequently occur, and are not confined to any one locality.*

The clearance of common house-drains, as well as sewers, when made on the hypothesis that they will accumulate deposit, is a source of constant expense. On an inquiry as to the cost of

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* In places where, under Local Acts, tubular house-drains are now introduced, the expenditure for the purpose of drainage is not much better provided for. The following is an extract from the Report of the town surveyor of Liverpool:—

"Besides the difficulty of getting the parties who are most deeply interested to entertain proper views as to the position of the drains, I have frequently had to complain to the Committee of the difficulty of ensuring the proper execution of the work in private drainage, unless assisted by the co-operation of the owners of property. Under a false notion of economy, an owner will employ a contractor whose sole recommendation is his assertion that he can do the work more cheaply than a man of character who intends to pay honestly for his labour and materials; and, as a matter of course, he is deceived. The work is performed and the street tunnelled under, it may be by night, and without the control and supervision, and, as easily may be supposed, without even the knowledge of the officers of the Committee.

"After a time complaint is made that the drain does not fulfil its purpose, the house is damp and pervaded by bad smells, which did not exist before; an inspection is ordered, and it is discovered, on examination, that there is no connexion with the sewer, that pipes have been put in with dry joints, that there is no trap, and that, as a natural consequence, when water has been turned into the mock drain without an outlet, it has followed the natural law of fluids, and first filled it and then overflowed.

"It is sufficiently surprising that a man should be at all guilty of the folly of injuring his own property; but it is almost incredible that, having done so once, and suffered by the act, he should be found to repeat it; but such is the case."

cleansing the brick-drains of 8,000 middle-class houses in the metropolis, it was found to be, on the average, nearly 1*l.* each per annum, which, as it included the expense of making them good, as well as of opening and cleansing, may be said to include the expense of repairs. If the expense of cleansing the brick street sewers were charged upon each house according to the frontage, at the average expense of about 29*l.* per mile per annum, it would amount to 6*s.* or 8*s.* per house, in addition to the expense of cleansing the brick-drains.*

If the expense of removing all the stoppages which have occurred either in tubular house-drains or sewers were to be taken as a necessary and constant charge, it would be very trivial in amount as compared with the expenses above referred to. But stoppages in earthenware pipes are found to be due to want of care or skill, and are preventible. The stoppages in pipe-sewers, where they have occurred, have been chiefly from the bad quality, the thinness, and the breakage of the pipes in sandy or slippery soils, where they have been laid without proper protection,—from the inlets not being properly protected,—from not putting cesspits to prevent the admission of granite detritus into pipes, sewers provided with only very small or intermittent runs of water,—from the inlets of the house-drains not being protected against the admission of large solid substances,—or from the drains being badly laid, with insufficient fall, or through ignorance or gross carelessness laid with reverse inclinations. In the metropolis, however, during the years 1849, 1850, and 1851, there have been laid down about 50 miles of pipe-sewer, and upwards of 150 miles of private pipe-drains, or a total of 200 miles, which keep clear by the action of their ordinary runs of water, where the older constructions—large sewers and brick drains—regularly accumulate deposits. The expense of cleansing the old brick sewers in the metropolis has been from 17,500*l.* to 18,500*l.* per annum. The same extent of cleansing, if it had been performed by hand labour or cartage, would, at the former contract prices, have been more than ten times as much. In the metropolis upwards of 18,000 houses have been pipe-drained.†

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* The stoppages and cleansing of the house-drains were extremely irregular, some going on with accumulations for years ; the expenses of opening and cleansing varied from 3*l.* to 30*l.*, and much higher sums.

† In a recent Report of the Council of the Borough of Manchester is the following remark :—

"It will be seen from the last statement, that the cost chargeable to owners of property for paving and sewering has been materially diminished during the last four or five years ; and your Committee would observe that

But tubular drains have frequently been laid under the most ignorant and careless arrangements; the work in the street being done by one man, the work in the house by another; probably at different times, sometimes with water and at other times without it; sometimes even when pipe-drains are laid, foul cesspools are retained upon the premises.*

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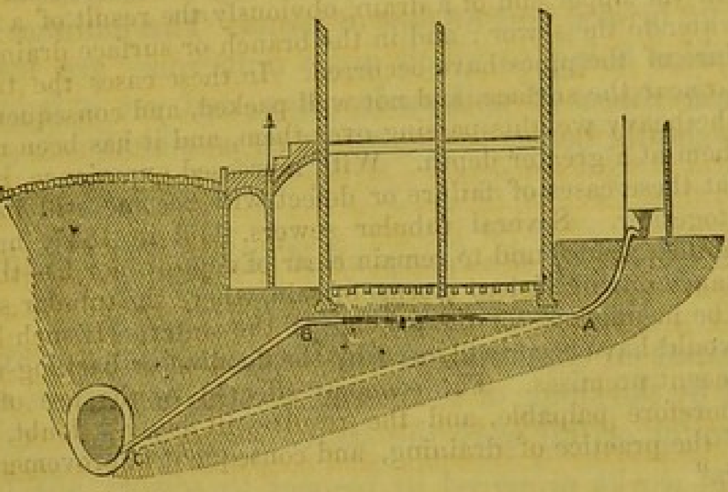
this is in part resulting from the use of tubular sewers, and in part from the paving by public tender. Your Committee continue to use glazed tubes for sewers and drains, in all cases where their size is applicable, and their use has been hitherto remarkably successful. They have been used as main sewers to the extent of about 25 miles, without a single case of failure by breaking in, or displacement. There have been two or three cases of partial stoppage near the upper end of a drain, obviously the result of a defective supply of water to the sewer; and in the branch or surface drains, a few cases of failure of the pipes have occurred. In these cases the tubes had been laid too near the surface, and not well packed, and consequently were broken by the heavy weights passing over them, and it has been necessary to replace them at a greater depth. With increased experience, it is to be expected that these cases of failure or defect will become still more rare, or cease altogether. Several tubular sewers, laid in 1847, have been recently examined, and found to remain clear of deposit, nor has there been a single instance during violent storms of rain, where the tubular sewer has appeared to be insufficient for the passage of the water. If such had been the case it would have been evidenced by the flooding or backing-up of the water to adjacent premises. The economy effected by the use of tubular sewers is therefore palpable, and the result will be, no doubt, a great extension of the practice of draining, and consequent improvement of the public health."

To show the extent of progress of the new system, it may be mentioned, that one manufactory alone turns off between 10 and 11 miles of glazed earthenware pipes for sale weekly. It is stated that probably not less than 50 miles of sewer and drain pipes are now made weekly, or upwards of 2,600 miles per annum, equal to 13,728,000 feet; and that the sale is fast increasing.

* The manufacture of sewer and drain pipes being of very recent date, and having been undertaken by persons using most imperfect means and possessed of little capital, pipes have been made of clays and marls unfitted for the purpose, badly tempered, worse formed, and imperfectly burned; such pipes when taken from the kiln have been rough on the surface, porous and absorbent in substance, and untrue in section; to such an extent that two pipes of 12 inches diameter, placed with their ends together in work, show an unevenness of joint to the extent of an inch or more. Then as to the character of joint: there have been made butt-joint, socket, half-socket, and rabbet, several varieties of each; some of the sockets have been imperfectly joined to the pipe, and many of the pipes have been so imperfect in sectional form that the plain end of a pipe could not be inserted in a socket. Such pipes have been laid in very large quantities throughout the country, and without any skill or judgment. Pipes 9 inches in diameter have been jointed on to others of 6 or 4 inches; and not unfrequently a pipe-sewer or pipe-drain has been divided or continued by means of a sewer or drain of larger dimensions, square on section, and formed with bricks set dry, or with dry rubble. During the recent prevalence of cholera, in 1849, every tile-pipe maker's yard was cleared out, and even

In some districts the sewers with which these drains are connected are charged with a greater or less amount of decomposing deposit, and are water-logged during two thirds of the day. The relief, therefore, from foul smells, must from such imperfect works be (as forewarned) only partial. Three fourths of the stoppages of the tubular house-drains are however, upon inquiries which the Board have directed to be made as to the working of the new system, found to have been occasioned by bad laying of the pipes, at wrong levels, or at reversed inclinations; of which the following cross section presents an example of not unfrequent occurrence; in which, instead of the




fall being made uniform or regularly progressive from the point A, to the outlet C, to save a slight additional expense of extra digging the drain is brought close under the floor from A to B, and the greatest fall is given at the outlet.

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pipes which had been thrown by as refuse, were, by persons not over scrupulous, eagerly purchased, and were hastily laid by parties utterly ignorant of any rule of correct drainage. The causes of failure from mere ignorance and want of skill have been sufficiently numerous, but it has been found that to these have been added others, arising from the hostility of interests, in the more expensive forms of works, and from prejudice against alteration; that many pipe-drains have been so laid as to create obstructions, and these failures, though the causes were obvious and gross, have been eagerly held forth as proofs of the failure of the principle. Experience has generally been most unfavourable to employing for the execution of new works men habituated in the practice of old works, which it is necessary to supersede. Though the demonstrations of the errors of former works were admitted at every step by such men, and although they have themselves proffered illustrations of such errors, yet no sooner was any authoritative direction of new works withdrawn than the old practices were immediately reverted to.—*Vide Appendix:* Paper as to Pipe Construction.

The new practice of bringing main drains up close to the back of houses, instead of placing them in the centre of a front street, does not offer the same temptation to do the work imperfectly. The present mode must cause obstructions, and perpetuate occasions for periodical repairs.

In the trial works with smaller-sized drains, it was found that stoppages generally commenced by the detention of large or small substances at the joints, and therefore, the less numerous and more perfect the joints, the less the probability of such obstructions. Pipes, as generally made, present one joint only at every length of 3 feet, but a yard length of a 15-inch drain constructed of 76 bricks, has 69 feet of joints; and a yard length of 18-inch drain has 92 bricks, and 83 feet of joints. The joinings between bricks, besides being so much more numerous, are much less perfect than those of well-made pipes, and yet it is important that those should be made as perfect as possible.*

## *Increased Power of the Sweep of Water gained by Alterations in the Forms of Sewers.*

It appeared on examination that accumulations were greatly influenced by the shape of sewers, where the conditions as to run of sewer water or fall were the same.

The trial works prepared in respect to sewers are here adverted to as illustrative, on a large scale, of the principles of construction previously noticed.

Mr. Roe, surveyor of the Holborn and Finsbury division, who made one of the earliest advances in the improvement of the construction of sewers, had shown that, by an alteration of the form of sewer from a flat segment to an egg-shape,—with the same quantity of water, at the same inclination,—the deposit was reduced one half.

As a point of pecuniary economy accompanying improvement in construction, it was shown that the number of bricks required to construct a sewer, A, with upright sides, 75 inches long, would suffice for the construction of an egg-shaped sewer, B, with the same sectional capacity, 122 inches long.

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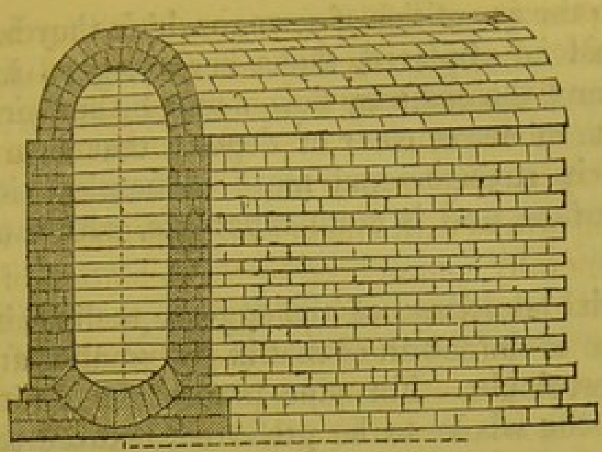
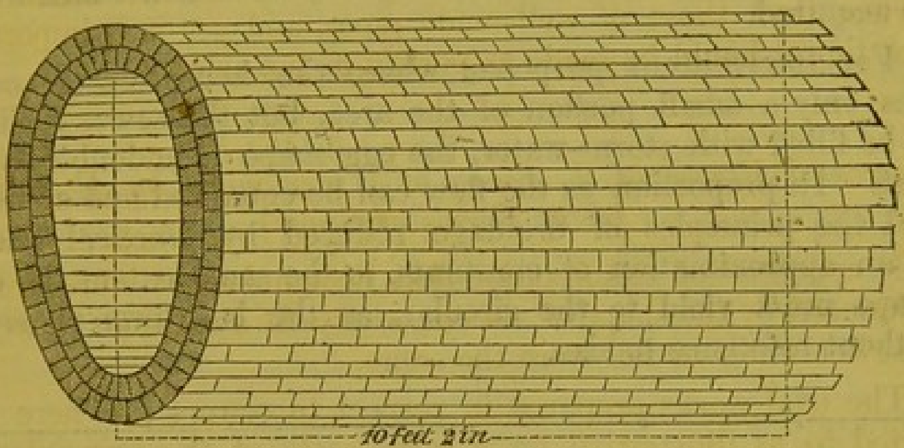
* The greater rapidity of discharge and the diminished friction through pipes is proved by the fact of pieces of paper being carried through the pipe-drains of Croydon, and discharged at the outfall; but paper is scarcely ever seen at the outfall of brick-drains, being detained in them until reduced to pulp.

A



6 *feet* 3 *in.*

B



*10 feet 2 in.*

Other examples might be adduced of improved results obtained by variations in form, without any change of the internal capacity of sewers.*

The egg-shape possesses an advantage over the circular sewer in the increased scouring action derived from the greater rapidity of flow when the stream is small, and occupies only a small proportion of the area; and this is the general condition where sewers are made large enough for men to traverse them, without

* The diagrams already given (*ante*, p. 32) displaying narrow and deep channels frequently cut by streams in the surface of the soft deposit accumulated in flat-bottomed sewers, were demonstrative of the very little observation on which eminent engineers have declared that the form of the bottom of a sewer is of no consequence. It was declared, at the outset of the investigation, that a sewer with upright sides and wide-spreading footings was the best and most certain form of construction. The examinations, directed in the subterranean survey, have proved the erroneous doctrine, in extensive failures of that form of sewer when carried through

reference to the quantities of sewage which they have to convey; but it should be observed, that wherever good inclinations are obtainable, and the ordinary flow would be sufficient to keep the circular form of sewer clear of deposit, that form is to be preferred. It is stronger and more economical, it presents less frictional surface, and is more capacious, with the same amount of material.

The special advantage of the egg-shape diminishes moreover with the size of the sewer, so that in the smaller areas it becomes scarcely appreciable. For pipe-sewers and drains the circular form is on the whole to be preferred, because the greater risk of unevenness of form, and the difficulty of obtaining the same accuracy of joint with the egg-shape, more than counterbalance the advantage of the small increase of flow which would be acquired.

For intermittent purposes, where the house-sewage occupies only a small portion of the area, but the sewer is liable to be filled with storm-water, the egg-shape is undoubtedly the best. In proportion as the flow can be equalized and adjusted, and the principles of drainage reduced by practical science to an approximation of constants, to the same extent the egg-shape must yield to the circular, as the best form of sewer, without reference to size.

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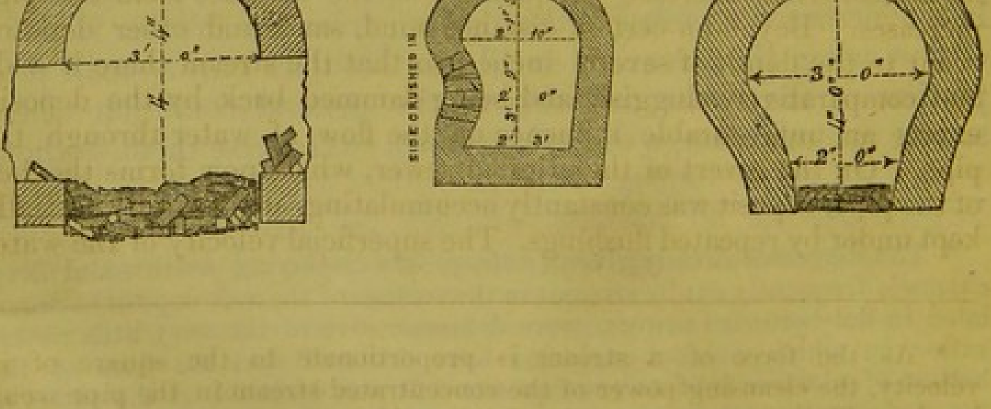
slippery ground. In some instances whole lines have been found driven in at the sides, thus:—



## *Trial of Tubular Sewers. Increased Power gained by Alteration of Size, as well as Alteration in Form of Sewers.*

The following is an account of several trial works, and illustrates the effects of altering the size as well as shape of the channel of conveyance, with a better adaptation to the run of sewer water, and the service to be performed. It is contained in a Report of Mr. Hale, the surveyor, who was directed to make the trial.

"The main line of sewer in Upper George-street is 5 feet 6 inches high and 3 feet 6 inches wide, and runs from the Edgeware-road to Manchester-street, where it falls into the King's Scholars' Pond sewer. I have laid a 12-inch pipe 560 feet long upon the invert of this main line, and have built a head wall at the end of it, so that the whole of the sewage discharged by the collateral sewers above the pipe, as well as what sewage may find its way independently into the upper part of George-street, is forced to pass through the pipe.

"The whole area drained by the sewers running into the 12-inch pipe in George-street is 213,778 square yards, or about 44 acres. Observations are being continually made on the work, and the results are as follows: The velocity of the stream in the pipe has been observed to be four-and-a-half times greater than the velocity of the same amount of water on the bed of the old sewer.* The pipe has not been found to contain any deposit, but during heavy rains stones have been distinctly heard rattling through it. When the pipe is nearly filled, the velocity and concentration of the water are sufficient to clear away any matter which may have been drawn into the pipe from the large sewers, and much of which matter it may be presumed would never enter a well-regulated system of pipe sewers; also the force of the water issuing from the end of the pipe is sufficiently great to keep the bottom of the old sewer perfectly clean for 12 feet in length; beyond this distance a few bricks and stones are deposited, which increase in quantity as the distance from the pipe increases. Beyond a certain distance mud, sand, and other deposits occur to the depth of several inches, so that the stream there is wide and comparatively sluggish, and being dammed back by the deposit, exerts an unfavourable influence on the flow of water through the pipe. On the invert of the original sewer, which now forms the bed of the pipe, deposit was constantly accumulating, and was only partially kept under by repeated flushings. The superficial velocity of the water

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* As the force of a stream is proportionate to the square of its velocity, the cleansing power of the concentrated stream in the pipe would be above 20 times as great as that in the wide sewer, consequently stones, &c. which might rest in the latter, would be swept away by the more rapid flow.

in the pipe is generally three, four, and five times greater than the superficial velocity which obtained *under the same circumstances*, in the original sewer, and the velocity of the *whole mass of water* in the pipe approximates much more to its surface velocity, as ascertained by a float, than does the velocity of the *whole mass* of water in the sewer approximate to its own surface velocity.

"On one occasion I had the sewer in Upper George-street carefully cleaned out immediately below the pipe, and then caused a quantity of deposit, consisting of sand, pieces of bricks, stones, mud, &c. to be put into the head of the pipe; the consequence was, the whole of the matter passed clear through the pipe (560 feet long), and much of it was deposited on the bottom of the old sewer, at some distance from the end. When the pipe was flowing nearly half full, two pieces of brick, one weighing one pound and three quarters, and the other one pound thirteen ounces, were impelled by the force of the water through the whole length of pipe, and struck the legs of the man at the end of the pipe with considerable force. A live rat was also washed with great violence through the pipe, and struck the legs of a man with such force as proved the rat had no control over its own motion. When the water was only 5 inches deep in the head of the pipe, nearly a whole brick, weighing four pounds, was put in it; it was heard for a few seconds moving down the pipe, but was not caught at the end.

"(The bulk of the stream at the head of the pipe is diminished to about half its dimensions when it arrives at the end, the velocity being greater.)

"A great number of irregular-shaped stones, each of several ounces weight, were washed through the pipe with the same apparent ease as marbles, and the distinct rattling noise I occasionally heard them make might convey a correct notion of the considerable force with which they must have been impressed.

"All the foregoing results were effected when the pipe was either only half full, or less than half full of water, which have been gauged in the pipe. The following is a statement of the quantities of water:—

September 28 and 29.—Very wet both days and nights; there was at this period 96 hours' continuation of rain, and the pipe was never observed to be more than half filled.

October 19.—Morning, depth of water in pipe, 3 inches; afternoon, depth of water in pipe, 2 inches.

October 21.—Heavy rain, and rain all day; depth of water in the pipe, 4 and 5 inches.

October 23.—Morning, 3 inches; afternoon, very heavy rain, when the pipe filled.

October 24.—Morning, depth varied from 2 to 2½ inches; afternoon, from 2½ to 3 inches.

October 25.—During the day, depth of water varied from 2 inches to 3 inches.

October 26.—Morning, depth varied from 4 to 3 inches; afternoon, from 2½ to 3 inches.

During the above three days the weather was mostly fine. The *considerable* variations are due to the times of the water being 'on' at the houses; the sewage at such times is much clearer, as well as increased in quantity.

October 27.—On this day a storm occurred, which for a short period was very violent, the waters filled the pipe and rose above it 18 inches, but did not reach the top of the head wall; when the waters had obtained this maximum height, they receded to nearly the level of the pipe in 20 minutes.

It may be here observed, that vitreous pipe-sewers, if properly made, will bear very considerable internal pressure. The smaller sized stoneware pipes have been tested to several hundred feet. Common redware clay pipes of 6 inches have been tested to between one and two hundred feet of pressure. Pipe sewers and drains, properly laid, and cemented with Roman cement, may therefore be used under pressure. Experience as well as a consideration of the difference of structure, shows that it is not safe to use sewers of the common brick and mortar construction full.*

Oct. 28.—Depth during the day varied from 3 inches to $1\frac{1}{2}$ inches.

October 30.—Ditto, 2 inches to $2\frac{1}{2}$ inches.

October 31.—Ditto, $1\frac{1}{2}$ inches to 2 inches.

November 1.—Variation of depth, from $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches.

November 2.—Ditto, 2 inches to $2\frac{1}{2}$ inches.

" The house-drains connected with the experiment in George-street are in most respects like the rest of the house-drains of the metropolis; the general characters of the whole are great size, irregularity of form, and filthy and bad-smelling condition. The variations in size are from nearly half a square foot to four square feet cross section, and the different forms include the circle, the square, and square bottom and sides with semicircular top; their inclinations seem not to vary more than from horizontal to a fall of two inches in ten feet. Their condition with respect to quantity of matter deposited in them does not seem to be regulated by their inclinations. This may be accounted for by the fact, that their wide and irregular inverts

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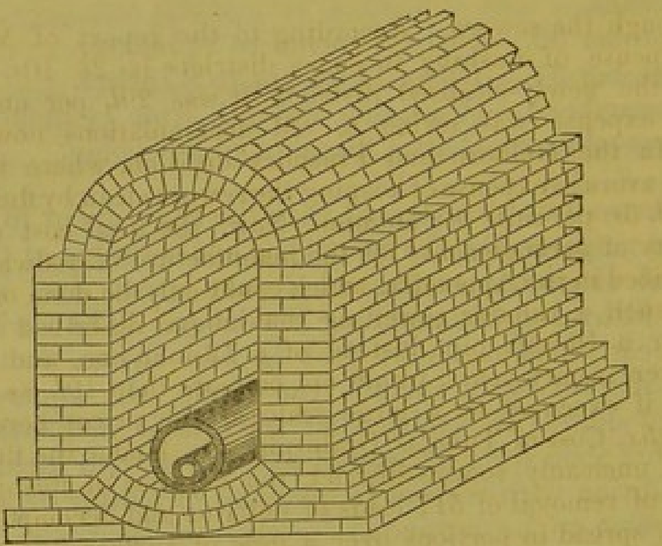
* With respect to a great number of the recently built and most expensive brick sewers in the metropolis, it is reported by the officers engaged in the subterranean survey, " that with one fourth the strength of a man, you may drive a searcher through the brickwork and several feet beyond; then by using the searcher as a lever, you may shake the whole sewer for a yard round;" and that the works cannot be reasonably expected to stand for more than ten or twelve years, much less any full flows of storm-water.

spread the small streams and destroy their force, and cause matter to lodge with greater security. Many of the ends of the drains are so dilapidated, that their original form cannot easily be distinguished; but enough can be determined to know that the sum of all their areas (480) would exceed the area of a circle of 30 feet in diameter.

"Much of the rubbish and obstructions in the house-drains have been found to consist of heaps of pieces of brick and mortar which from time to time have fallen from the soffits and sides of the drain, as it has progressively become dilapidated. Various species of fungi shoot out from the interstices of the brickwork; and the existence of old cobwebs around the sides, and sometimes nearly covering the mouth of the drain, furnishes another proof, in some instances, that the drain has not been for a long time, if ever, half filled with water. These old drains are the special harbours of rats and other vermin."*

The following is a view of a sewer, in which another trial work was most carefully conducted by Mr. Lovick, Surveyor, to determine accurately the amount of sewage from 1,200 average-sized houses in the metropolis, on the days when there was an intermittent supply of water from the different water companies; *vide Report on the Water Supply of the Metropolis*, p. 188.



* An inquiry was directed to be made as to the expense of laying down a mile of 16-inch pipe in an old sewer, with junctions of 4-inch branch pipes to every house-drain made good, when it was estimated that the expense would be 254*l.* 14*s.* 5*d.* per mile; and it appeared that in many such situations as those where, according to the views of various engineers, cleansing by flushing or hand labour would be required, such a line of pipe would keep the sewer entirely clear of deposit, and, so far as the sewer itself was concerned, clear of smell, while it would greatly diminish, if not prevent, the circulation of foul gases from the house-

In this sewer, which had a flat segmental bottom 3 feet wide, a sectional area of 15 feet, and an average fall of 1 in 118, the deposit from the 1,200 houses regularly accumulated at the rate of 6,000 cubic feet per month. But a pipe of 15 inches diameter placed along the bottom of this sewer, with a somewhat less inclination, (1 in 153), kept it perfectly clear of deposit. The average flow, without rain-fall, was about 51 gallons per house per diem; the absolute drainage, apart from rain-water, from all the 1,200 houses would have passed through a 5-inch tube, (of the relative size of the smaller one shown, within the 15-inch tubular pipe, placed along the bottom of the brick sewer), or not one third the area of the minimum sized drain, which had, up to the time of the investigation, and upon the advice of professors of architecture, been declared and enacted in the Metropolitan Building Act to be necessary for a single house; namely, one of not less than 9 inches diameter.

On the same rate of flow, the whole of the mere house-drainage from all the houses in the metropolis might be discharged through a sewer of 3 feet in diameter.*

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drains through the sewers. According to the report of Mr. Lovick the present expense of flushing in some districts is 2*l.* 10*s.* per mile per week. In the newly-cleansed districts it was 29*l.* per annum per mile. Even this expense was owing to old accumulations now in course of removal. In the Holborn and Finsbury division, where the flushing is regular, the average expense of keeping the sewers clean by flushing, at piece-work, is 17*l.* 5*s.* per mile per annum. Now, the total cost (assuming the practicability of arrangements for the manufacture of redware pipes, such as are described in the Appendix, which could only be done on a very large scale,) of such a tubular sewer as that above described by Mr. Hale, allowing for a 16-inch pipe instead of a 12-inch one, and spreading the payment over twenty years, would not be more than 19*l.* 8*s.* 5½*d.* per mile per annum, if executed on a large scale at the prices herein described. (See *Appendix*, Cost of Tubular Drain-pipes.) Under the flushing system in the least uncleanly sewers district, the expense of flushing represents the expense of removal of 517 loads of detritus and decomposing refuse at 8*d.* per load, spread in portions over a mile of surface 3 feet wide on the average, until it is removed at weekly and fortnightly intervals. At an extra annual expense of 2*l.* 3*s.* the retention and spreading of a proportionate part of these 517 loads may be prevented in streets where there happens to be a sufficient fall.

* It will be obvious that by this calculation it is not intended to convey the meaning that a 3-feet sewer would suffice for the drainage of the metropolis, but merely that assuming the average of the whole of the house-drainage alone to be that which was found in this experiment, and that the whole were flowing in one channel, at the same rate, a 3-feet sewer would suffice to convey it.

## *Expedients in default, or in substitution of improved Works for the Removal of Cesspools.*

One of the first projects urged upon the Commissioners of Inquiry, in respect to the mass of matter in cesspools, drains, and sewers (assuming its presence to be inevitable), was to disinfect it, for which purpose various patent preparations were proposed. This subject is fully examined in the Second Report of the Metropolitan Sanitary Commissioners (*vide* pp. 33—71, 125), by whom it was considered that the whole were unsatisfactory as "disinfectants," and that the most successful were entitled to the designation of "deodorizers" only; and it was subsequently proved that much time was often lost before they could be applied; that, when applied, their effects were incomplete; and that their application on a large scale would be far more expensive than effectual cleansing.*

Another set of expedients, (still assuming the inevitable presence of the matter,) urged as cures or palliatives in respect to this mass of ordure, was its ventilation by various means, one of which, the steam jet, was tried, and at the immediate spot proved very efficient; but although the steam jet gave relief to a particular sewer, yet it diffused a proportionate amount of gaseous matter, which, even if decomposed and altered by combustion, was yet not pure air, and was a less effectual remedy than entirely avoiding the evolution of poisonous vapours by preventing any accumulation of decomposing refuse. (*Vide First Report*, p. 66.) The expense, moreover, of the construction of furnaces and high chimneys, and the working expenses, were on several plans as great or greater than the expense of improvements, by which the removal of the matter, before it could enter into stages of decomposition, were ensured.

A third set of expedients, called for by private individuals,

* At the prices charged for Sir William Burnett's fluid, and with the quantities for deodorizing the cesspool matter in drains and sewers as well as in the cesspools weekly, the expense would be 644*l.* per week, or 34,000*l.* per annum for the metropolis for the fluid alone. The expense of a sufficient quantity of another fluid (Ellerman's) would have been 43,700*l.* per annum. When to this expense that of the labour is added, the total cost would have been certainly much greater than the cost of proper works for the non-offensive and continuous removal of the refuse. For deodorizing night-soil, it is stated that one ton of peat charcoal would suffice for two tons of excreta. With this material, therefore, the requirements for the metropolis would be about a ton per house, or in round numbers 300,000 tons per annum. The sale price of the peat charcoal is 2*l.* per ton. The annual expense of an improved water-closet would be much less than one fourth of the present price of the material alone proposed to be used for deodorizing the contents of a privy.

was arching over uncovered sewers, and trapping openings into the streets; but this, although it might sometimes screen particular houses, it was proved, only masked the evil, and often, by confining the noxious gases generated, made the sewers themselves more dangerous; and, moreover, occasioned such additional escapes through the house-drains as no traps could withstand, and thereby augmented the diffusion of impurities in private dwellings; whilst the expense of arching over some of the wider sewers was greater than that of proper tubular drainage works, by which the whole of the noxious deposit might be removed. *Vide ante*, p. 28, note; and Report on Suburban Land Drainage, p. 14 to p. 16.

A fourth set of expedients, urged especially by engineers, was the abatement of the evil by systematic flushing.

Most of these plans assumed the faultlessness (at least to any very important extent) of the present constructions, and several eminent engineers signed a report to the corporation of London approving of large sewers, and proposing the introduction of a river as means of their effectual cleansing. Extensive flushing was, indeed, recommended by the Metropolitan Sanitary Commissioners on the approach of cholera, but only as an immediate means of mitigation, and such means had been adopted, at the instance of Mr. Roe, in one division of the Metropolitan Commissions of Sewers. It had been the general practice, and continued to be so, in a majority of the old sewer districts of the metropolis, when the accumulations in the sewers were allowed to go on until the mouths of the house-drains were covered, to remove them by hand labour and cartage, at an expense of from 10*s.* to 11*s.* per load. By flushing, the removal of the refuse was effected more rapidly and completely at about 8*d.* per load.* The temporary extension of this process was,

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* One circumstance which first directed the attention of Mr. Roe to the necessity of having recourse to flushing was, the effect of clearing out foul deposit upon the health of the men employed in such labour. He gave an instance of a man, who the moment he arrived at the effluvia from the deposit, was obliged to leave it immediately, and go home, where he was ill of fever for a month. The men were also in many cases afflicted with dysentery. The operation of flushing was thus performed:—The sewage was first penned up so as to *cover* the refuse; the refuse *underneath* was then loosened and stirred up, diluted with water so as to abate the intensity of the effluvia; the head of water was increased, and the penstock being liberated, the whole was flushed away, and a draft of air down the sewers was also created. The whole process diminished the noxious evaporation, and gave immediate relief; but on hearing that something was going on during the cholera, certain parishes petitioned against the process of cleansing, ascribing to it the extension of the pestilence.

therefore, recommended, notwithstanding the additional pollution of the river, on the ground that the matter was less injurious there than when retained beneath or among the houses.

The prospect of the continuance of decomposing accumulations underneath habitations, even with the possibility of an intermittent removal, appearing to the members of the Board exceedingly unsatisfactory, they pursued the investigation farther. In each of the proposed remedies the state of the sewers themselves was assumed to be the whole or the main evil, whereas, supposing them to be in a foul state, they present only one fourth of the whole surface evaporating noxious gases, the cesspool being another fourth, while private house-drains supply fully two fourths of the noxious surface, which portions most closely beset the dwelling-house, and from which, were the sewer itself completely cleared, noxious smells would continue to be emitted.

## *Adjustments of the Sizes of Tubular House Drains and Main Drains required for the Discharge of Storm Waters.*

Whilst the drains for the discharge of soil-water from within houses are made of 3 or 4 inches diameter, (not, as already shown, that even such a reduced capacity is required for the removal of the usual quantity of waste-water, but because such are the smallest convenient sizes,) the main-drains and sewers will require some enlargement (beyond the space required for the ordinary waste-water from the houses) to receive variable quantities of rain-water.

The necessity of provision for the reception of these variable quantities of water was alleged as one justification of the enormous sizes of the sewers as, until recently, constructed; but on examination the data were found to be wholly insufficient to warrant such dimensions.

The greatest storm which need be considered,—such a storm as occurs in England only in the course of years,—would be a fall of about 2 inches in the hour, or 44,789 gallons per acre. Now it was proved by the trial works that a *three*-inch tube, at an inclination of 1 in 120, will clear away more than this amount of rain-fall from 10 squares, space enough for three labourers cottages, classed as fourth-rate houses under the Building Act in the metropolis; at a fall of 1 in 80 it was found that it would clear away the rain-fall from 12 squares, or one first-rate and four fourth-rate houses; at a fall of 1 in 40, from 17 squares, or five fourth-rate houses; and with a fall of 1 in 20, it would serve for 25 squares, or the space of two first-rate houses, or eight fourth-rate houses. A 4-inch tube would carry away nearly twice as much water ($\frac{16}{9}$) as one of 3 inches diameter. That size is, therefore, for such an area, more than sufficient for the greatest contingency.

Observation of the flow of any outfall of storm-water, and of the tributaries from a hill-side, offers to an unscientific person some approximate conception of the sizes of the channels or tubes which would be required to convey it away; so in a town, the observation of the flow of storm-water in the rough kennels or channels of streets, where there is no under-drainage, would be suggestive of the maximum sizes of the underground sewers required for its removal. But it was found on investigation that, for side streets, and streets where the storm-water never rises above the side gutters, enormous sewers had been constructed of a capacity sufficient to receive water enough to cover the whole surface several inches deep, and to give it the appearance—which it never had—of a river.

The occasional bursting of large sewers has been referred to as a proof of the necessity of their large size for the discharge of storm-waters; but it appeared upon investigation that the burstings were caused by accumulations occasioned by the large sizes of the sewers, by their irregularly-constructed bottoms, their junctions at right angles, and by other causes. On the occurrence of a sudden storm, one accumulation is rapidly driven up the incline of another, occasioning a complete stoppage. When the internal condition of the sewers was examined, at the places where these burstings occurred, it became a matter of surprise that such accidents had not more frequently happened. *Vide ante*, p. 30 and 31, for illustrations of the common condition of sewers, for bursting under accumulated heads of water from extraordinary storms, for the prevention of which, it was frequently recommended that such sewers should be made yet larger.

One plea often urged in justification of the extravagant sizes of the old drainage works, even for lines of streets in which but little extension could be reasonably expected was, that they were made so large to meet an assumed probable extension of the population. Such outlays are open to the objection, that immediate and certain levies ought not to be made, upon the present population, to provide for contingencies altogether remote and uncertain. It is overlooked in such expensive provisions, that the reduced rates at which improved works may be constructed, as compared with former defective works, will pay for their removal, within very short periods. Further, it is presumptuous to say that no improvement can be reasonably expected upon existing works, and that they will for ever be the most eligible. Moreover the plea cannot be sustained, even as regards the future, for reason has been generally found for believing that the same lines of sewer would admit of considerable additional heads of water without any increase of size whatsoever.

The provision of extra capacity for such purposes has, however, been frequently made on the assumption, that the increased area required would be proportional to the population, whereas it appeared that an additional head causes, by the increased velocity, the discharge of the additional quantity through the same sized sewer; an effect not then understood, but which was displayed in the trial works. It would be in exceptional cases only that the drainage area would be increased with increase of population.

Neither is the formation of a *whole* system of sewers of extraordinary sizes justifiable on the pretext of their being required on the occurrence of extraordinary storm-waters.

In many cases an increase in the number of the higher branch lines may ultimately necessitate an increased size in the valley lines; but in respect to all the branch lines it may be concluded that the concentration and economy of the ordinary flow, and the most rapid and complete daily sweep of the sewers preponderates in importance over the inconvenience occasioned by extraordinary storms, occuring at intervals of many years, and sometimes only at intervals of generations, such as the storm which fell upon parts of the metropolis in 1846, of four inches in the hour.

Various formulæ were presented to the Commissioners for inquiring into the means of improving the Health of Towns, as furnishing the means of obtaining greater certainty in the construction of town sewers, and plans for the sanitary improvement of large town districts were prepared upon those formulæ; but the sewers thus designed were still so large, and consequently so very expensive, as to offer very formidable obstructions to the extensive voluntary adoption of works of sanitary improvement. These plans were apparently thought repugnant to common and empirical observation of natural outfalls of the nature above referred to, and therefore it was found necessary that trial works should be instituted for the better determination of the proper sizes. The chief results of these trials, made with the smaller and more manageable channels for the removal of sewage or drainage water, have been already described in the evidence cited (p. 37).

In respect to the larger channels, the branch and main sewers, there occur elements not ascertainable by any readily manageable trial works;—such could be determined only by observation, from an ascertained rain-fall upon a given town area, how much did really reach the outfall, and within what time.

To test compendiously the statements as to the alleged necessity of such large sizes, for the removal of varying quantities of storm-water, observations were directed to the flows of water at the outfalls from large districts, after rain. The following portions of an examination of Mr. Roe exemplify the course and results of these investigations:—

"Have you carried on any set of practical observations as to the flow of sewers of different sizes and capacities under different circumstances?—Yes, I have. Ever since I have been in the service of the Commissioners of Sewers for the Holborn and Finsbury divisions, I have carried on observations as to the velocities of water in the river Fleet sewer; subsequently I have, at Mr. Chadwick's suggestion, extended the observations to branch and collateral sewers of different descriptions.

"Can you furnish the result of these observations, or tables founded upon them?—I have begun to form tables, which I hope to live to complete.

"What area is drained by the river Fleet?—About 4,400 acres, of which 1,888 acres are covered, or town area, and 2,512 acres uncovered, or rural area.

"What is the capacity of the river Fleet sewer, and what its inclination?—The sewer is 12 feet high and 12 feet wide, with a sectional area of 120 feet in the largest part in the Holborn and Finsbury divisions; but the capacity of the whole line varies generally according to the quantity of surface drained by each portion. With regard to its inclination, it varies from 1 inch in 100 feet to 1 inch in 2 feet, whilst some portions are on a level.

"What is the sum of the capacities of all the sewers that fall into it?—About 550 feet.

"What is their number?—Sixty, that are called sewers.

"Then the capacity of the main would be as about 1 to 4 of the capacity of the sewers, of which it is the general outlet?—Yes.

"Can you furnish an approximation to the average inclination of the sewers which fall into the Fleet?—In most instances they vary; some of them are a quarter of an inch in 10 feet, others are 3 inches in 10 feet.

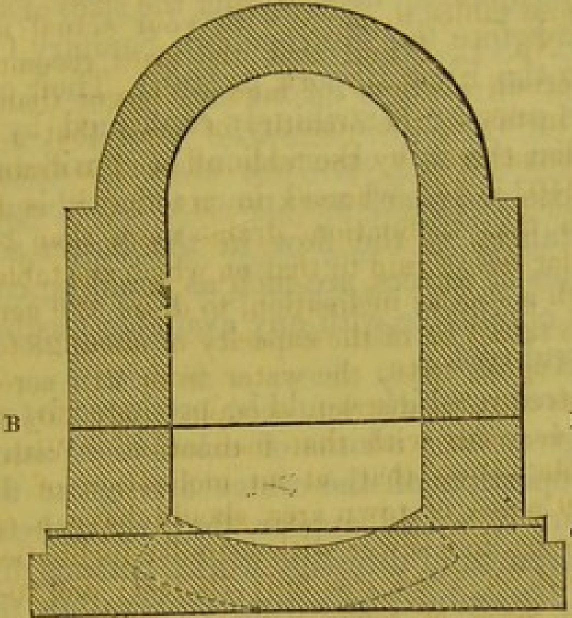
"Suppose that every house within the district had a drain of 9-inch diameter, what proportion would the sum of the capacities of the house-drains bear to the sum of the capacities of all the sewers?—About 16 to 1.

"And to the capacity of the main outfall?—About 75 to 1."

"Engineers and theoretical writers have set forth various formulæ as to the flow of water; and in the Second Report of the Health of Towns Commission there are some tables, by Mr. Hawksley, on the capacity of sewers required for various areas of drainage; how do you find those tables to agree with your actual measure?—Taking the table No. 1., I find that the sizes recommended for sewers to drain certain portions of land are larger than the actual requirements; for instance, the quantity of acres that a cylindrical sewer 48 inches in diameter is, by the table, allowed to drain, when the inclination is 1 in 240, is 47; whereas in practice it is found that such a sewer, with that inclination, drains more than 100 acres of town area at a similar fall of rain to that on which the table is formed. Again, a sewer, with a similar inclination, to drain 129 acres of town area, should (by the table) be of the capacity of about 28 feet; but in the great storm of August 1846, the water from 215 acres of town area, and 1,785 acres of rural district, occupied only 30½ feet of the superficial area of a sewer with that inclination. With respect to larger sizes, the table shows that, at an inclination of 1 in 480, a sewer to drain 329 acres of town area should have a capacity of about 78 feet: whereas, in a sewer with a similar inclination, the area occupied in the storm of 1844 was only 79 feet; and to this sewer there drained 1,181 acres of town area, and 2,656 acres of rural district."

In the formation of the tables for showing the proper size of sewers, it has usually been assumed that a certain large proportion of the rain falling upon a town area will flow into the sewers as quickly as it falls, and that the channels for its conveyance ought to be large enough to carry that quantity away, supposing it all to enter at the head. Mr. Roe finds from long continued observations that a very much smaller part of the rain runs off into the sewers in the same time than has been assumed, (*i. e.*, that very heavy falls of rain are much shorter in continuance than the floods they occasion), and that sewers receiving along their course the confluence of many smaller channels will convey away far more water than if it all entered at the head. He consequently finds that sewers of much smaller section than the usual tables indicate are amply sufficient, and therefore that the use of such tables, or of the formulæ on which they are constructed, has led to large unnecessary expenditure.

The observations, already referred to, as having been carefully conducted at Earl-street by Mr. Lovick, of the outfall drainage of 1,200 houses, included the discharge of storm-waters from 43 acres of paved or covered surface, afforded similar results, as to the wide variation between the sewers provided up to the time of the investigation, and the actual sizes practically needed. The upper line B, of the following cross section, marks the greatest height to which the storm-water rose at any one time:—




Since Mr. Roe gave the evidence already cited, he has been compelled by illness to resign his office of chief surveyor to the Metropolitan Commission of Sewers; but he has since his retirement, and during his convalescence, occupied himself in completing for the Board a table of dimensions of sewers, founded upon his observations, in the Holborn and Finsbury district of the metropolis, of branch as well as main lines of sewers: observations the most extensive of any which have yet been made. The runs of water through the smaller-sized pipes are corroborated by the results of trial works, promoted in pursuance of the investigations directed by the Metropolitan Sanitary Commission.

The discrepancies of the formulæ adopted by various eminent authorities for calculating the run of water through pipes are well known. Some mathematicians appear to have deduced their constants from experiments on a scale so small as could be tried in a room, and to have assumed that empirical formulæ so obtained were of universal application; but the results of such calculations are frequently at variance with fact, and with each other. And correct though certain formulæ may be, for determining the discharges of water through simple pipes or channels, under certain conditions, it is quite certain, from all the most recent and careful investigations, that the ever-varying conditions connected with the complete drainage of a town or district renders the application of any of the formulæ hitherto used not merely impracticable, but productive of serious constructive error. The objections to the use of all the tables prepared from such formulæ for determining the sizes of sewers were stated in evidence before the Metropolitan Sanitary Commission (*vide* Appendix to the First Report, p. 320.) Their entire inapplicability for this purpose is strikingly confirmed by Mr. Roe's table, founded upon the only observations of considerable extent, in the sewers themselves, which are known to have been yet made; and the circumstances of the flow in the larger sizes, and of most extensive lines of sewers, are such as could be corroborated by no trial works obtainable with any available means, or within reasonable time and cost.

The size of a stream which would be produced by a given fall of rain upon a given area admits of calculation, assuming that all or a given proportion of the water arrives at the drain at a given rate; but it would appear, that, notwithstanding the enormous expensiveness of drainage works, persons directing the outlay had never determined by actual observation the greatest rate at which the water did really run off, and consequently could not know of what size drains should be made.

The proportion of the flow which actually reaches the sewers differs greatly under different circumstances of season, soil, and surface, and especially of different rates of rain-fall in a given time. In long-continued rains, and in heavy storms, for which the table is calculated, a much larger proportion reaches the sewers than on ordinary occasions, the greater flow from the covered portion of the surface usually having time to pass away before the rain falling on an absorbent surface of garden, meadow, or arable land, reaches the sewer.

The Rev. J. Challis, in his report on hydrostatics and hydraulics to the British Association, remarks, that the latter department of science is in an extremely imperfect state, and that "the motion of fluids in pipes and vessels has not been treated with any success, except in the cases in which the condition of steadiness is fulfilled;" that is to say, under circumstances of much less complication than in the case of flow through sewers.

In respect to the uncovered portions of area, it was frequently found, that after even considerable rain-falls of short duration in summer, not any arrived at the outfall, the whole being absorbed. In the course of the official examinations, when the sizes of capillaries for land-drains were attempted to be deduced, from the facts admitted in respect to the observed flows at the outfall, similar discrepancies were found to those displayed in the graduation of sizes for town drainage. It is necessary, therefore, to guard Local Boards and their officers, with reference to special and complicated works of town drainage, against the errors that would necessarily be committed from the empirical use of formulæ which at the best can only be safely applied to some isolated and normal circumstances of velocity and discharge. The hypothetical dogmas founded upon a display of algebraic signs and quantities, cannot always be called in question by the members of Local Boards; the results of actual experience in such matters, upon a large scale, are therefore presented in a much more intelligible form for their guidance.

The following is Mr. Roe's Table, and his account of its formation:—

TABLE showing the Quantity of Covered Surface from which Circular Sewers (with Junctions properly connected) will convey away the Water coming from a Fall of Rain of 1 inch in the Hour, with House Drainage, as ascertained in the Holborn and Finsbury Divisions.

| | DIAMETER OF PIPES AND SEWERS IN INCHES. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 24. | 30. | 36. | 48. | 60. | 72. | 84. | 96. | 108. | 120. | 132. | 144. |
| | acres. | acres. | acres. | acres. | acres. | acres. | acres. | acres. | acres. | acres. | acres. | acres. |
| Level - | 38¾ | 67¼ | 120 | 277 | 570 | 1,020 | 1,725 | 2,850 | 4,125 | 5,825 | 7,800 | 10,100 |
| ¼ inch in 10 feet, or 1 in 480 | 43 | 75 | 135 | 308 | 630 | 1,117 | 1,925 | 3,025 | 4,425 | 6,250 | 8,300 | 10,750 |
| ½ inch in 10 feet, or 1 in 240 | 50 | 87 | 155 | 355 | 735 | 1,318 | 2,225 | 3,500 | 5,100 | 7,175 | 9,550 | 12,400 |
| ¾ inch in 10 feet, or 1 in 160 | 63 | 113 | 203 | 460 | 950 | 1,692 | 2,875 | 4,500 | 6,575 | 9,250 | 12,300 | 15,950 |
| 1 inch in 10 feet, or 1 in 120 | 78 | 143 | 257 | 590 | 1,200 | 2,180 | 3,700 | 5,825 | 7,850 | 11,050 | 14,700 | 19,085 |
| 1½ inch in 10 feet, or 1 in 80 | 90 | 165 | 295 | 670 | 1,385 | 2,486 | 4,225 | 6,625 | | | | |
| 2 inches in 10 feet, or 1 in 60 | 115 | 182 | 318 | 730 | 1,500 | 2,675 | 4,550 | 7,125 | | | | |

"The table is formed from results obtained from observations extending over a period of 20 years in the Holborn and Finsbury divisions.

"In some instances the observations were carried on during the whole period of heavy rains, being commenced as each storm began, and continued until the effect had ceased in the sewers, the depth of water being taken every five minutes, and the velocity of the current repeatedly noted at every depth.

"In some instances the observations were continued day and night for several months in different years, and in others they were conducted day and night for a period of two years; rain-gauges being kept to ascertain the depth of rain that fell.

"The particulars from which the table is compiled fill upwards of 100 memorandum books.

"The first saving which these observations enabled me to make was about 4,000*l.*, by lessening the size of a proposed portion of main line, by which a reduction of two guineas per foot lineal was effected in a length of nearly 2,000 feet. In other sewers of smaller size, savings were effected to the amount of several thousands per annum for many years.

"In 1843, I was called upon to report on the best means of saving the town of Derby from the disastrous effects of floods.

"It was from the knowledge obtained during the course of these observations, that I was enabled to suggest the size of the sewers which would convey the flood-water of the Markeaton-brook, the overflowing of which shortly before had not only caused damage to the amount of many thousand pounds sterling, but also loss of life. From the time of the completion of the sewer to this date, it has answered every expectation, no flooding having been complained of, although in August 1846, more rain fell in a short space of time than I find on record at any other period.

"This knowledge also enabled me to judge of the size required for a main line of sewer in the town of Birmingham some years since, and which has also answered every requirement.

"The necessity of carefully forming the sewers, so that no obstruction to the passage of the water may obtain, cannot be too strongly impressed on the minds of all connected with such works.

"At the head of the table I have named, 'junctions properly connected,' nor will the respective sewers drain the area stated, unless this important matter be duly attended to.

"Every junction, whether of sewer or drain, should enter by a curve of sufficient radius. All turns in the sewers should form true curves, and as, even in these, there will be more friction than in the straight line, a small addition should at curved points be made to the inclination of the sewer. I may mention a case or two in illustration. In 1844, a great quantity of rain fell in a short space of time, over-charging a first size sewer and flooding much property. On examination, it was found that the turns in the sewers were nearly at right angles, and also that all the collateral sewers and drains came in at right angles. The facts and suggested remedy were reported to the Holborn and Finsbury Commissioners, and directions given by them to carry out the works. The turns and junctions were formed in curves of 30 feet radius, and curved cast-iron mouths put to the gully-shoots and drains; the result was, that although in 1846, a greater quantity of rain fell in the same space of time than in 1844, no flooding occurred, and since then the area draining to this sewer has been very much extended without inconvenience.

"In another case flooding was found to proceed from a turn at right angles in a main line of sewer. This was remedied by a curve of 60 feet radius, when it was found that the velocity of current was increased from 122 (as it was in the angle part) to 208 (in the curved part) per minute, with the same depth of water.

"In the winter season, on meadow ground 82 acres in area, having a clay subsoil, 3 feet per acre per minute was the greatest quantity that came at one time from a fall of rain of half an inch in depth, and this amount did not reach the sewer until three quarters of an hour after the rain had ceased.

"From similar ground during the summer, when a greater fall of rain took place, no water ran off the surface, and that which percolated to the land-drains did not reach the sewer until after the greatest flow from the streets and houses had passed away.

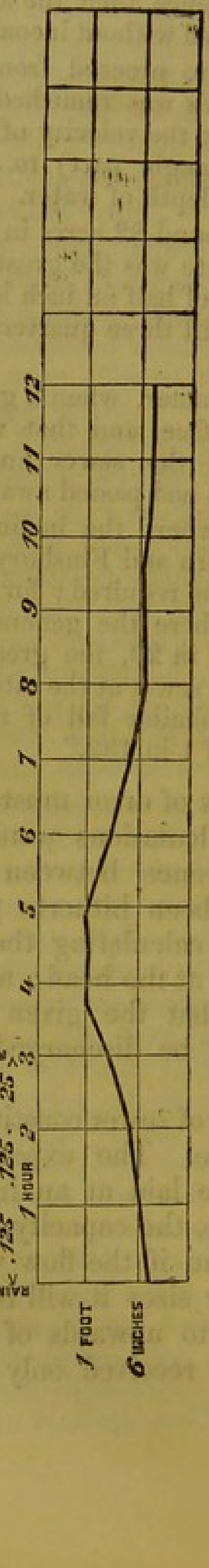
"In applying the table to localities where the inclination of the surface is greater than that of the Holborn and Finsbury divisions, a modification of the sizes of sewers will be required; for instance, in one case that came under my notice, where the general inclination of the surface of the streets was about 1 in 20, the greatest flow of water from a thunder-storm came to the sewer at the rate of one third more than it did to a sewer draining a similar fall of rain from an area with a general surface inclination of 1 in 132."

In examining this table, two points of error must be guarded against, into which the ordinary calculations would lead, and which constitute the striking difference between the results here noted, and those which have been hitherto put forward for guidance; namely, the error of calculating the discharges obtained only from pipes running full at the head; and the error of assuming, without observation, that the given quantity of rain falling in a certain time would be discharged within the same period.

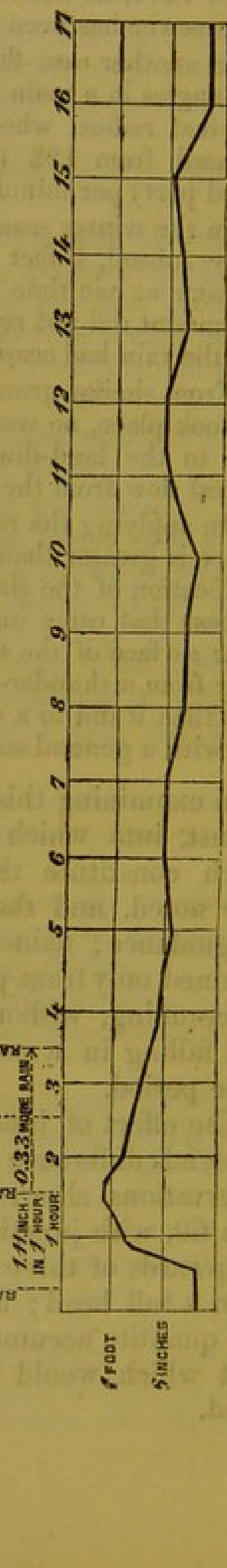
The effect of junctions on the line of sewer constitutes a most material difference in the discharge. The experiments and observations show, that with a pipe laid at an inclination of 1 in 60, with junctions along its line, the capacity of discharge is upwards of three times greater than if the flow were merely from a full head; and in the larger sizes it will be found that the quantity accumulated increases to upwards of eight times that which would be discharged if received only from a full head.

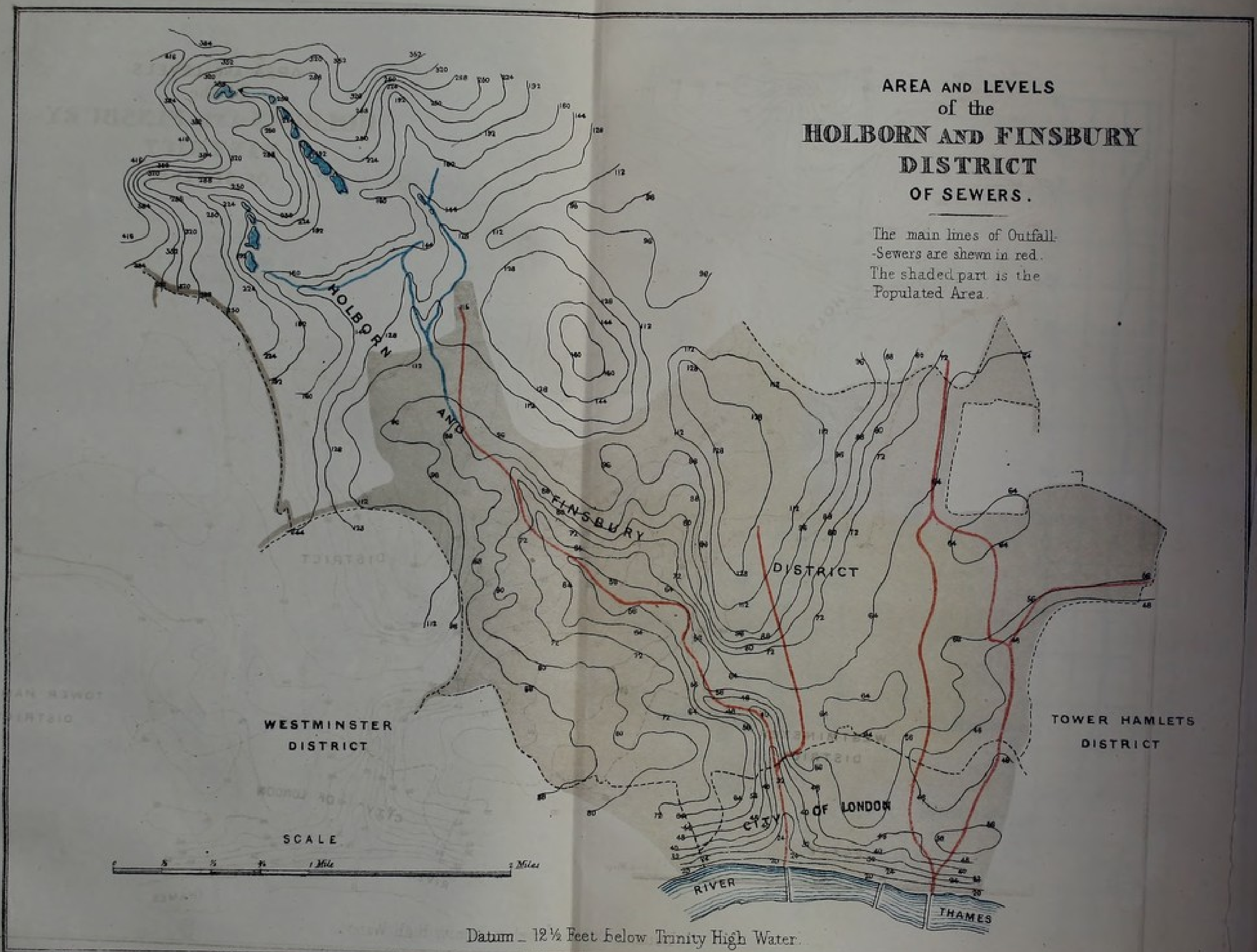
On the question of the period of discharge of a given quantity of rain, Mr. Roe gives the following illustrative diagrams, from actual observations :—

No. 1.




No. 2.




AREA AND LEVELS
of the
HOLBORN AND FINSBURY
DISTRICT
OF SEWERS.
The main lines of Outfall-Sewers are shewn in red.
The shaded part is the Populated Area.
HOLBORN AND FINSBURY DISTRICT
WESTMINSTER DISTRICT
TOWER HAMLETS DISTRICT
CITY OF LONDON
RIVER THAMES
SCALE
1 Mile
2 Miles
Datum _ 12½ Feet below Trinity High Water.
Day & Son, Lithrs to The Q

From the first, it will be observed that a rain-fall of half an inch in 3 hours took 12 hours in discharge, that is to say, 12 hours elapsed from the commencement of the rain, before the flow in the sewer resumed its ordinary level. In the second case, a rain-fall of 1·11 inch in about an hour, with an addition of 0·33 in the next two hours, being nearly an inch and a half in 3 hours, occupied in discharge 15¾ hours from the commencement of the rain.

It is desirable to point out that the conditions of drainage are so various that no table of sizes of sewers can be used empirically for all cases; but the conditions being given under which a table is formed, it may at all times be adopted as a valuable guide, if the modifications to suit the varying circumstances are carefully and judiciously considered, with the aid of skill and experience.

The following will be points for consideration in the application of the table here given to different cases. The table is formed upon the calculation of an inch fall of rain in the hour. It is only in thunder-storms, occurring at distant intervals, that this amount of rain-fall takes place in the southern parts of England; but where greater falls are of more frequent occurrence, corresponding allowance may be made in the sizes of the sewers.

It is true that instances are on record in the metropolis of considerably greater falls of rain within the hour than that upon which the table is calculated, but it would not be judicious to incur a greatly increased cost throughout the whole system of drainage, and risk of its efficiency for ordinary use, to avoid the inconvenience of an hour or two, which will only occur at intervals of many years. At the same time it should be stated, that a margin has been left, even in calculating for an inch of rain, and the pressures which would occur in the sewers when fully charged would compel a greatly increased flow before any flooding could occur.

The form, surface inclinations, and condition of the area, will be material points also for the modification of sizes.

Annexed is a sketch of the contours of the Holborn and Finsbury district, where the observations have been conducted which form the basis of the table.

The general inclinations of the surface, and of the valley lines are shown, the form of the district, and the proportion of covered and of rural area. This will serve for guidance in the use of the table for other places. If the district or part of a district under consideration is compact in form, has considerable inclination, and is mostly covered with houses, the size of the outfall must be proportionately increased, as the rain-fall would flow towards it the more rapidly, unless the inclination which can be given to the outfall or receiving sewer would compensate for the difference.

On the other hand, if the area is lengthened and distant, with little inclination towards the main, and there is a considerable portion of rural area, the conveying sewer may be proportionately less. In such cases the flow from the nearer portion of the district will frequently have been discharged before that from the distant area will have reached the main, and at all times the rain-fall on the rural portion will be proportionately longer in reaching the sewers.

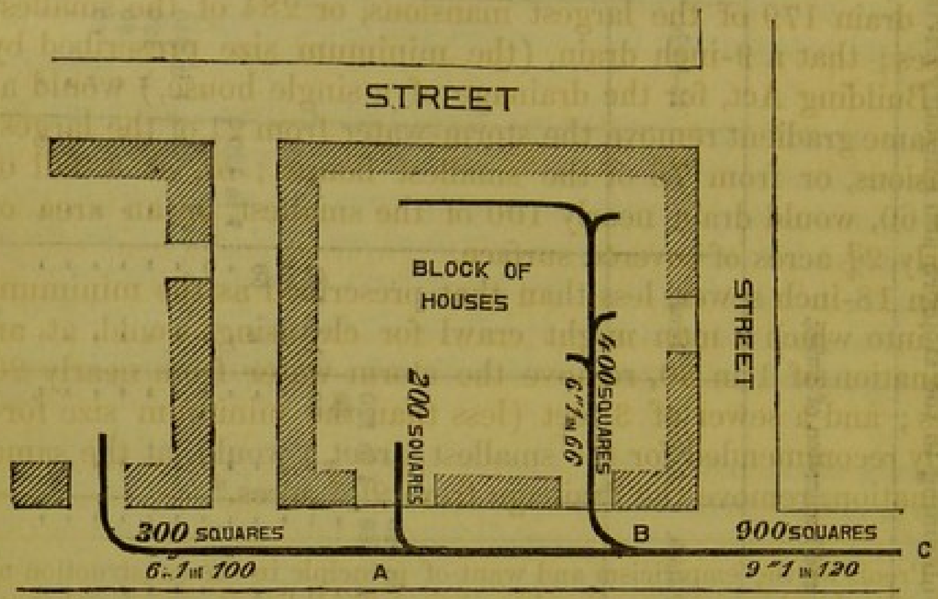
It should be observed that although the actual sizes given in the preceding table would more than suffice for the drainage of the areas stated, with the houses thereon, yet in relation to the smaller sizes, for the drainage of courts and collections of houses, some modifications will be found necessary. In these cases, many of the reasons alluded to, which are seen to operate in great reduction of size of sewer for larger areas, and for space from which several connexions would be formed, more or less distant, will not be in action. The rain-fall from the smaller spaces will flow more immediately to the drains, and their capacity must be equal to its discharge with corresponding suddenness. The pipes themselves, moreover, are often not of the full sizes which they are stated to be, and their greatest effect is not obtained from unevenness of form. The risk of carelessness in laying and jointing is greater also in the smaller sizes, where it is of the most importance, and operates still further in reducing the available capacity of the pipes. These points have so far influenced the practice that 3-inch tubes have scarcely been used hitherto, except for branch house-drains.

For these reasons it is considered advisable to admit of greater margin in the calculation of sizes, for this purpose; and the following separate table has been prepared by Mr. Roe for special application to house and court drainage :—

TABLE showing the SIZE and INCLINATION of MAIN HOUSE-DRAINS for given Surfaces, and the Number of Houses of either Rate thereon, calculated from Mr. Roe's Table for a Fall of Rain of 2 inches in the Hour, as obtaining in the Holborn and Finsbury Divisions.

| Surface occupied. | | Number of Houses of either rate, either of which may respectively be drained. | | | | Diameter and Inclination of Tubes. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acres. | Squares of 100 feet. | 1st. | 2d. | 3d. | 4th. | 3-inch. | 4-inch. | 5-inch. | 6-inch. | 7-inch. | 8-inch. | 9-inch. | 12-inch. | 15-inch. | 18-inch. |
| $\frac{1}{8}$ | 54 | 1 | 2 | 3 | 4 | 1 in 120 | | | | | | | | | |
| $\frac{1}{4}$ | 112 | 2 | 4 | 6 | 9 | ,, 20 | 1 in 120 | | | | | | | | |
| $\frac{4}{10}$ | 195 | 3 | 7 | 10 | 15 | - | ,, 40 | | | | | | | | |
| $\frac{1}{2}$ | 224 | 5 | 8 | 13 | 18 | - | ,, 30 | 1 in 80 | | | | | | | |
| $\frac{6}{10}$ | 265 | 5 | 9 | 15 | 21 | - | ,, 20 | ,, 60 | | | | | | | |
| 1 | 448 | 10 | 15 | 26 | 36 | - | - | ,, 20 | 1 in 60 | | | | | | |
| $1\frac{1}{5}$ | 528 | 11 | 17 | 29 | 40 | - | - | - | ,, 40 | 1 in 120 | | | | | |
| $1\frac{1}{2}$ | 648 | 15 | 23 | 39 | 54 | - | - | - | ,, 20 | ,, 60 | 1 in 120 | | | | |
| $1\frac{4}{5}$ | 814 | 19 | 28 | 49 | 67 | - | - | - | - | - | ,, 80 | | | | |
| $2\frac{1}{10}$ | 912 | 21 | 32 | 55 | 76 | - | - | - | - | - | ,, 60 | 1 in 120 | | | |
| $2\frac{1}{2}$ | 1,094 | 25 | 38 | 65 | 90 | - | - | - | - | - | - | ,, 80 | | | |
| $2\frac{3}{4}$ | 1,200 | 27 | 42 | 71 | 99 | - | - | - | - | - | - | ,, 60 | | | |
| $4\frac{1}{2}$ | 1,970 | 45 | 68 | 117 | 162 | - | - | - | - | - | - | - | 1 in 120 | | |
| $5\frac{2}{10}$ | 2,308 | 52 | 79 | 136 | 189 | - | - | - | - | - | - | - | ,, 80 | | |
| $5\frac{4}{5}$ | 2,534 | 59 | 88 | 150 | 208 | - | - | - | - | - | - | - | ,, 60 | 1 in 240 | |
| $7\frac{4}{5}$ | 3,432 | 79 | 118 | 205 | 284 | - | - | - | - | - | - | - | - | ,, 120 | |
| 9 | 3,976 | 90 | 135 | 234 | 324 | - | - | - | - | - | - | - | - | ,, 80 | |
| 10 | 4,404 | 101 | 152 | 263 | 364 | - | - | - | - | - | - | - | - | ,, 60 | 1 in 240 |
| 17 | 7,400 | 169 | 253 | 439 | 608 | - | - | - | - | - | - | - | - | - | ,, 120 |
| $19\frac{2}{10}$ | 8,700 | 200 | 300 | 520 | 720 | - | - | - | - | - | - | - | - | - | ,, 80 |

The following diagram will at once illustrate the use of this table in laying out the detailed drainage of the various blocks of houses*:—




The area shown is supposed to consist of 900 squares laid out in courts, and containing upwards of 50 houses. The fall of the ground, and the relative depths of sewer required, admit that an inclination of 1 in 120 may be given to the line of sewer from B to C, which will receive the drainage of the whole area; and on reference to the table, it is seen that a sectional capacity of pipe of 9 inches diameter is sufficient for the drainage under these conditions. An area of 400 squares will fall into the branch-drain, coming in at B, to which an inclination of 1 in 60 may be given; and the table shows that a pipe of 6 inches diameter will be sufficient for the drainage. Into the line above A, the sewage from 300 squares will fall, and an inclination of 1 in 100 may be obtained; and it is found that a pipe of 6 inches diameter is also required for the drainage. In distributing the inclinations, which a given fall in any continuous length will admit of, it should be borne in mind that it is always desirable to graduate them, so that the utmost inclination which may be practicable should be given to the upper part of the line, where there will be the less current and force of sweep. The drains should always be laid at the greatest inclinations which can be obtained; and this should always be kept in view, therefore, in selecting the sizes from the table.

* The sizes of the drains will require modification according to variations in the area and inclinations of the ground, and the number of houses to be provided for.

From this table it will be perceived, that the sewer formerly proposed as the smallest size admissible for the drainage of a "mansion," viz., 15 inches, would at a fall of 1 in 120, drain 179 of the largest mansions, or 284 of the smallest houses; that a 9-inch drain, (the minimum size prescribed by the Building Act, for the drainage of a single house,) would at the same gradient remove the storm-water from 21 of the largest mansions, or from 76 of the smallest houses; or, at a fall of 1 in 60, would drain nearly 100 of the smallest, or an area of nearly 2¾ acres of covered surface.

An 18-inch sewer, less than that prescribed as the minimum size into which a man might crawl for cleansing, would, at an inclination of 1 in 80, remove the storm-water from nearly 20 acres; and a sewer of 3 feet (less than the minimum size formerly recommended for the smallest street,) would, at the same inclination, remove the drainage from 295 acres.*

* Proofs of the empiricism and want of principle in the construction of works for the objects in question have been afforded as it were by chance. Thus a 6-inch earthenware pipe having been laid down for the drainage of one detached house, the drains of one house after another, as they were built, were joined to the same pipe, until at the end of several years this one 6-inch pipe was, to the surprise both of surveyors and builders, found to be clean, in perfect action, carrying away the drainage of 150 houses, and doing the work for which a sewer might have been provided of sufficient size for the entrance of a man to remove the deposit. In another case a labourer, by a blunder, put down for the outfall of a large block of houses a drain-pipe intended by the architect for a single house, and elicited evidence similar to that obtained by the trial work at Earl-street. Similar illustrations have been obtained accidentally in respect to apparatus for the distribution of water. Thus in some of the northern towns it was the common rule to put in a service-pipe of an inch diameter for the supply of a single house. A pipe of that diameter was led to a single house, and thence continued from one house to another, as new houses were built, until it was found that it served as a main, and supplied perfectly a row of 40 houses. Now a branch-main of three quarters of an inch diameter is found to be ample for the constant supply of courts containing more than 13 houses. (*Vide* Report on the Supply of Water to the Metropolis.) In respect to the larger distributory apparatus, as a temporary make-shift during some repairs, a short length of 7-inch pipe which had been put in at the bottom of a 3-feet stand-pipe for the purpose of emptying it, was used to pass whatever quantity of water it would. To the surprise of the engineer it was found to pass a quantity adequate to the supply of 34,000 houses. Until the late investigations no conception had been formed of the quantity pumped in worse than waste under the intermittent method of distribution—a quantity exceeding the annual rain-fall upon the covered area supplied. Even where the constant supply had been adopted, it appeared to be unknown what was the actual domestic consumption of the population; and it was proved upon inquiries and admeasurements by the Board's Inspectors in various places, that many of the common estimates, presented to Parliamentary committees as scientific truths, were in excess more than double. (*Vide* Report on the Supply of Water to the Metropolis, Appendix III., Report of Dr. Sutherland.) No conception appeared to be

## *Special Arrangements requisite for the Drainage of low-lying Districts, and Economy of the constant Removal of Sewerage from them by Steam Power.*

In the course of the inquiries made under the Public Health Act, in towns already provided with waterworks, it has been proved, that where additional supplies of water were carried into

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entertained of the deterioration in the quality of water by its stagnation and exposure in open reservoirs or receptacles in the vicinity of towns, or of floodings from the surface-washings of lands. Many large arrangements for the supply of towns were proposed, on assumptions that they were founded on exact data of hydraulic science, practically applied; whereas, the data, for the most important works, continue in a very loose state. In Italy, for instance, where the measurement of the quantities of water distributed for irrigations has been the subject of dispute for centuries between the government, the distributors, and the owners and occupiers, the consumers throughout the irrigated districts, no completely satisfactory water-meter, or mode of measuring the quantities delivered, has yet been invented. (*Vide* Report of Captain Baird Smith on the Irrigations in Italy.) The institution of varied and adequate trial works for the complete and authentic settlement of a number of such questions of economical arrangement would be of national importance. Many undertakings are in progress at the present moment for which immense outlays are required, with reference to which the state of knowledge as to the strength of materials, is similar to that displayed in the declarations by large majorities of professional men, to the effect that the Crystal Palace could not bear the weight of its visitors, and must give way before the first storm; or to those which rested in such arrangements of materials as have led to fatal catastrophes. For all this want of practical data and real science the public has frequently to pay the penalty of a double and treble expenditure beyond what would have been required had the estimates been formed on exact and proved data. Already, however, examples of contracts taken and works performed within the estimates, have been afforded by means of surveys and other necessary information obtained previously to the commencement of works, under the Public Health Act.

It accounts, in part for the singular want of agreement among the opinions and reports put forth, even by persons whose duty it was to understand the subject well, respecting the laws of water currents in open or close channels, to observe, that, as in hydrostatics, some of the phenomena depending on the mere weight and diffused pressure of water appear so extraordinary to persons beginning the study, or imperfectly acquainted with the laws, that such phenomena have been called "hydrostatic paradoxes;" so in hydraulics, some simple consequences of the well-known laws of falling bodies, and of atmospheric pressure, are so unexpected and unintelligible to ordinary conception as to deserve similarly the appellation of "hydraulic paradoxes." One of these last is the fact that a uniform, sufficiently sloping, open channel, which at its top is freely receiving from a reservoir, or a meeting of currents, so much water as completely to fill its mouth, can yet receive into its stream lower down, large additional quantities of water through lateral inlets, and will then discharge from its bottom opening, which is of the same size as the top opening, even several times as much water as entered at the top. Another of these "paradoxes" is the fact, that if a common funnel or a short piece of tube with a gaping mouth houses unprovided with proper channels for its removal, not only were the foundations of the particular house surcharged with the excess of water, and the walls by absorption rendered more damp, but by the neglect of proper means for removing the surplus water, it became a cause of nuisance to other houses. The

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be held under a water-cock, and as much water be allowed to fall into it as to maintain it nearly full, and if then a pipe of the same diameter as the lower outlet of the funnel, or piece of tube be joined to it so as to lengthen it below, the quantity of water passing through, instead of being lessened by the friction of the additional downward pipe, as happens when an addition is made of horizontal pipe, will be increased in a proportion to the length of pipe added, until that length reach a level of about 34 feet below that of the mouth of the apparatus. A water column of 34 feet has a pressure nearly that of the atmosphere.—The first of these remarkable facts is a simple consequence of the law known to everybody, that a body falling freely is always increasing its speed, whether its course be directly down, as of an apple from a tree, with increase of speed of 32 feet per second, or be oblique, as when a railway carriage carelessly left loose at the top of a steep slope gets away, and soon has a velocity which dashes it to pieces against any obstacle met below (the increasing speed in such a case being proportioned to the steepness of the slope or incline); and whether the descending body be solid, as in the cases just mentioned, or fluid as in the water of a perpendicular cascade, or in that of rapids shooting along sloping portions of a river channel. The phenomenon of the acceleration of a fluid current under the continued influence of gravitation is well shown where a viscid fluid like treacle is poured from a height. A mass at first slow moving, and as bulky as a man's wrist may be seen gradually tapering as it descends to the size of a finger or less, the diminution of size being everywhere exactly proportionate to the increase of speed; and however long the experiment be continued, the tapering cascade retains the same form. Similarly, a water stream, in a sufficiently sloping uniform channel, becomes less bulky as it descends, and as the speed increases; although of course the same quantity of water passes along every portion of the channel; and hence, a larger space, or area of the uniform channel is left unoccupied by the water, as the speed of this increases, and so more room is left for additional streams to enter the channel from around its descending course. Because, however, friction of the water against the sides of the channel increases rapidly, as the speed of the current increases, while the force of gravity tending to accelerate remains the same, a state of equilibrium is soon reached between these opposing forces, after which the stream, however long, goes on uniformly, with speed proportioned to the slope. This is seen in all rivers of uniform current. In the annexed woodcut, are sketched sections at three points of a sloping pipe in which a stream was running and becoming less bulky as the speed increased. The other hydraulic paradox above mentioned, of a common funnel or gaping short piece of pipe, (and in certain cases of water-drains,) being caused, by having an addition of pipe made at the lower opening, to transmit much more water than what fills the mouth, which pipe may be either perpendicular or oblique, is owing to the disturbance of the atmospheric pressure which is acting on all things at the surface of the earth, and therefore on the top and bottom of the column of water in the pipes. It happens thus:—in the cases supposed, the descending stream, if free, would quicken its speed, and become lessened in bulk in its descent, (as already explained above for open channels, or for free descent in the air,) but in a long tube, artificial supplies of water to a closely-occupied town district are commonly nearly equal to a rain-fall upon its surface; consequently, where the neglect to provide proper drains for the removal of the pipe-water is common to blocks of houses, or to the districts occupied by the poorest classes, the waste water thus introduced amounts to a daily rain-fall, which, from its constant recurrence, keeps the premises always damp, and aggravates the evil of stagnant flood-water at the periods when the rain-fall is excessive. (*Vide Report on the Supply of Water to*

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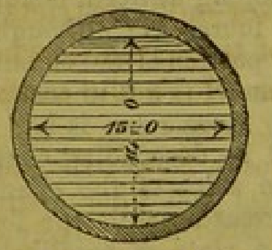
having openings only at the top and bottom, and both openings filled with water, the stream cannot lessen its bulk without leaving a vacuum in the tube, which vacuum, the pressure of the atmosphere at the top and bottom tends to prevent. Thus, therefore, the part of the tube below, as well as that above is kept full of water, the weight of which balances or destroys more or less of the upward atmospheric pressure at the lower opening, and lets the undiminished atmospheric pressure above act, as an unopposed force, to urge more water through. If the tube below had its mouth exposed to the air, (that is, were not immersed in water,) and were roomy enough to allow a stream of air to ascend by the sides of the stream of water descending, no increase of water flux through the general tube would be produced by an addition of tube below.

In illustration of the above, may be given the following instance of one trial :—

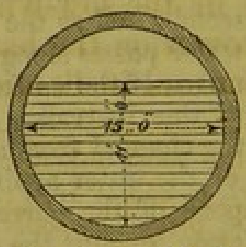
"*Velocity* and *amount* of water flowing through 235 feet of 15-inch earthenware pipe, temporarily laid at Hitchin, at an inclination of 8 inches in the 235 feet, or, 1 in 352½, an opening being made for the admission of air at the centre of the pipe."

No. 1.
Sectional area of water
10 feet from inlet.



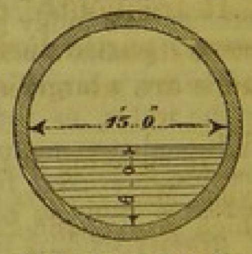
Water being 14 inches
in the pipe.

No. 2.
Sectional area of water
at mid-channel.



Water being 11 inches
in the pipe.

No. 3.
Sectional area of water
at outlet.



Water being 6 inches
in the pipe.

"The velocity of stream was about 188 feet per minute, and the amount of water discharged 1,025 gallons per minute, or, 1,476,000 gallons in 24 hours.—The gauging of No. 1 section was taken 10 feet from the inlet to secure the fair current of water, the pipe being full at the outer end."

In respect to town drainage, the practice of architects and engineers was to enlarge the area of any main pipe in the proportion of the sectional area of each junction into it; whereas, it was found, by the trial works, that the addition of eight junctions, each of three inches diameter, into a main line of pipe of only four inches diameter so increased the velocity of the stream, that there was no increase of its sectional area.—(Appendix No. 2. to Report on Water Supply; Medworth, p. 191.)

Enormous works have been constructed in neglect of these principles, and at worse than double cost to the public.

*the Metropolis*, p. 127 to 137.) When the site of a town is undulating, waste water accumulates at the lower levels; for which reason, even if both occupier and owner, from a false notion of pecuniary economy, agreed to bear the excess of dampness themselves, they should be debarred from inflicting the nuisance upon others.

Very numerous instances might be cited from the reports of the superintending inspectors, showing that where court-yards and premises extend laterally along the sides of rising ground, as they do to a very great extent in many districts (the property of the several owners respectively forming steps one below another,) if without proper drainage, not only is the value and durability of each property diminished, but the health and lives of the poor occupiers endangered.*

Since experience has proved that the *smallest* tubular house-drains, which have, in proportion to the flow of water, the most friction, are kept free from deposit without special supplies of water in flushing,—we may be perfectly certain that the larger mains, when due adaptations are made in respect to form, size, material, and inclination, having, in proportion to the run of water, much less friction, will be kept clear by the same, but more concentrated, runs of water. This has also been established by the evidence of actual practice, where there are sufficient natural inclinations for the discharge of the sewage. The end accomplished is in fact *natural* and *constant* flushing, for the prevention of deposit, to supersede *artificial* and *occasional* flushing for its removal.

It frequently occurs in the low-lying river-side districts of towns, particularly in towns on the banks of tidal rivers, where there are no sufficient natural inclinations, or where the outfalls

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* In speaking of two of the most unhealthy places in Newcastle-under-Lyme, Mr. Lee says (*Report*, p. 25), "In Friar-street and Church-street, which rise considerably, the privy cesspools are placed successively one above another at the backs of the houses, and there is an offensive drainage from many of them to the premises next below. There has been much fever and cholera there." In the Report on Rotherham and Kimberworth (p. 11), he says, "The privies on Mr. Ward's property are above the roofs of two houses belonging to Mrs. Holland, and occupied by Scott and Pearson. The filth percolates down and under these cottages into Wellgate. The liquid from five piggeries drains the same way. This is another instance of property undrained on a hill-side. I examined the house occupied by Scott, and found his wife just recovering from fever, after being ill between two and three months. I saw night-soil on the floor of the kitchen, and oozing through the wall." These two belong to a large class of cases in which both the owners and occupiers of one property are injured by those of another, and in their turn injure the next below, and yet with a fall which, with proper arrangements, would effect the perfect removal of all refuse.

are below high-water mark, that the flow is interrupted, and the sewer water pent up, until a discharge can be obtained at the fall of the tide.

This is peculiarly injurious, for as the sewage accumulates in these sewers, the foul gases with which they were previously filled is displaced and forced, some into the streets through gully-holes, some into dwellings through house-drains. The nuisance thus occasioned is sometimes felt at a considerable distance from its source; for when the lower part of the sewer is filling, the air may escape at openings from the upper sewers communicating with it. Thus persons at above a mile distance from the sewer have been made aware that the tide was rising, by the extra quantity of foul air forced from the sewers.

As it was the general practice in respect to house-drains not to alter their form, or principle of construction, but to provide mud-traps to be cleared periodically; so in respect to the sewers, where deposit was accumulated, from inordinate size, insufficient inclinations, or interrupted flow, or from any other cause, it was the practice to recommend the removal of refuse by immense flushes of water.

It appears, however, that this practice was founded in the absence of proper estimates of the quantity of water to be removed, and that on the like principles of arrangement on which water is collected, and pumped into a town, and distributed there, it may, and at similar rates of expense, be as constantly pumped out of a town, to be re-distributed where wanted; and that with respect to the cases of interrupted flow by the action of tidal rivers, and the common practice of detaining the sewage during high water, and allowing the deposit to settle and accumulate in the interval, the cheapness of the removal of water by steam power has been overlooked.*

* At the opening of the investigation the general feeling of the majority of engineers appeared to be to treat the rivers as being, of necessity, the only outfalls of all town drainage; and several eminent engineers, at the Metropolitan Sewers Commission, spoke of and against the use of pumping, as opposed to what they called the "natural" method of discharge, without pumping. But on reconsideration, the sanitary consideration prevailed, and the following resolutions were, amongst others, eventually adopted by them unanimously:—"To maintain a continual and unintermitting flow, with the aid of lifts where necessary, in all the sewers along their whole length, by which the evils arising from pent-up sewage, viz., the generation of noxious gases, and the unavoidable formation of deposit in the sewer during its stagnation, may be avoided:" "To construct the sewers at inclinations so proportioned to the volume of fluid to be carried off by each, that the velocity of the current shall keep them clear of deposit, without the need of regular periodical flushing, which experience has shown to be not only troublesome and expensive in its operation, but also very injurious to the sewers and drains in which it is practised."

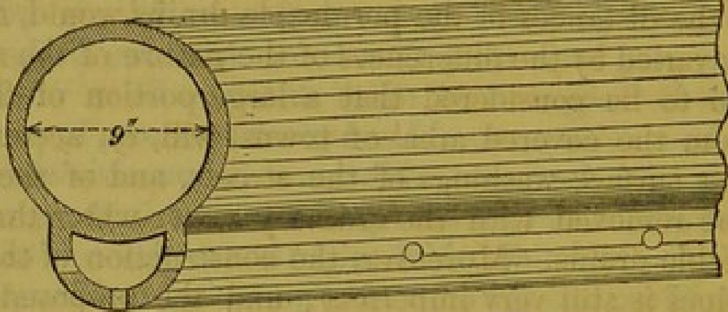
The cost of ensuring a continuous flow in such cases is merely the cost of steam power for giving a continuous lift. The working expense of lifting 30,000 gallons 10 feet high, with a steam-engine of 25-horse power, is only 1*s.*; and with an engine of 180-horse power, less than half that sum, coals being about 12*s.* per ton. (*Vide Report on Water Supply, Appendix* II. p. 25.)

Many extensive fen districts are by steam power kept clear of surplus rain-water, at an expense of from 2*s.* to 5*s.* per acre per annum, including all expenses; and it has been estimated that the expense of pumping out the sewage, as well as the whole rain-fall from a difficult district on the Southwark side of the metropolis of 4,000 acres, by a lift 31 feet high, and discharging it at Deptford, would be about 1*s.* per house, or 2*d.* per inhabitant per annum; and little more than twice that sum, if the surplus water were discharged at 12 miles distance, for a work which, as a mere house charge, would be a great economy, by preventing dilapidation from dampness. Moreover the expense of excess in the sizes of sewers and works requisite to contain the sewage impounded during high tide, which might be saved, would of itself be a large set-off against the expense of pumping, and in some cases would exceed that cost; and further, the default of pumping at the outfall, to produce a continuous flow, must be remedied by the expensive alternative of pumping at the other extremity of the works, to supply for the sewers additional quantities of water in sufficient volume to move and flush away the matter deposited and indurated during the time when the discharge at the outfall is intermitted; so that, apart from the sanitary evils and inconvenience from detaining masses of stagnant sewer-water, and decomposing deposit amidst habitations, the continuous discharge of sewage by pumping is, in such cases, the more economical alternative.

By pumping, it is practicable to amend the defects of fall upon any table land, and, if needed, to accelerate any natural fall to the extent to which it may be considered necessary, so as, by properly stationing the pumps, to secure the great desideratum of a good fall throughout every part of the system, and that with any desired current or inclination. With a proper and complete system of combined works of water supply and tubular house-drains, connected with properly-adjusted branch and main sewers, there is, therefore, no exception to the rule that refuse need not, nor should be permitted, to remain underneath or near houses, beneath streets, or near the sites of towns. All might be in a constant state of inoffensive and entire removal at a rate of about three miles an hour, and in a current of such velocity no deposit could remain to accumulate.*

*The impermeable and the permeable Lines of Drainage not always coincident.*

In the course of the sanitary inquiry it was suggested, that, by means of machine-made pipes, the impermeable and the permeable systems,—the channels for the conveyance of foul or sewer water, and for the removal of spring or plain surface water,—might be united, and put down in the same trenches; in accordance with which suggestion, house-drains were prepared of the following form :—




Sewers were proposed to be constructed on the same principle, of hollow bricks, with perforations in the sides. *vide* p. 94.

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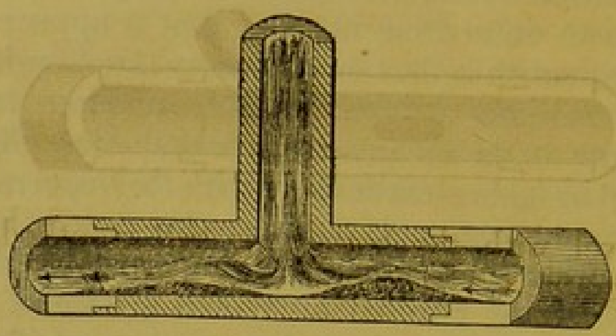
* It is an illustration of the insensibility, as to any existing evils, of those who are most impatient of any new annoyance, (however slight or fanciful,) that the most strenuous opposition was made to the discharge of cesspool matter into the sewers, and thence into the river Thames, and also to flushing of the sewers, on the ground that the pollution of the river would be increased thereby ; though the objectors seemed quite insensible to the far greater evils arising from the retention of ordure beneath their houses, and the vast swamp of subterranean filth existing in their sewers, and discharging the products of decomposition into their streets and houses. It is, no doubt, very desirable that the pollution of the river should be reduced to the minimum, though at the best it would be quite unsuitable for drinking, for washing, or other domestic purposes. Again, whilst no objection was made to the pounding up of foul water in the sewers, and the accumulation of deposit there,—both of which practices cause the extensive diffusion of poisonous emanations,—*vide* notes, *ante*, p. 28, and *ante*, p. 45,—the most violent opposition was raised to the formation of small pumping establishments, or sumps for removing the sewage, which could not possibly cause *addition* to the filth,—must have immensely reduced the evaporating surface of sewage water and cesspool matter,—and would have facilitated the removal of that which did and does exist, and that too in a manner far less objectionable than that now practised. When the sewerage is removed properly, it is removed before decomposition can take place, and before it becomes in that state in which it now usually is when removed, and when the act of removal, as commonly performed, is, for the time, a nuisance.—*Vide* pages 80 and 99.

The objections which on consideration prevailed against this mode of construction were chiefly these:—that the conditions requiring the removal of spring or surplus rain-water from land were by no means coincident with those requiring the removal of foul or waste water from houses; that it appeared to be frequently expedient to collect and remove land-spring water at higher and sometimes at lower levels than sewer water; that it did not appear to be frequently necessary that the permeable drains should be laid co-extensively with the impermeable drains, and that it would commonly suffice to lay down the permeable drains much wider apart than the impermeable drains, as the land-drainage of the covered area of a square of houses may frequently be effected by a single line of pipe outside the square; and that the distances of the permeable drains would, moreover, be widely varied by the differences of the nature of the substrata. It is also to be considered that a large portion of the storm-water from the covered area of towns, will, on account of its containing surface-washings of the streets, and of the roofs of houses, be removed with the ordinary sewer-water through the impermeable drains. Moreover, the construction of the present simple pipes is still very imperfect; and the proposed arrangement would have occasioned additional difficulty in placing and jointing, as well as in construction. For which reasons it has not been recommended, (without deciding that there might not be cases in which it would be expedient and practicable,) that the suggested principle of construction should be generally prosecuted. (As to the general conditions of permeable drainage, *vide* Minutes of Information, on the Drainage of Lands forming the Sites of Towns, and Road Drainage.)

### *The Junctions of Drains and Sewers.*

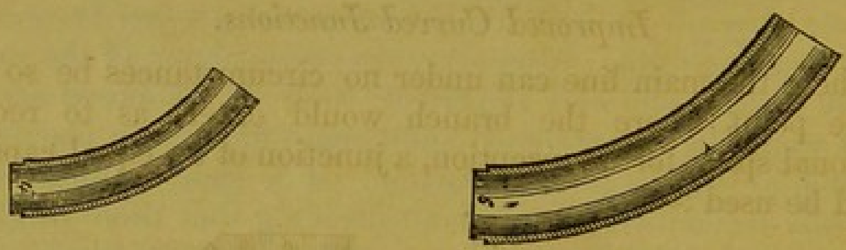
It appeared on examination that the general practice of the engineers and surveyors who designed and executed this class of works, was to make the junctions of sewers, as well as of house-drains, at right angles. Mr. Roe, who greatly improved the shape of the sewers within his district, proved experimentally that when equal quantities of water, with equal falls, in a sewer, were running *direct* at a rate of 90 seconds, an equal discharge required, with a turn at *right angles*, 140 seconds; whilst with a turn or junction in a true *curve* the discharge was effected in 100 seconds. (*Vide Sanitary Report*, 1842, p. 57.)

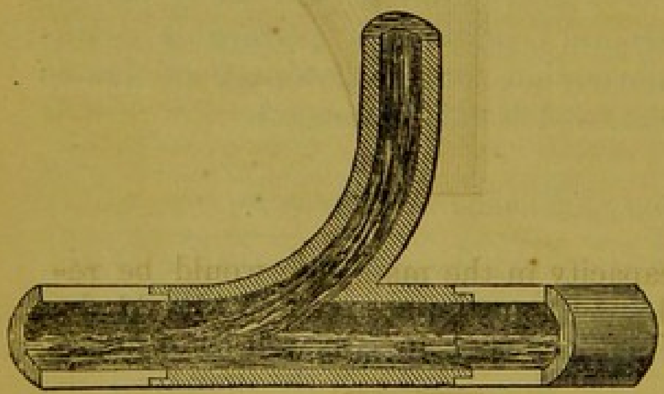
The effect of junctions of house-drains at right angles, whether horizontal or vertical, is greatly to retard the flow, and to cause accumulations. With the drop junction at right angles, the effect of the splashing of soil and refuse is such as that displayed in the following diagram:—

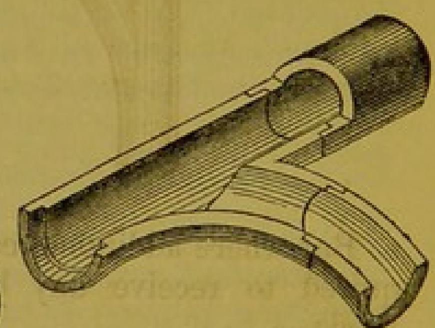


With horizontal junctions similar retardations occur.

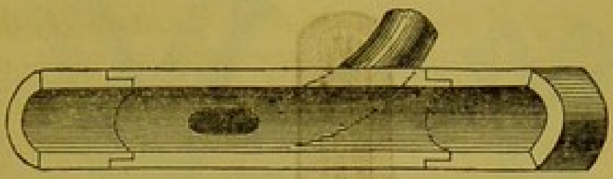
The following are eligible curves for the bends of drain-pipes, whether mains or branches:—



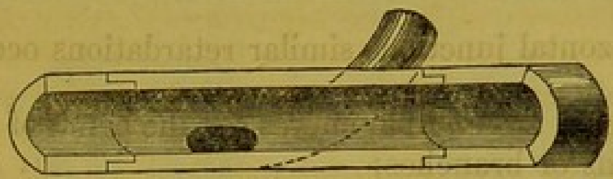




The smaller the flow of water to be conveyed, the more carefully ought the power of the flow or sweep to be economized, for the sake of preventing, or, if formed, of clearing away any deposit. Exactness of workmanship is most important for small pipes which are spread within dwelling-houses; and the arrangements ought then to be most carefully considered, with reference to the entire system:—whereas in practice, they are the least so, because they are left to the most ignorant and incompetent hands. The construction of tubular pipes has been exceedingly careless. For example, junctions of pipe-drains were often effected at the middle of the side, thus:—

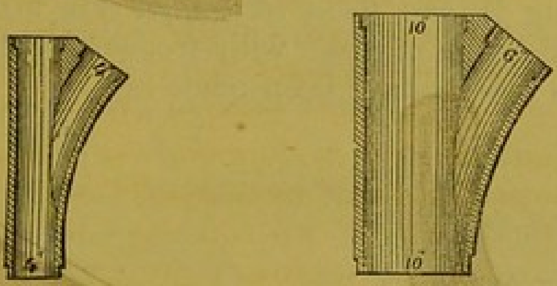


instead of level with the bottom, or bell-mouthed, as in the following diagram:—

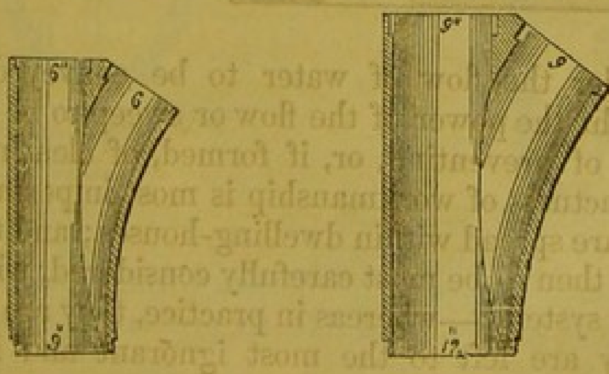


*Improved Curved Junctions.*

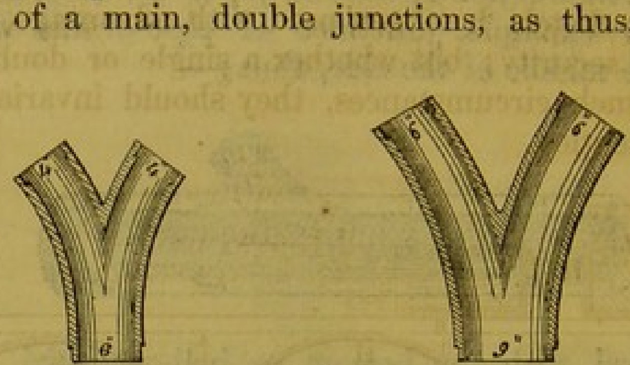
Where the main line can under no circumstances be so full, at the point where the branch would enter, as to require additional space for its reception, a junction of an equal capacity should be used:—



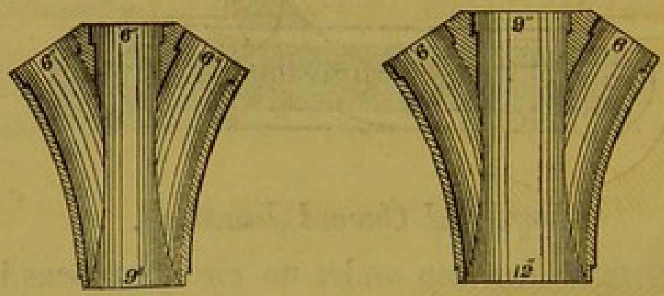
But where additional capacity in the main line would be required to receive any branch, a tapering length should be used:—



Where two equal drains unite to form the head or commencement of a main, double junctions, as thus, should be used :—

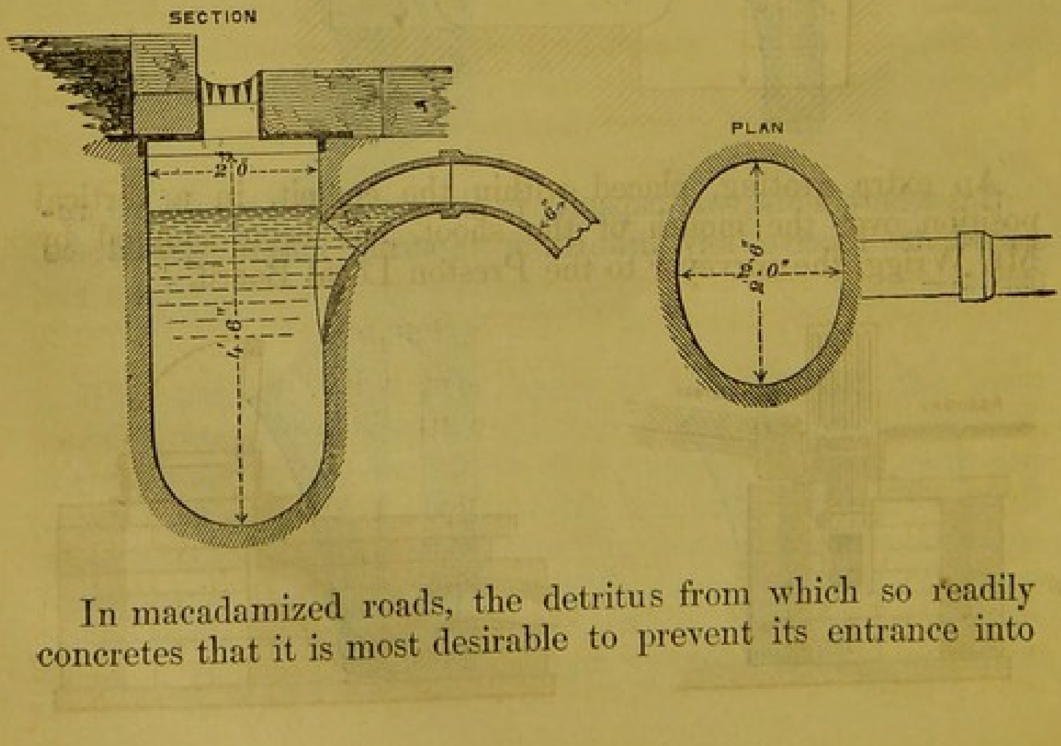


Where opposite branches fall into a main which would require enlargement to receive them, triple junctions should be used :—

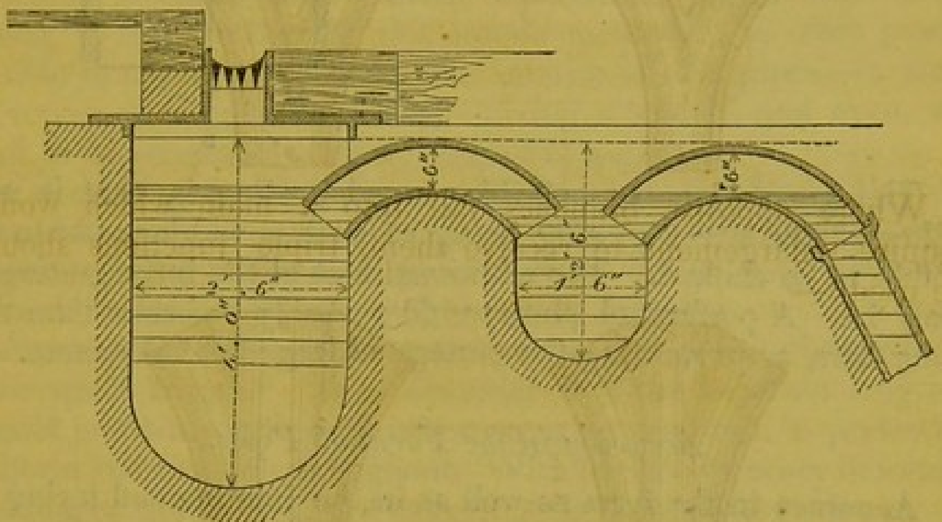


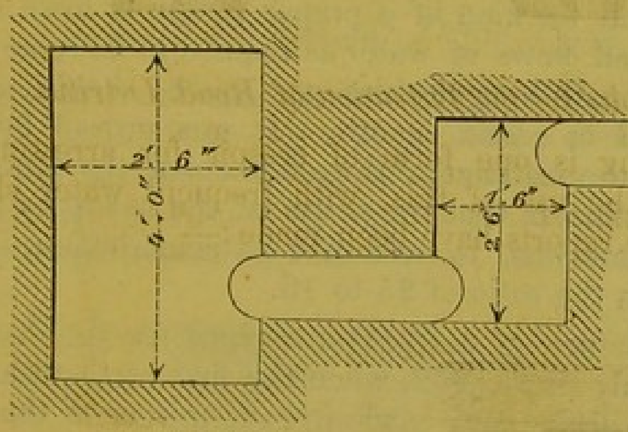
*Cesspits for the Detention of Road Detritus.*

The following is one form of cesspit for arresting street detritus. Of the use of this, with frequent water cleansing, very favourable reports have been made :—

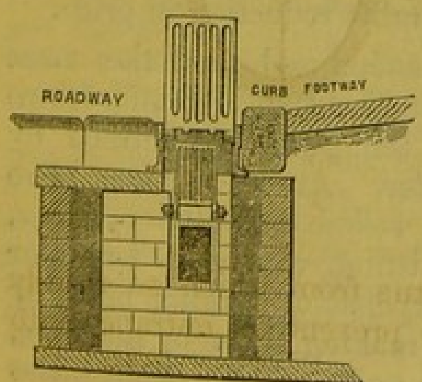


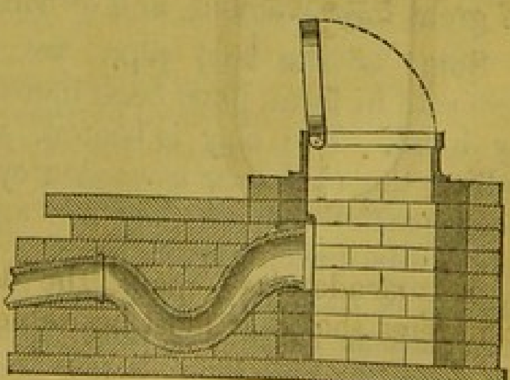

In macadamized roads, the detritus from which so readily concretes that it is most desirable to prevent its entrance into the drains, a double cesspit and connecting curve, according to the following sketch, has been used with advantage, and forms an additional security; but whether a single or double trap be used under such circumstances, they should invariably receive periodical attention.

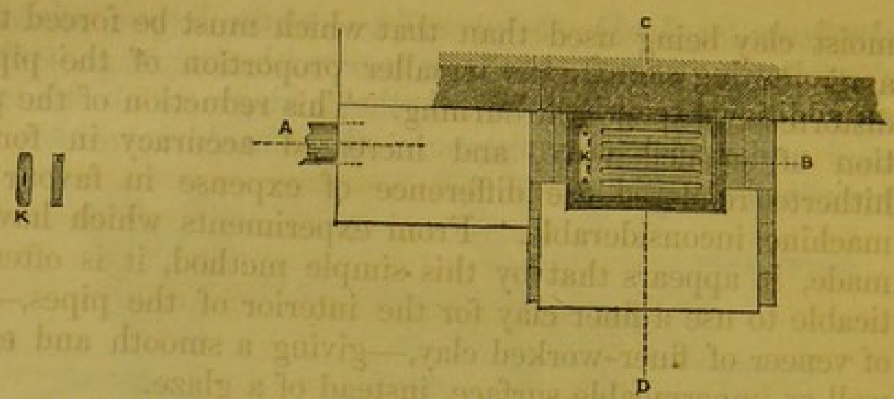



An extra grating, placed within the cesspit, in a vertical position over the mouth of the shoot, has been adopted by Mr. Wrigg, the surveyor to the Preston Local Board.






The great advantage of this second grating is, that it will allow of the street grating being of such a width as not to be liable to be choked. The additional cost of the inner grating is only 1*s*. A perforated plate would probably be better than the long bars, as preventing the passage of large flat substances.

### *Accuracy in the Form of Pipes.*

Accuracy in the form as well as in the jointing and laying of pipes, so as to preserve the true line, is of great practical importance to the well working of a proper system of town drainage. With such small flows of water as require to be removed from houses even small irregularities are apt to detain matter in suspension, and to cause deposit. It was proved by experiments tried at the instance of the members of the Metropolitan Sanitary Commission, that the power of the sweep by the same quantity of water was, by evenness of construction, increased one half, *i. e.* in the ratio of 25 to 16.

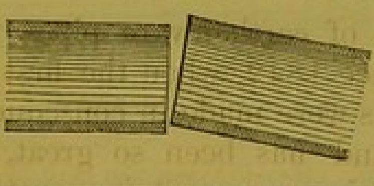
The manufacture of earthenware pipes for the drainage of houses dates only since 1842, when the first earthenware glazed pipes for house-drains were made in consequence of the sanitary inquiry. The demand has been so great, and the profits so high, that any large improvement in construction has not yet been entertained. There has been only limited machinery, and less science, applied to the manufacture, which is susceptible of great improvement, and of considerable reduction in price.

Some of the best pipes yet manufactured, and the most accurate in form, have been those manufactured in Staffordshire by hand. The clay is beaten, and the pipes are formed by rolling the clay over a wooden cylinder. After the pipes have been partially dried, they are again rolled upon the cylinder, when any inaccuracy in form, or twisting, caused by irregular drying, is rectified. Although the expense of making pipes by hand labour is greater than that of making them by machine, yet from the clay being better beaten and worked,—from a less moist clay being used than that which must be forced through a die by pressure, a far smaller proportion of the pipes are distorted and spoiled in burning. This reduction of the proportion of spoiled ware, and increased accuracy in form, has hitherto rendered the difference of expense in favour of the machine inconsiderable. From experiments which have been made, it appears that by this simple method, it is often practicable to use a finer clay for the interior of the pipes,—a sort of veneer of finer-worked clay,—giving a smooth and even, as well as impermeable surface, instead of a glaze.

Considering the high prices paid for pipes, the Local Boards should be extremely particular in insisting on compactness, and impermeability of material, freedom from inequalities, perfectly smooth interior surface, straightness of cylinder, evenness and uniformity of section, and sufficiency of substance throughout their whole length.* It is essential that the separate lengths should join truly with each other, so as to maintain a perfectly uniform and true line throughout. With perfect accuracy in form, the longer the lengths, the better, as the joints will be fewer.

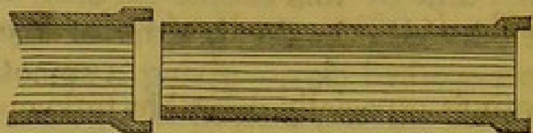
### *Joints for Tubular Drain Pipes.*

The first joint used was the butt-joint. The objection to this joint is, that unless it be laid with care, in a compact and even soil, in a bed excavated with great exactness, and unless it be covered in with care, it is very apt to get out of the true line; when one length rises above the other at the joint, in the manner shown:—



* The inferior makers, whilst competing with each other in price, have reduced the substance of the pipes, to make some gain in the saving of the stoneware clay (which when worked up costs as much as 10*s.* per ton), and also to save carriage. They have made the pipes so thin that they will not bear the pressure of shifting soils, or the rough usage of workmen unskilful in pipe-laying. Of the stoppages of tubular pipes which have occurred, next in number to those occasioned by the common builders putting in the pipes at wrong inclinations, are the stoppages occasioned by the breakages of the pipes from their being made too thin. It is proposed as a practical rule, even with respect to the best stoneware pipes, that the pipe should have one twefth of an inch in thickness of material for every inch of internal diameter. One reason, perhaps, for rabbet-jointed pipes answering so well for water carriage, is, that they are necessarily made with a thick body, or a body sufficiently thick to enable the rabbet to be formed.

And in this state the flow is interrupted, substances detained, accumulations of deposit formed, and an opening left for the escape of the liquid, causing saturation of the soil. The joint now most commonly in use, is the socket-joint, which from its frequent inaccuracy in form is liable to the like displacement as the butt-joint:—



In pushing the end of one length of pipe into the socket, the cement is apt to be squeezed into the pipe itself, where in careless workmanship it has been found in ridges, creating permanent obstructions and accumulations. This defect is apt to be occasioned by careless workmanship with any cemented joints; well-worked clay is therefore found to be a better material for jointing; but in any case the surveyor should take care to obviate any defect of this kind by having an instrument passed down the pipes as they are jointed, to remove any superfluous material. The joints should be examined as the work proceeds.*

To obviate these inconveniences, Mr. Austin proposed a half socket-joint, which might be manufactured either with the half-socket at one end only of each length of pipe, or at the lower half of both ends, and used alternately with a length without any socket:—

The half-socket forms a bed or foundation, which keeps the respective lengths in place; as each successive length is *laid* in the half-socket, and not *pushed* in, the cement is not raised in ridges, and every joint may be inspected, and the faulty ones rejected after the pipes have been laid. It has the further advantage of allowing any length of pipe to be taken up without difficulty.

One objection to any description of socket-joint is the projection formed by the socket itself, which acts as a sort of fulcrum for

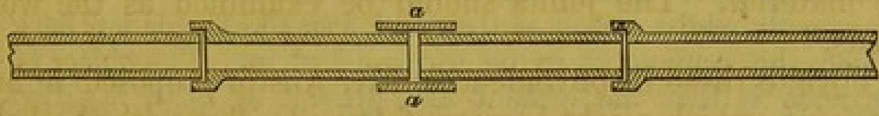
* In laying socket-jointed pipes, great care must be used to give the pipes a full bearing, and not to allow the plain ends of the pipes to "*bind*," or rest solely on the socket, as, by doing so, pipes are frequently broken.

leverage, with the length of pipe, in any disturbance of shifting beds, or any vibrations, such as occur in turns and streets. The effects of these disturbances and vibrations are most seriously felt in the joints of iron water-pipes. To obviate them a ground cone-joint is in some places used, when the joints are smeared slightly with paint or cement, and simply run up close into each other.

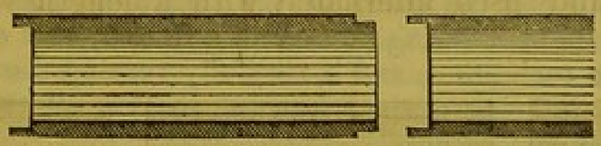
The report of the working of these joints in streets of considerable traffic is very good.—(*Vide Report on Water Supply*).

In cases where it is especially desirable to keep the drainage-pipes water-tight they should be laid on a bed of well-wrought puddle and gently pushed down into place, after this the space on each side and up to a level of 6 inches above the crown of the pipe should be filled up with the same material, thus forming an uniform and impervious matrix (similar to a mould of wax) all round them.

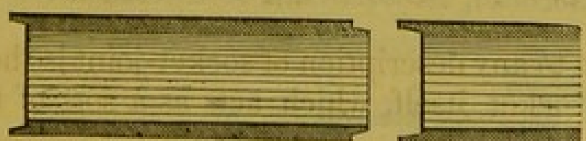
Long collars over butt-joints are used to stiffen and carry pipes safely through irregular strata. They are sometimes used to repair breakages in lines of pipes with socket-joints; as at *a a*.




In earthenware the rabbet-joint is sometimes used,—

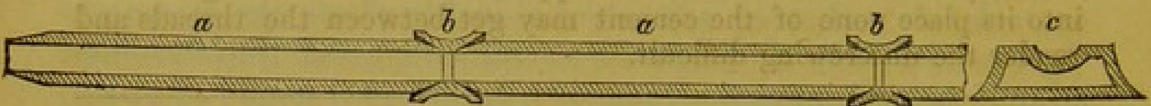


The advantage is, that these joints form one continuous line, lying evenly in the beds, and vibrating more evenly than pipes with the protuberances of socket-joints. To give room for the formation of the rabbet-joint, more clay is required; they must be thicker than with the common socket-joint; but the labour in making them is less than in making the socket-pipe, and they ought to be produced as cheaply. Pipes of red clay, with a rabbetted cone-joint, thus—



well connected with Roman cement, have been in use many years at Weymouth, for the distribution of water.

The sinking of the earth, or an unusually heavy vibration of it, as by the rapid passage of heavily-laden vehicles, will often exercise a powerful leverage on a very long and perfectly rigid line of pipe, and even iron pipes are often subjected to dislocation and breakage from such causes. For the less certain strata, and for cases where the more stiff collar jointed pipes were found to be subjected to breakages, in Switzerland, pipes with conical joints inserted in sheaths, as displayed in the following cut, are used for the distribution of water; and they may be commended, as of frequent service, for the removal of soft water:—

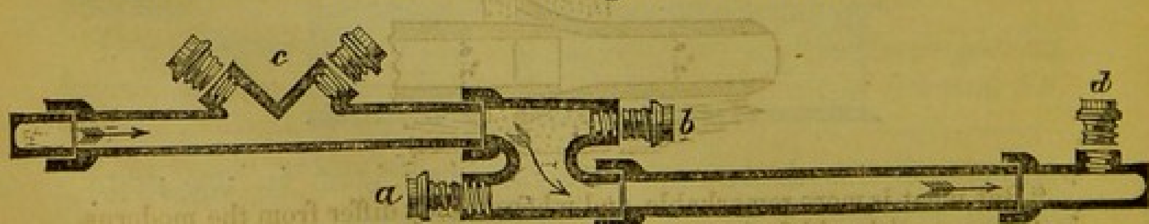



They are thus described:—

"The straight pipes *a a* are finished uniformly at both ends in a cone shape, and fit into the conical mouths of the joint pieces, *b b*, which are, however, bored rather wider, in such a manner that the end of the pipe touches or stands against the bottom of the interior of the sheath, whilst except at that part, a small space is left between, in which the cement is to be well worked in. The object of this contrivance is that the cement may present as small a surface as possible to the pressure of the water. The cementing by this method becomes a very easy process, and consists merely in rubbing both ends of the pipe and the inside of the sheath or rings several times with cement, and in covering them with a thin layer of cement, in fitting them into each other, and in carefully turning them at the same time the pipe is being pushed forward, so that all the superfluous cement may be pressed out."

In order to spread the base in very uncertain ground, these pipes are laid upon a sort of sleeper or cradle formed as at *c*.

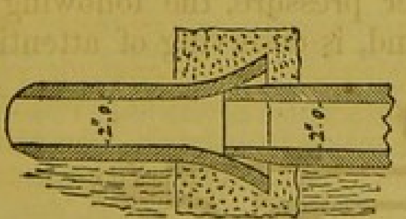
As showing an advance in the manufacture of earthenware pipes as an expedient for pipe-water distribution, which may frequently be applicable (as part of a complete system of tubular drainage) for the application of soil-water as liquid manure, with full pipes and under pressure, the following arrangement, also in use in Switzerland, is deserving of attention:—



They are thus described, as made and used from the manufactory of Mr. Ziegler, at Winterthur, near Zurich :—

"When straight pipes are laid down for great distances, intermediate pieces are introduced at certain intervals. They are provided with screws, *a b*, or, if there be no pressure, with simple stoppers, and are for the purpose of emptying the pipes when required. To let the air escape to remove any trifling stoppage, side openings are made in the pipes, and fitted with one or two screws. These screws, which are likewise made of clay, and glazed, afford the advantage that the flow of water can be readily shut off even at a high pressure.* The thread of the screw is rubbed with a mixture of resin, oil, and tallow, and a small roll of cement is laid carefully round the head of the stopper, so that in screwing it down into its place none of the cement may get between the threads and render the unscrewing difficult."

* The precautions with which the distribution of water is effected in France under intermittent pressures, often of between 100 and 200 feet, is by the proper distribution of air cushions, and by using screw-down taps, which cannot be suddenly closed. The Roman distribution, under average pressures of 100 feet, was often with very common earthenware. At the points of extreme pressure, at the bottom of valleys, it was their practice to strengthen a line of earthenware pipes, by continuing it through banks of perforated stone. In France, they arm the lower portions of syphoidal lines of earthenware pipes by short lengths of iron. A Continental correspondent, giving an account of the use of earthenware pipes for the distribution of water, says : "I can furnish you with satisfactory evidence of their almost imperishable durability, when properly made and bedded, in the remains of an ancient Roman water conduit in our own neighbourhood (about 10 miles from Zurich), where a spring is carried from a hill of about 500 feet in height, called the *Lagern*, to a village where formerly a Roman station and highroad was situated. Here the water is carried in earthenware pipes laid into the ground through a distance of several miles, great part of which is not only still in existence, but actually doing service. The perpendicular height of the column of water is not less than 200 feet, and the pressure, therefore, equal to about seven atmospheres. The pipes are roughly made, but not glazed inside, but with that attention to sound practical objects, disclaiming useless ornament, and choosing the simplest and shortest means to accomplish their purpose ; the Romans paid particular attention to the joints. There is no separate coupling-ring as in Mr. Ziegler's pipes, but they are stuck into one another, the lower (receiving) pipe being trumpet-mouthed, and the upper one slightly conical, thus :—



"But what is more remarkable, and wherein they differ from the moderns, is the care with which they secured the joints ; these are inclosed in an

Before information was obtained of the manufacture and uses of screw joints in earthenware on the Continent, the use of the expedient was suggested to some of the chief potters at Stoke-upon-Trent, but they doubted their practicability. They have, however, been since exceedingly well made for other purposes by Messrs. Doulton, potters, at Lambeth. Screws are so easily made that they may be commended to the attention of gentlemen who have tile-kilns of their own, and desire to improve the manufacture of pipes. They will be found to be of frequent use for the pipes used for temporary purposes, to be screwed up in washers, and after use to be unscrewed and removed.

Long lengths of pipes, formed true in the inside, are great desiderata in town drainage, particularly for vertical drain-pipes to lay close to outside walls, for the drainage of high tenements let off in flats, for soil-pipes, &c. &c.

*The Materials for the Construction of Sewers.*

In the early period of the official investigation, attention was directed to the unsuitability of the ordinary form of brick for sewer construction, and to the advisability of substituting other forms and arrangement of material. A reference to some of the sections already given will fully illustrate the impossibility of obtaining strength and efficiency of construction with the common form of brick in the smaller sizes of sewer. Radiating bricks have been used for some years with great improvement,

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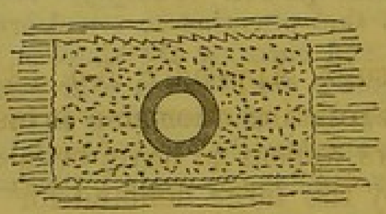
envelope of mortar, composed of pounded brick (the same material as the pipes themselves are made of), and forming at the same time the bed and roof for it, as seen in cross section: —

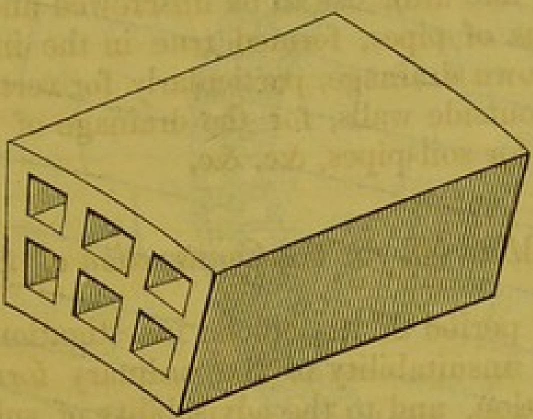


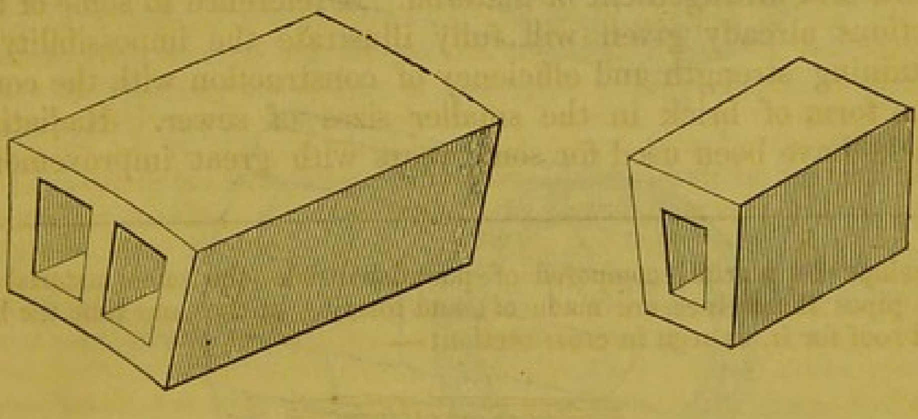
"This casing of mortar when old becomes as hard as the pipe itself, and forms but one mass. Otherwise, the pipes are laid into the loose soil, with the exception of a slightly hollowed-out bed at the bottom, made of broken pieces of pottery, united with a little mortar. These joints have hitherto proved immoveable, and in order to take two pipes asunder, it is necessary to break them. This method seems to me commendable, especially in similar situations, viz., on the slope of a steep hill. The pipes are not above 2 inches diameter. I shall try to send you a specimen along with the rest, merely as an historical curiosity in the arts of manufacture."

but probably owing to some trifling difference of cost, their introduction has been most partial.

Proposals were made during the inquiries by the Health of Towns Commissioners, to construct sewers of slabs of earthenware formed to the required shapes and sizes. On the reconstitution of the Metropolitan Commission of Sewers, some trials of this kind were directed, and also for the preparation of hollow bricks for the purpose.

Among others, the following form of hollow bricks were prepared, and experiments tried, under the direction of Mr. Roe,

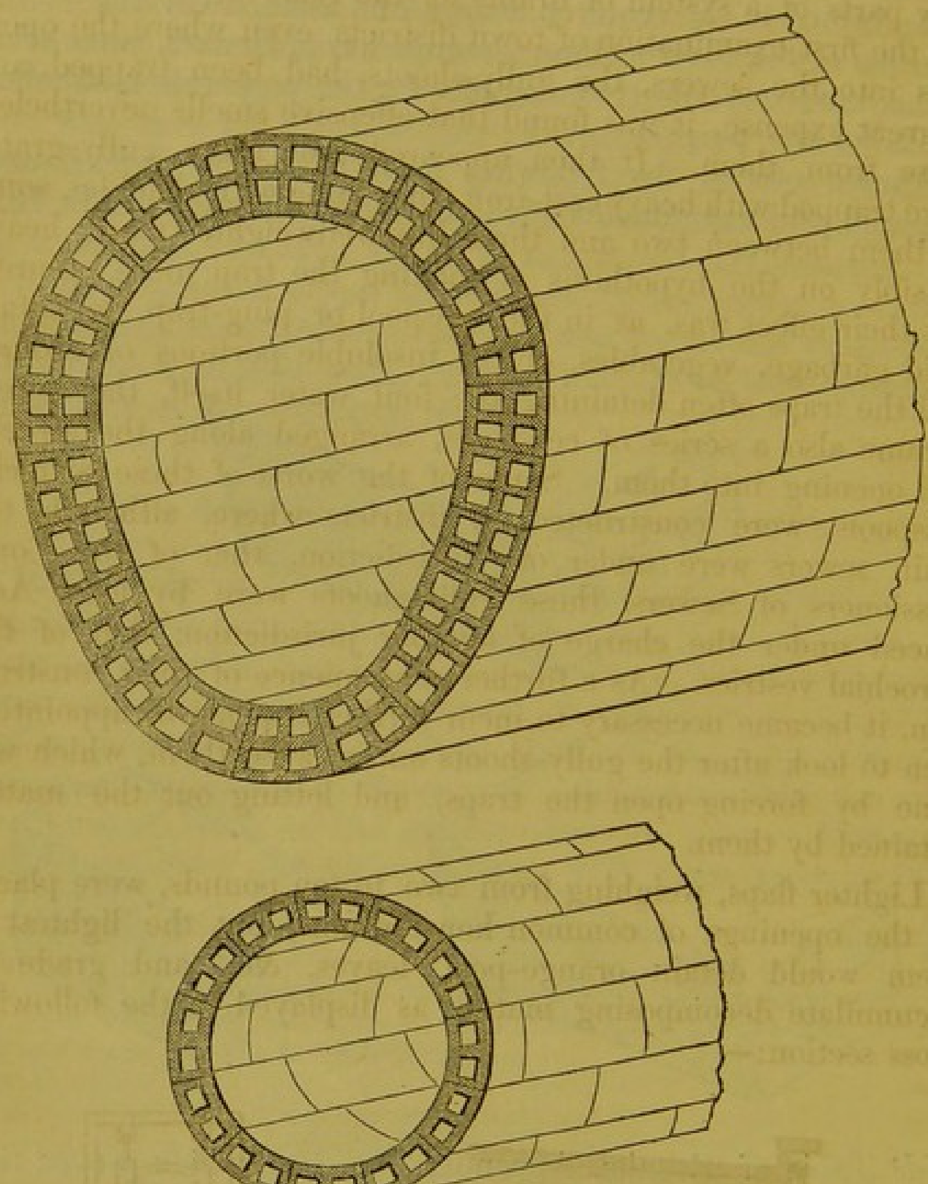




(*vide* Table of Results, Appendix, No. 13), which proved that they were capable of resisting enormous pressure. The attention of the manufacturers appear to have been since that period so entirely absorbed by the large demand for pipes, that little or no progress has been made in the introduction of better material for the larger class of sewers.

The many advantages obtainable from the hollow brick, the greater density of material, increased strength, impermeability, and economy, would appear to recommend this principle (which has been subsequently brought into use for house construction), with various forms and sizes specially adapted to the construction of the larger sewers, and the covering of the larger tanks.

Forms of the following character were designed for the purpose, which being drawn to a few different radii, would accommodate themselves to a complete graduation of circular and egg-shaped sewers of the required sizes : —

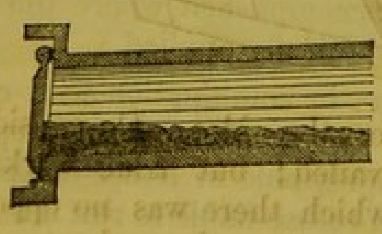


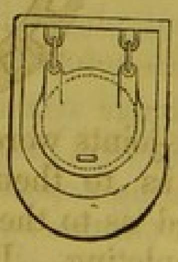
Lock-joints were proposed for the sides. On consideration doubts as to their utility prevailed; but trial works were proposed as to the end-joints, which there was no opportunity of completing. It appeared probable, that when manufactured on a large scale, impermeable structures on the principle herein described might be made at little more expense than hollow brick wall; in respect to which it was shown that hollow wall of 4 inches thick, set in Roman cement, might be constructed at 1*s.* per superficial yard, and 9-inch wall at 2*s.* 6*d.* per superficial yard, also set in cement.

*Expedients to prevent the Ingress of foul Gases into Habitations.*

Valves or traps, to impede the passage of effluvia, are necessary parts of a system of drains for the removal of foul matter. On the first examination of town districts, even where the openings into the sewers, the gully-shoots, had been trapped, and at great expense, it was found that offensive smells nevertheless arose from them. It then appeared that these gully-grates were trapped with heavy cast-iron flaps, hung with shackles, some of them between two and three hundredweight, (made heavy possibly on the hypothesis of making the trap more secure,) but their effect was, as in the cesspool or plug-trap, to detain solid garbage, vegetables, or the insoluble portions of ordure; and the traps often detaining the foul water itself, the sewers became also a series of cesspools, arranged along the streets, and opening into them. Some of the worst of these artificial cesspools were constructed in districts where, although the main sewers were under one jurisdiction, that of the Commissioners of Sewers, these gully-shoots were by local Acts placed under the charge of another jurisdiction, that of the parochial vestries. As a further consequence of their construction, it became necessary to incur further expense by appointing men to look after the gully-shoots and cleanse them, which was done by forcing open the traps, and letting out the matter detained by them.

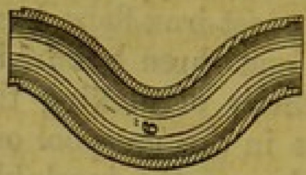
Lighter flaps, weighing from two to ten pounds, were placed at the openings of common house-drains, but the lightest of them would detain orange-peel, leaves, &c., and gradually accumulate decomposing matter, as displayed in the following cross section:—





The stoneware flaps which were attached to stoneware pipes were often well ground, so as to make an effectual air-tight fitting; but, if a straw or stick be detained at the mouth of the trap, or if viscid matter accumulate at the mouth of the drain, it becomes untrapped; the valves might, like curtains, obstruct powerful currents, but they were of little avail to prevent the entrance and diffusion of the more subtle and poisonous gases.

The best form of trap, the most simple, the least liable to derangement, and the most economical, and, therefore, the one to be recommended for house-drains, and for general adoption, is the syphon water-trap. For the ends of drains, the syphon-traps will be formed thus :—



These traps should, when practicable, be placed a little below the openings, so that the force of the fall of water may effectually discharge the previous contents. It must be always borne in mind, however, that the efficiency of this trap is dependent on the regularity and sufficiency of the supply of water. In respect to other forms of syphons, *vide seq.* But no trap is to be relied upon for the protection of dwelling-houses or rooms against the pressure of volumes of gases arising from decomposing deposit.

Water rapidly absorbs gases evolved by decomposition; this property renders it of the more service when the quantity of gas is moderate, but where it is considerable, the water is rapidly saturated, and then is found to give off and to diffuse the gas on the one side, as it is absorbed on the other. The only effectual protection is the removal of all refuse matter, before it can get into a state of advanced or active decomposition, to such a distance that its fumes may not reach dwellings; and this important object is effectually accomplished where the several principles herein set forth are practically applied.

A tubular system of drainage, in combination with constant water service, properly applied, has no decomposing deposit, no evaporating deposit, which is appreciable in house-drains, or in sewers. On this system, when all refuse liable to run into decomposition is immediately received in water, and carried along with considerable rapidity, it will be removed from beneath houses, and from the whole site of a town before decomposition can have advanced, and before any of it can get into those ultimate stages of decay which, in the present methods of town-drainage it now usually reaches before removal. Under such arrangements the cold and recently fouled water does not diffuse wide-spread emanations.* Even at the outfall itself, there are no such odours as those which are diffused from the old sewers and drains into the houses and streets of the metropolis, and other ill-drained urban districts. When the pipes are tolerably full, and the discharges rapid, instead of diffusing upward currents, the friction of the water upon the air carries with it a downward current of air, which is strong in proportion to the velocity of the stream. Under the ordinary circumstances of the drainage of houses, and the removal of soil-water by properly arranged tubular drains, the syphon-traps are found to be perfectly effectual.

The prevention of the more offensive smells by the altered arrangements, which avoid masses of decomposing matter beneath or near habitations, though it renders unnecessary the use of double traps, (which are often found only to occasion an accumulation of foul air between them,) cannot however be practically carried to the extent of abolishing the necessity of any traps whatsoever. Some odours may be expected from the soil-water smear or deposit, however slight, on the sides of the earthenware drains, such as may be left on the sides of pails or vessels from which foul water has been discharged. It may be

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* On this subject Mr. Cuthbert Johnson, chairman of the Croydon Local Board, speaking from his own observation, says, "I have found, by the experience of about three years, that house-sewage drained through impermeable pipes into a water-tight tank may be stored even for four or five days without becoming offensive, when, in the summer months, owing to our cutting the grass, and irrigating the cleared space almost daily, the sewer-tank is so regularly and completely emptied, at least once in every 48 hours, that upon removing the lid of the tank there is no more, or perhaps not so much, odour perceptible as from a London water-butt. The house-sewage retained in an impermeable receiver for even a few days, differs very strangely indeed in its degree of fluidity and other qualities from the noxious contents of an ordinary cesspool, from which the more fluid portion of sewage is constantly oozing. From these and other observations I am led to the conclusion, that town sewage conveyed on to the the land, not from overflowing cesspools, but direct from the houses, through impermeable pipes, will not possess any properties offensive to the adjoining inhabitants." Since this was written, Mr. C. W. Johnston has added (March 23, 1852):—"The truth of these observations on the inoffensiveness of rapidly-discharged house sewage has been confirmed by the result of our experience with the town sewage of Croydon. This is conveyed through glazed stoneware pipes, with impermeable joints, to one common outlet, which is at a place where, under a covered building, the sewage is passed through strainers before it is discharged by other pipes into the river Wandle, at a place about half a mile from the town. In visiting this straining-house, every person is impressed with the almost total absence of even the slightest odour. It is only when the strainers are cleared of the matters which will not pass through them that any smell is evolved, like that from an ordinary brick sewer."

anticipated that these odours will arise and accumulate so as to be appreciable (if the air in the pipes be confined) upon the water-traps in upper apartments. Therefore, whenever a water-closet, even with the best sort of syphon-trap, is introduced into a house, it will be well to provide an escape into the outer air. Where several soil-pans or sinks from the apartments of a large house are discharged into a common soil-pipe, or vertical main, the main should be continued up to the roof and opened to the air, and, if practicable, it should be carried near the chimney. Pipe sewers must also have ample ventilation provided at all available points. If the air is confined, it is most dangerous when it breaks forth, which sooner or later it will do.

Where soil-water is conducted to a covered reservoir, and there is occasion to store the contents, the mouth of the pipe leading into the tank should be so low down, as to be always covered, and an evaporating surface no larger than the sectional area of the pipe exposed towards the houses; the communication towards the houses should be carefully guarded by additional water-traps; and vent should be given to the products of any decomposition into open space, where it may be rendered innocuous by dilution with pure air, otherwise the tank will form a species of retort for the generation of noxious gases, spreading through the connected pipes, and bearing upon all the traps so as to pass those which are inefficient. If the quantity of sewage stored be large, or the emanations offensive, they may be decomposed and rendered innocuous by passing them through a fire.

### *The Principles of the Construction of the Water-closet.*

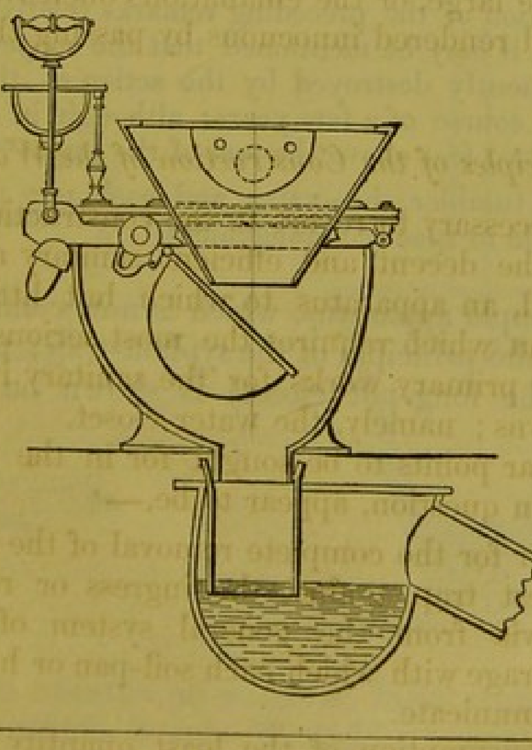
It is now necessary to revert to the construction of the chief apparatus for the decent and efficient sanitary arrangement of every household, an apparatus to which but little attention is usually paid, but which requires the most serious consideration, as one of the primary works for the sanitary improvement of houses and towns; namely, the water-closet.

The particular points to be sought for in the construction of the apparatus in question, appear to be,—

1. A scour for the complete removal of the soil.
2. The best trap against the ingress or regurgitation of effluvia from the general system of drainage and sewerage with which each soil-pan or house-sink must communicate.
3. The consumption of the least quantity of water for a complete scour and perfect trap.

4. Durability, or freedom from the liability of—
   *a.* Breakage in consequence of frost.
   *b.* Derangement of the machinery.
   *c.* Breakage by careless usage.
   *d.* Stoppages.
5. Easy repair.
6. Cheapness when manufactured on a large scale.

In the original statements as to the superior economy of a systematic removal of all decomposing town refuse in suspension in water, as compared with the cost of retaining it in cesspools, cleansing them by hand labour, and removing the accumulation by cartage;—and, to obviate any chance of under-estimating the expense of the improvement proposed, it was assumed, that the most expensive form of water-closet, costing 10*l.* each, would be used for even the poorest descriptions of houses in towns. (*Vide Sanitary Report*, 1842, p. 223.) And for all towns, the superior economy even of this form of apparatus over the common modes of cleansing is demonstrated. But apart from its expense and the complexity of the machinery, it is objectionable from its inefficiency as a trap to prevent the return of effluvia into the premises, and its difficulty of repair. The following is a transverse section of the common apparatus in use in first-class houses, with a statement of the objections to it, by a working plumber.*



* Mr. Crump, of Derby.

"One great objection to its (the pan-closet's) use is the impossibility of freeing it from the offensive effluvia escaping into the room whenever the contents of the pan are discharged into the cast-iron receiver; and the longer the closet is in use, so also the smell becomes the greater. This arises from the cast-iron receiver being coated so repeatedly with soil delivered from the dish or pan, and the construction of the closet not admitting the water to wash any part of the apparatus, excepting the earthenware basin and dish. In numerous instances the coating has so accumulated in the receiver behind the dish as to prevent its being worked at all, until taken down and properly cleansed out.

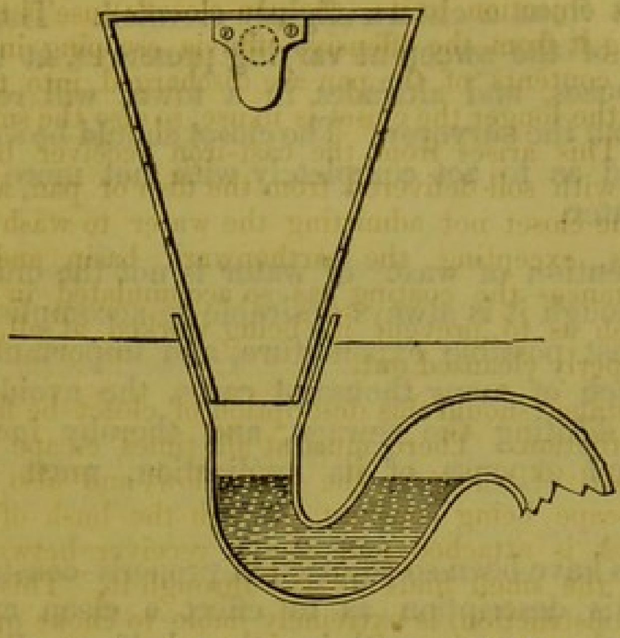
"In no instance should this description of closet be fixed without thorough ventilation. There must at all times escape effluvia, although the seal of water in the trap below, and also the dish, is secure, the escape being constant through the bush of the axle to which the dish is attached, and as the receiver between the two becomes foul, the smell finds its way through it, This closet, from its peculiar construction, is extremely liable to choke up in the trap or soil-pipe. Servants emptying into it the contents of chambers and buckets, flannels, scrubbing-brushes, combs, and other improper things have repeatedly found their way into the trap and produced the stoppage.

"Servants, ignorant of the construction of the closets, imagine that in discharging the contents of the dish into the receiver they have disposed of any article improperly thrown into it; but though cleared from the dish, it merely finds its way into the trap, and leads to its being stopped up.

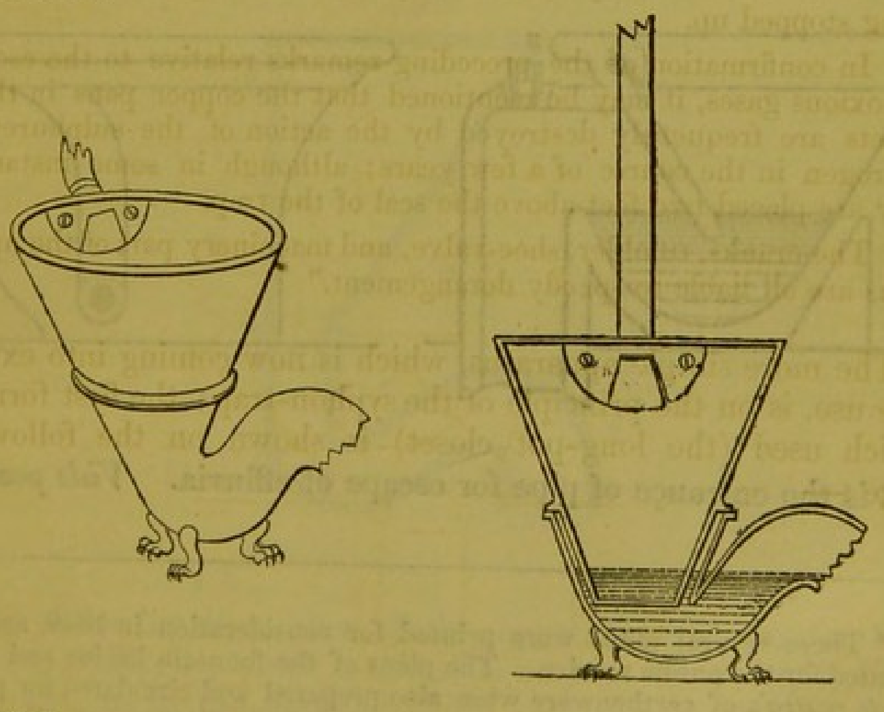
"In confirmation of the preceding remarks relative to the escape of noxious gases, it may be mentioned that the copper pans in these closets are frequently destroyed by the action of the sulphuretted hydrogen in the course of a few years; although in some instances they are placed two feet above the seal of the trap.

"The cranks, tumbler, shoe-valve, and machinery part of the apparatus are all liable to speedy derangement."

The more simple apparatus, which is now coming into extensive use, is on the principle of the syphon-trap; the first form of which used (the long-pot closet) is shown on the following page:—



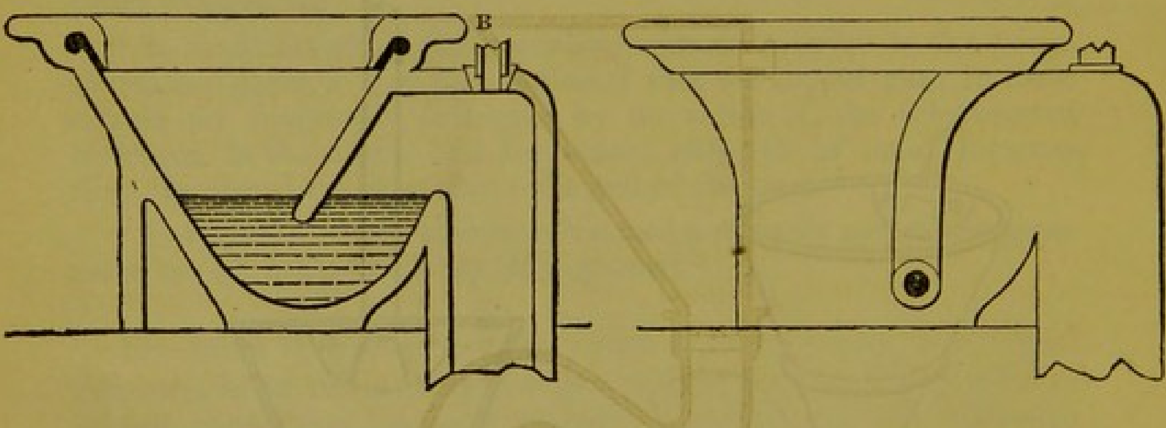
The defects in the first construction of this form of closet were, that the water did not come sufficiently high up the pipe from the trap to meet the earthenware basin; therefore, and because the water was otherwise inadequately applied, a coating of soil was left inside the pipe. The following, by the same witness, is an example of the more simple forms since introduced:—



With a small quantity of water at high pressure, a *force* of sweep is given which is only effected by a large quantity when the supply is from a cistern slightly elevated. The adjustment of the force of the sweep at varying pressures, at the different levels of houses, and altitudes in a town, will require much attention from the surveyor. The closet should be so constructed and adjusted as to act completely with not more than half a gallon of water.

The prevention of waste of water is not the only advantage sought. Though it is always desirable to accomplish any object with the least possible expenditure, and important to prevent waste in each of many thousand cases, the avoidance of unnecessarily diluting the sewage, and thereby increasing the difficulty and expense of its application, must not be lost sight of.

Spreaders have been so adjusted in properly-constructed apparatus of this description as to effect a clean and complete removal of the excreta, with less than half a gallon of water, and yet to leave a sufficient trap. The plan suggested in 1847 by the Metropolitan Sanitary Commission,* for general use, was a syphon closet, made wholly of earthenware, with the top of the pan spread out about four or five inches, so as to form a sufficient self-sustaining seat, needing no woodwork for fixing; thus :—




B is the entrance of pipe for escape of effluvia. *Vide postea.*

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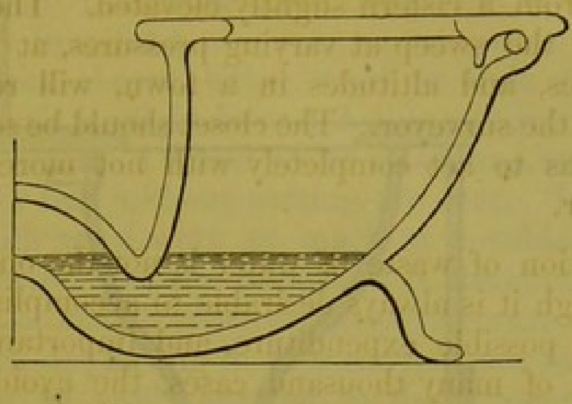
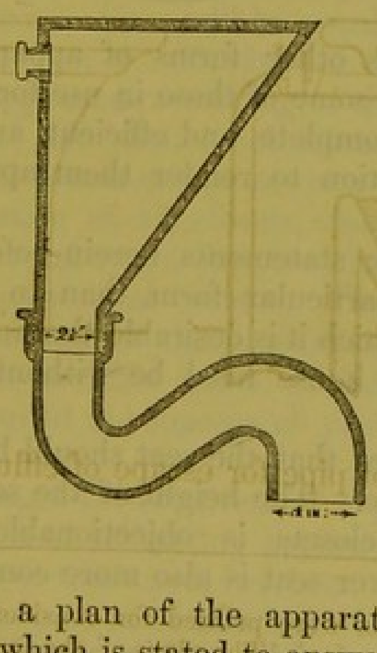
* These several plans were printed for consideration in 1849, and circulated for the public service. The plans of the fountain basins and sinks (*vide postea*), of earthenware were also prepared and circulated for public use by the Board; they are, therefore, open to the use of all manufacturers, and no subsequent registrations or patents for them are of any validity.

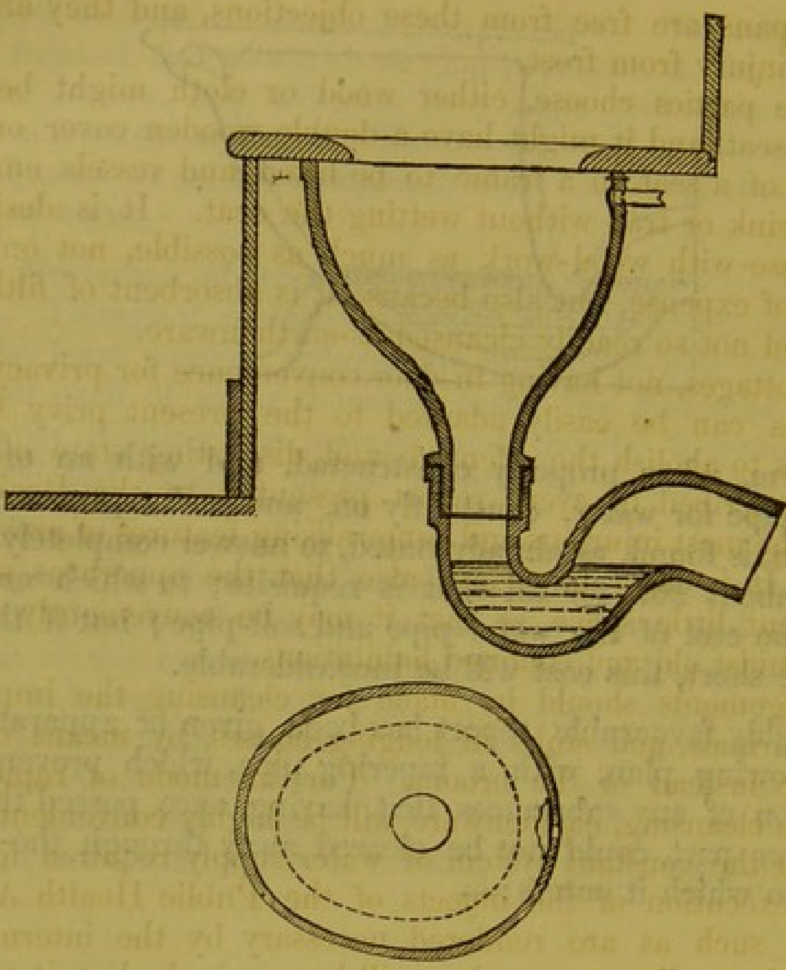


This form, when properly constructed, and with an ordinary service-pipe for water, constantly on, and under pressure from the main, is found, as already stated, to answer completely. The cost is about 20*s.* for all that is requisite; to which must be added the cost of the water-pipe and soil-pipe; but if the distance be short, this cost will be inconsiderable.

A highly favourable report has been given of apparatus on the following plan, with a tapering pipe, which prevents the admission of any substances that, having once passed through the lower part, could not be cleared away through the larger area into which it enters:—



The following is a plan of the apparatus in use for the cottages at Rugby, which is stated to answer excellently. *Vide* Appendix, as to the expense of its construction as part of a set of combined works for house-cleansing and drainage, and the supply of water:—



There are various other forms of apparatus combined on the same principles; some of those in use for the higher classes of houses are very complete and efficient, and only want more economical construction to render them applicable for general use.

The object of the statements herein-before made is less to commend any one particular form, than to show the principles of construction on which it is desirable that improvements should be made, so that no house need be without so convenient an appurtenance.

It is of advantage that the seat should be low,—lower than those in common use. The height of the seats of the common privies and water-closets is objectionable on physiological grounds, and the lower seat is also more convenient for children and young persons.

In respect to materials, cast-iron pans are found to be objectionable; they oxidise rapidly by the action of wet and air. This bad quality is attempted to be remedied by glazing; but if there be any part of the glazing defective, or as soon as it becomes so, the pan is rapidly destroyed. The stoneware pottery soil-pans are free from these objections, and they are not liable to injury from frost.

Where parties choose, either wood or cloth might be put over the seat, and it might have a double wooden cover on the principle of a seat in a frame to be lifted, and vessels emptied into the sink or trap without wetting the seat. It is desirable to dispense with wood-work as much as possible, not only on account of expense, but also because it is absorbent of filth and gases, and not so readily cleansed as earthenware.

For cottages, not having in-door convenience for privacy, this apparatus can be easily adapted to the present privy building, so as to abolish the offensive and disgusting state of such places, described in every report presented to the Board, as among the most injurious and demoralising features of provincial towns. It is most important also that the apparatus should occupy but little space, so that it may be conveniently introduced amidst old and confined habitations.

Arrangements should be made for cleansing the improved privies, urinals, and sinks in lodging-houses, by means of jets of water instead of the broom. For this mode of rapid and complete cleansing, earthenware will be highly convenient.

Under the constant system of water supply required for the proper execution of the objects of the Public Health Act no cisterns, such as are rendered necessary by the intermittent supplies by trading companies, will be required; but it will be requisite that the surveyor should advise as to the adjustment of the water for such apparatus, according to the force of the sweep with varying levels. He should not allow any house-drain to be introduced into the common pipe-sewer until he has inspected the condition and action of all closets, sinks, and other tributaries, with their several traps, and certified to their efficiency and conformity to the general system. This will be protective of the occupier or owner of the property against the culpable ignorance, as well as reckless waste, of tradesmen and workmen, which have spread the sources of pestilence amidst town populations.

Considering the degraded condition of a portion of the population, the general use of self-acting apparatus of various kinds, acting from the seat or footboard, has been urged as necessary; but though in the instance of common privies such an apparatus may be desirable, it is not indispensable, for soil-pan apparatus as above described, and without such mechanism, has now been in use in improved model lodging-houses and dwellings, and in old houses, occupied by upwards of 2,000 of the poorest classes: in one district it has been used by common colliers, and in another by the poorer Irish. In these instances the supply of water by the trading companies was intermittent, and it was otherwise badly applied. In a very large proportion of cases where the soil-pans were cleanly, they had to be kept so by cans of water, in consequence of the defective application of the intermittent supplies. Where a stoppage had been occasioned it was easily removed; and out of the whole of the cases, in four instances only had it been necessary to take up the pipes, and in two of these the stoppage was occasioned by brick-bats having been thrown into the pipe whilst being laid down, during the temporary absence of the workman; a third stoppage was occasioned by a brick enclosed in a thick piece of flannel, and the fourth by a large accumulation of rags, flannel, and hemp. The self-acting apparatus would, therefore, appear, so far as experience has gone, to be far less necessary than was anticipated, and its necessity may as yet be said to be confined to the cases of the common lodging-houses, public privies, and places where a perpetual succession of untaught and unteachable occupants may be expected, and where perverse ignorance as well as carelessness must be guarded against. Self-acting apparatus attached to the door is a convenient arrangement; but all such places should be subjected to the inspection of some one under the direction of the surveyor.

In order, however, to check excessive waste of water, one or other form of self-closing valve appears to be essential.*

Whilst providing this soil-pan apparatus, provision for the covering of it, that is to say, for "the privy, properly so called," must, with respect to many neighbourhoods, be considered, so as to secure the means of privacy and decency.

In suburban districts the cesspool and the privy are, in the fourth-rate houses, often placed at the end of gardens. When the cesspool is filled up, and the soil-pan apparatus substituted, one reason of the site of the privy being so far distant from the house will be obviated. The expense of carrying separate water-pipes and separate drain or discharge-pipes to so distant a site renders it ineligible.

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* In one district where new combined works have been executed, and where the consumption of water was excessive, it was found upon investigation, that, from neglect of the surveyors, many water-closets and soil-pans, being of bad construction, did not clear away the soil, and that the occupiers kept the common taps open, allowing the water to run constantly, to keep down the smells, whereby the general consumption of water was made more than twice as great as where self-closing valves or taps, attached to proper pans, were required before any junctions with the main water supply were permitted.

Privacy, but above all the convenience of the feeble and the sick, especially in inclement weather, require that the site, if not within the house, should be brought near to it.

It is only when the house and main drainage is completely amended, and then with care, as recommended (*Vide ante: effluvia traps*), that the apparatus should be brought within the house. The water-closet being generally placed at the back part of the premises, it is suggested for the consideration of owners, whether they could not in most cases form the privies on the outside of the back part of the house, with a communication through the back wall from the landing of the staircase, or elsewhere.

In suburban cottage tenements and small dwellings, it is desirable that whenever the weather admits of it, washing should be done out of the house, in a shed which may be very conveniently constructed near the privy.

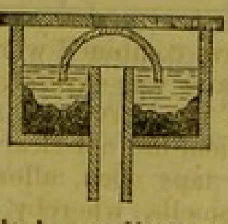
The pan-trap and ground-valve of water-closets may be continued in the better class of houses, where they already exist, and their cost is not a barrier to their use; but no water-closet so supplied should be allowed under any circumstances to communicate with the new drainage without the addition of the syphon-trap also.

In new houses, however large and costly, erected within districts in which there is constant water service and tubular drainage, the lever-tap, basin, and syphon may be safely recommended.

### *Means of removing waste Water from Kitchens, Outhouses, and Yards.*

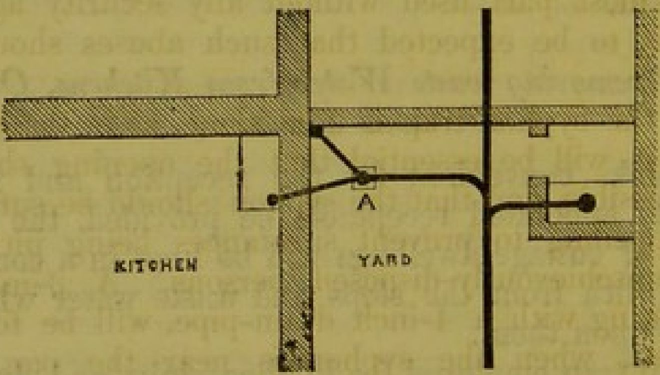
Unless sinks convenient for the reception and removal of refuse to its appointed receptacle be provided, the fronts and back yards of cottage dwellings will be kept in a constant state of wet and filth from the slops and waste water which will be thrown out upon them.

The usual trap employed for kitchen sinks and drains is the bell-trap,



and the method in which it is applied renders it little better than useless, while at the best it would be far inferior to the syphon. The bell-trap is mostly made so small, that the little water it contains must be immediately overcharged with the foul gas to which it should form a barrier. It is so constructed as to favour the constant accumulation of deposit, and requires such incessant clearing out that it is necessary to make the bell and grating a separate loose appendage, which being constantly taken up, is seldom found in its right place.* The employment of this trap under such circumstances is most mischievous, and is a constant source of annoyance and trouble. If the bell-trap is to be used at all in sinks, it should be made very considerably larger, of better form, and with fixed bell, even if the grating be moveable; but as under these circumstances the cost would be three or four times that of the syphon, with no single advantage, its discontinuance altogether may be safely advised. It appears to be thought necessary to apply the principle of the bell-trap to the heads of gully-shoots from streets as well as roads, to detain silt and other detritus, apt to be carried from the surface in excessive quantities; but in streets care should be taken, by means of the water-jet, to change the water, and cleanse them frequently.

Various forms and sizes of syphon-traps are shown in drawings No. 13 and 14, all of which would be useful under varying circumstances. Economy and advantage would arise from the use of the double and triple syphons shown in the drawing No. 14, where the various branches could be readily conducted to one point. This may very frequently be accomplished.




At A in the sketch the rain-water pipe, kitchen-sink, and yard-drain would be all trapped by one syphon; an arrangement cheaper and more efficient than the adoption of separate syphons to every branch. While the drains are thus quite as effectually trapped, their combined action upon one point affords greater security for keeping the syphon clear, the water frequently renewed, and the trap at all times charged.

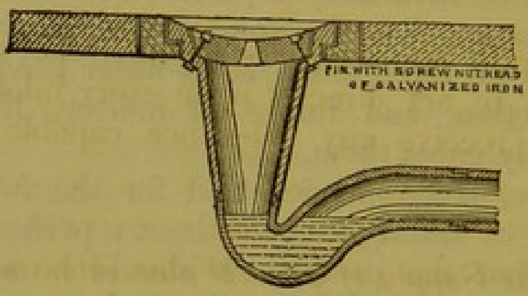
* This objection does not apply to a form of this trap patented by Mr. Lowe.

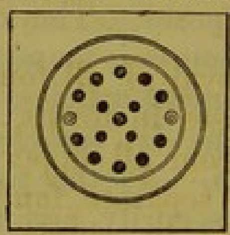
On looking at the extraordinary substances that are now and then found in the sewers—rags, bottles, broken china, cloths, brushes, and other matters,—apprehension is frequently expressed that small drains never can be successful: but when it is seen that not the slightest precaution is taken to guard against the admission of such improper substances, it is wonderful that so little solid matter of this kind finds its way into the sewers. There is scarcely a single opening in the present house-drainage that is permanently protected. The gratings and sink-stones of yards and areas are often either entirely loose, or so placed that they may easily be made so. The bell-traps of sinks are almost invariably separate, and are often opened by servants in order that the solid matter may with greater facility be sent down the drain. Rain-water heads have seldom any fixed protection, and lumps of mortar, tile, slate, and rubbish frequently enter them.

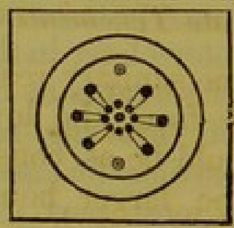
It is, therefore, recommended that for the future no drain whatever should be allowed to be without a perfect protection to every opening, that the protections should be so secured and arranged as to be immovable, and the drains rendered inaccessible for surreptitious and improper purposes. The ordinary form of water-closet in the better class of houses is found a ready opening for servants to dispose of inconvenient articles, and the practice of throwing matters down them is sometimes an amusing pastime for mischievous children. As the pan-basin is for the most part used without any security against such an evil, it is to be expected that such abuses should be met with.

Where the syphon-trap is used alone, as in the poorer class of houses, it will be essential that the opening should be as small as possible, and that the syphon should be sufficiently far from the opening to prevent substances being introduced by hand, by mischievously-disposed persons. A 3-inch syphon, communicating with a 4-inch drain-pipe, will be found a safe arrangement, when the syphon is near the pan. Nothing would then pass but such matters as would be carried through by the force of the water, and no danger need be apprehended. As the traps themselves, however, might frequently get choked by substances thrown down (especially in the first instance, before tenants became aware of the inconvenience to themselves), the traps should be accessible to the workmen of the Local Board without great labour or inconvenience. It is therefore suggested that a cap should in all cases be adapted to them, but not readily removable, lest improper substances should in that way be surreptitiously introduced.

The following drawings exhibit forms of stoneware heads and inlets to drains, for use in yards, areas, sculleries, and other similar places, with the covers so arranged as not to be readily removed. The holes or openings of discharge should be so small on the upper surface as practically to answer the purpose of preventing the entrance of obstructing substances, and should be enlarged or countersunk beneath, to the extent that the substance of the material will allow, in order to prevent the clogging of the aperture. Gratings, or covers with slits, or long openings, through which sticks and flat substances likely to choke the drain would readily pass, should be avoided.




The drawings at pages 116, 117, and 118 show different kinds of kitchen-sinks, or wash-hand-stands of stoneware for bed-rooms or chambers; but other sizes and forms may be manufactured, as convenience or taste may dictate. The branch-drain from the kitchen sink is that which at all times would probably be the most liable to stoppage, by reason of the grease and small refuse matters constantly discharged from culinary operations. Especial care should be taken, therefore, to guard against this difficulty. The sink-holes should be small and well countersunk, but they should be much more numerous than they usually are, and the strainer should be invariably a fixture. Bell-traps should be disused where syphons are put in, as they impede the force of the discharge, and are themselves constantly liable to become choked. Where single syphons are used, they should be no larger than the waste-pipe of the sink with which they are connected otherwise the force of the water is destroyed. They should be placed near the floor, where they would be sufficiently removed for the water to acquire a flushing power, and yet not so distant that the greasy water would be cooled before reaching the syphon and be deposited within it.

With drains well constructed and their inlets properly secured, stoppages will be very rare ; but in case of accident, all appliances should be immediately at hand for the removal of obstructions, on application being made to the surveyor. For this purpose an important use might be made of the water supply-pipes. By having a length of flexible tube, which could be readily attached to any tap and applied to the inlet of the obstructed drain, when that inlet is at a distance from the tap, the whole pressure of the column of water in the supply-pipes might be brought to bear in any drain, and a most powerful auxiliary obtained for clearing it.

As a general rule, however, it is desirable that the taps should be so placed as to act directly upon every inlet of drain that may be likely to receive any substance capable of causing a stoppage.

*Provisions for the Supply of pure Water into, and the Removal of foul or waste Water from upper Rooms and Flats, or separate Tenements in Houses.*

The same sanitary reasons for the removal of all foul water and refuse from the lower parts of houses in towns, suggest that it should be as constantly removed from all upper rooms. Indeed, the larger houses occupied by separate families, in floors or flats, (and far too extensively in single roomed separate tenements,) are to be considered and treated as elevated courts or alleys, the staircase as a common passage, and each distinct occupancy, whether floor or single room, as a separate tenement, and each should have at least its water supply-pipe and sink, or waste and return pipe.

The retention of waste water in such rooms until it may be convenient for the occupant to remove it, is a great sanitary evil. The mother may be sick or unable to carry down waste water, and, as a consequence, impurities are retained just at the time when the condition of the inmates renders them most noxious. The superior salubrity and comfort of the rooms in the model lodgings and dwellings is in a great part ascribable to the conveniences of sinks, as well as to the water supply contained in each set of rooms. Under circumstances ordinarily advantageous, a water-pipe may be carried into every separate room or tenement, giving a constant water supply, and a convenient sink may be fixed up and maintained in good action, at an expense of from 1*d.* to 2*d.* a week.

If a poor woman can occupy herself with any of the worst-paid labour, even making shirts, and can obtain upon the upper floor occupied by herself and family, an abundance of pure water,—a hundred pailsful carried to the top of the highest house, if they choose to use it, for 1*d*., and, for the like payment, the removal of the waste water,—it becomes an extravagant waste of time and labour, *i. e.*, money, on her part, to fetch water from the ground floor, even if she could obtain it and the use of the pump gratis; and, so in respect to the economy of carrying down stairs the foul or waste water. The labour of carrying water up and of carrying slops down, is a great impediment to the free use of water, and a great discouragement to cleanliness.

The proposal to lay on water into separate rooms may excite surprise, and it will be alleged that it is not demanded by the tenants; and it is perfectly true that poor tenants have little idea of the practicability of such conveniences until they learn that they are introduced at a cheap rate, and with much advantage to health and comfort, into model dwellings and lodging-houses. As a general principle, it may be repeated, as stated in the Sanitary Report of 1842,—

"The interposition of the labour of going out and bringing home water from a distance acts as an obstacle to the formation of better habits; and it is an important principle to be borne in mind, that, in the actual condition of the lower classes, conveniences of this description must precede and form the habits. It is in vain to expect of the great majority of them that the disposition, still less the habits, will precede or anticipate and create the conveniences. Even with persons of a higher condition the habits are generally dependent on the conveniences; and it is observed, that when the supplies of water into the houses of persons of the middle class are cut off, by the pipes being frozen, and when it is necessary to send for water to a distance, the house cleansings and washings are diminished by the inconvenience; and every presumption is afforded, that if it were at all times requisite to send to a distance for water, and in all weathers, their habits of household cleanliness would be deteriorated.

"In Paris and other towns, where the middle classes have not the advantage of supplies of water brought into the houses, the general habits of household and personal cleanliness are inferior to those of the inhabitants of towns who do enjoy the advantage.

"The whole family of the labouring man in the manufacturing towns rise early, before daylight in winter-time, to go to their work; they toil hard, and they return to their homes late at night. It is a serious inconvenience as well as discomfort to them to have to fetch water at a distance out of doors from the pump or the river on every occasion that it may be wanted, whether it may be in cold, in rain, or in snow. The minor comforts of cleanliness are, of course, foregone, to avoid the immediate and greater discomforts of having to fetch the water."

These necessities as to the drainage of houses and rooms, have, however, been perceived at periods of less civilization. Mr. Layard found at Nineveh, drain-pipes laid from single rooms, leading towards what was presumed to be a general system of sewers. Drains are found from the *rooms* of Roman edifices, particularly from the tesselated pavements of the hollow floors of dwelling-rooms as well as of baths. Vitruvius gives instructions for the construction of these floors with an incline, that the waste water might run off to the sink or the drain provided.

In the higher classes of houses, pipe distribution of water into separate floors and into separate rooms, with proper return pipes, is not less economical of the labour and time of servants. In a first-class house almost the entire service of one servant may often be saved by proper arrangement of distributory and return apparatus. Where these conveniences are introduced *de novo*, even in the poorest houses, an increased rent will be justified and obtained for them. It is improper, indeed, to represent these works as burthens to any one; they are, when efficient, means to the reduction of existing burthens, and will be willingly paid for by those who are benefited, namely, the occupiers.* It will be a proper course for Local Boards to effect these objects, by private improvement rates and distributed charges. An obstacle to such arrangements is, the trouble they give to the officers, who, especially the older officers, are therefore apt to avail themselves of technical difficulties for avoiding them.

A labourer at Barnard Castle, having been told that the cost of laying on water to the upper floor, which he occupied, would be ¾*d*. a week, and being asked if he would pay it, with a proper spirit, replied, "Do you think I would make my wife a beast of burden for the sake of three farthings a week?"

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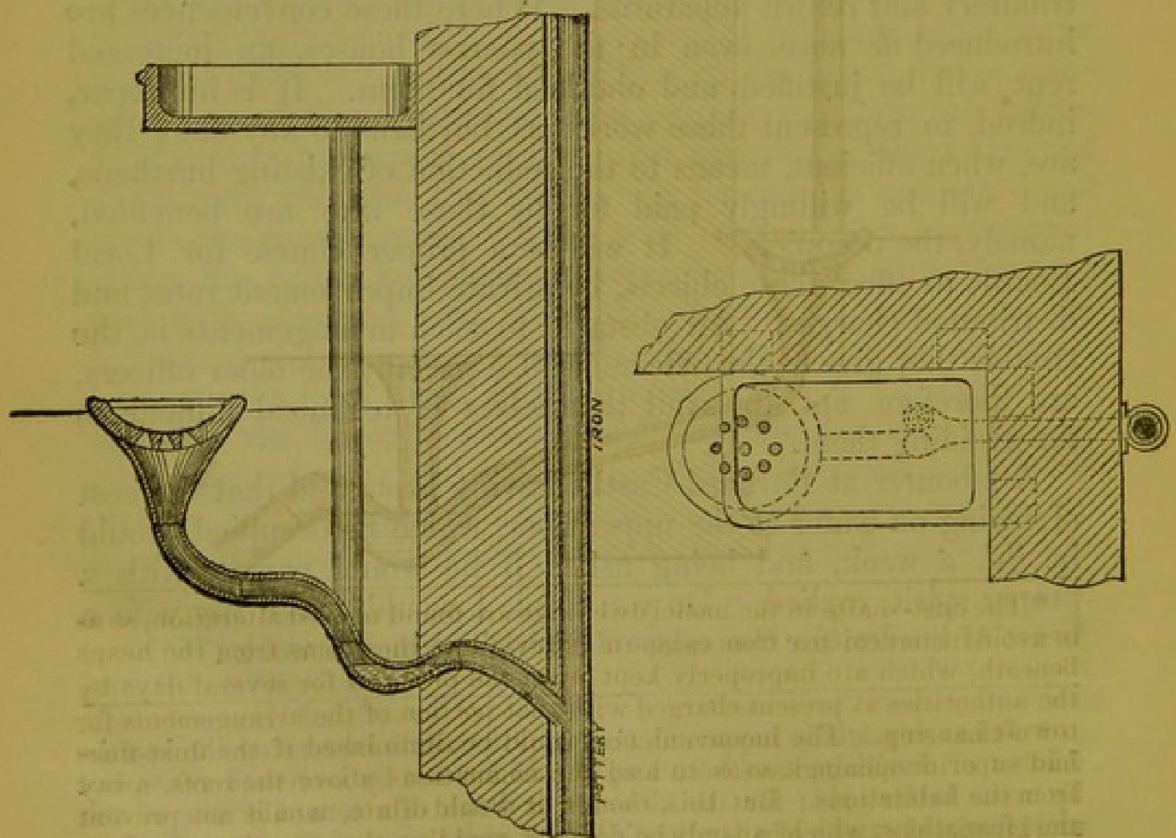
* It has repeatedly happened, that improvements increasing the healthfulness of dwellings have been amply paid for, not by increased rents, but by rents better paid; for the sickness or death of a tenant is one of the most frequent causes of a landlord's loss of rent.

Supplying water to any part of the population by means of public stand-pipes should be entirely discontinued, for they act as discouragements to the proper provision of water for the poorer class of houses, which ought to be supplied individually. The supply obtained from stand-pipes is very generally insufficient, and the waste excessive, while resorting to them is attended with great inconvenience, and leads to constant disputes and quarrelling. These objections do not apply to a provision of drinking-water to wayfarers, by means of very small self-closing taps, nor to troughs kept full of water for horses, cattle, dogs, &c., which animals suffer much in towns for want of water in hot weather.

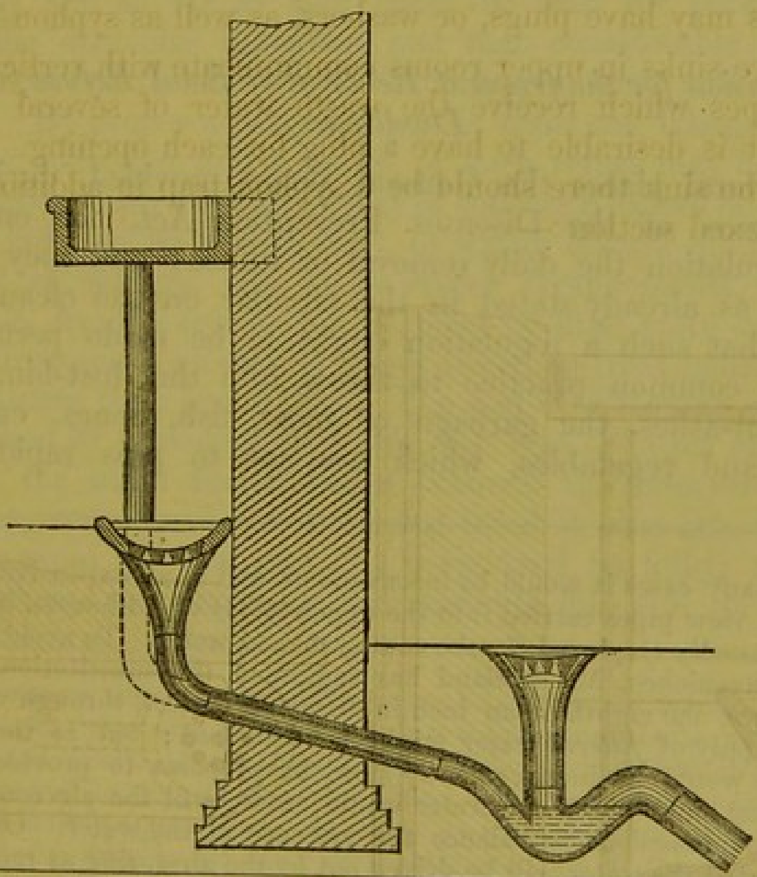
Earthenware sinks may be made cheaper than stone ones, and harder than those of common stone. They are better shaped, have more complete traps, and can be made more sightly, and be more easily and completely cleansed. The waste-pipes to the sinks may have plugs, or washers, as well as syphon-traps.

Where sinks in upper rooms communicate with vertical main drain-pipes which receive the waste water of several departments, it is desirable to have a plug for each opening. At the foot of the sink there should be a syphon-trap in addition, as in the annexed section :—

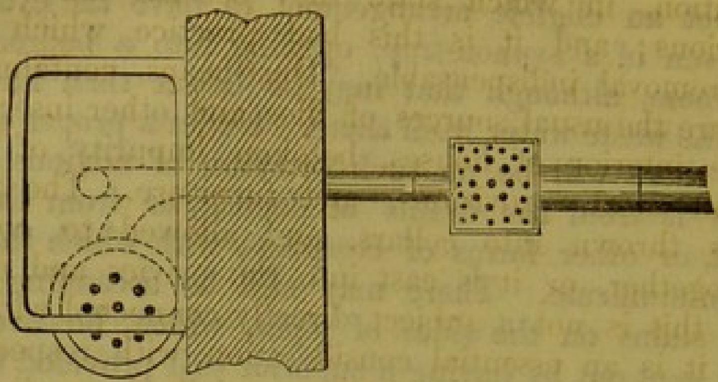


It is not an eligible arrangement to have the evaporating surface, even of a syphon-trap, opening into a bedroom or a dwelling-room, although that may be better than having the whole of the waste water itself there. Under a proper system of drainage, there will be no such pressure of noxious gases as there now is from the drains of deposit, or from the sewers of deposit, or other forms of cesspools, with which the house-drains communicate. There may still be ascending vapours from the stains on the sides of pipes, which, however slight, should be kept out by having a superior exit provided for them, so as to avoid their bearing upon the upper orifices.*

The sinks in rooms will be used for washing upon, and in bedrooms as wash-hand-stands. As it is inconvenient to lift tubs of water or baths used for washing children, it will be proper for that and other purposes to have a second sink at the foot of the stand, as shown in the subjoined plan :—



* The dust-shafts in the model dwellings are found to need alteration, so as to avoid inconvenience from escape of effluvia into the rooms from the heaps beneath, which are improperly kept upon the premises for several days by the authorities at present charged with that portion of the arrangements for town-cleansing. The inconvenience would be diminished if the dust-flues had superior openings, so as to lead the emanations above the roofs, away from the habitations. But this, though it would dilute, would not prevent the emanations, which can only be done by avoiding the retention of refuse.



The water service-pipe should be of small bore, and made of tin, glass, earthenware, or other innocuous material; and self-closing valve-taps, though a little more expensive at first, will be found economical by preventing the waste of water from carelessness.*

*Provision for the frequent Removal of Solid Refuse from Dwellings.*

In several places the General Board provided, during the continuance of the Diseases Prevention Act, for enforcing as a regulation the daily removal of refuse; and they are of opinion, as already stated in the circular on the cleansing of towns, that such a regulation ought to be made permanent, It is a common practice to throw into the dust-bin, along with coal-ashes, the garbage of meat, fish, bones, cabbage-leaves, and vegetables, which are apt to pass rapidly into

* In many cases it would be inconvenient, and in all expensive, to conceal from view pipes carried into the upper rooms of old houses, if so large as those usually employed for the conveyance of water. To avoid this cost and inconvenience, Mr. Holland has suggested the substitution of very small pipes, one eighth of an inch in diameter, or less, through which an ample supply of *filtered* water might be delivered ; but as the rate of discharge would be inconveniently slow, he proposes to provide an air-tight vessel, into which the water would enter until the air contained is so far compressed as to balance the pressure of the water. On the tap being opened the water will be driven out by the air-spring as rapidly as if supplied by a pipe as large as the plug-hole of the tap. It is necessary that the air-vessel shall be large enough to contain as much water as will be required at once ; it will gradually fill again between the intervals of drawing, and in a few minutes a fresh supply may be obtained. The water, being in an air-tight vessel, is not exposed to any risk of pollution. The pipes need not be larger than a tobacco pipe, and may be made of earthenware, glass, gutta percha, or other incorrodible material. Such pipes are very inexpensive, and may be concealed as easily as bell-wires.

decomposition, in which state they become alike offensive and injurious; and it is this bad practice which renders frequent removal indispensable. Dust-heaps, containing such garbage, are the usual sources of flies and other insects which infest the interior of houses, betoken impurity of the air, and befoul meat, provisions, and furniture. The refuse is sometimes thrown into cellars, and allowed to collect for months together, or it is cast into the privies and cesspools. Although this is not a subject directly connected with house-drainage, it is an essential consideration with respect to the health of the population, and one especially demanding proper provision in order to secure the house-drains and their appliances from improper usage; for it is highly probable that, in these confined spots, where cesspools are now improperly used as dust-bins, if no other convenience were afforded, the water-closet basins would too often become (at all events in the first instance, and as far as they could be used for such a purpose) the dust-bins hereafter, and that considerable expense, annoyance, and trouble would ensue in emptying and cleansing them.* By proper arrangements, the time and labour of more frequent collection and removal of such refuse may be greatly diminished. Increased frequency of collection causes no addition to the bulk to be carted away, or within certain limits, to the expense of cartage, and under proper arrangements, frequent removals, from house to house, need be little more expensive than infrequent removals of larger quantities from houses, made at a distance from each other. The cost of collecting might be diminished by providing moveable dust bins or boxes capable of holding the usual accumulation between the intervals of the cart being sent round, the box being lifted at once into the cart, so as to avoid the dust and dirt occasioned by filling the dust into baskets, and throwing the contents into the cart in the

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* In houses where the separate floors are let to different families, arrangements might frequently be made for providing dust-shafts, much to the comfort and health of the inhabitants. This provision has, in the model dwellings and lodging-houses been found to be a very great boon to the poor, and is duly appreciated. It is yet an inconvenience in those dwellings that the dust is not more frequently removed by the dustmen from the bottom of the shaft, *vide ante*, p. 116. The evils and inconveniences which the population suffer from accumulations of refuse are sorely oppressive; and the proverbial insolence and neglect of dustmen, often only to be overcome by bribes, amount to a direct tax upon the poor tenants, who, when they have scarcely wherewithal to buy bread, are found clubbing their halfpence together as inducements to these men to do their duty.

street, arrangements being made for changing the full receptacle for an empty one, at such short intervals as may be found most convenient. The dust-boxes may be advantageously provided by the Local Board, otherwise they will not all be of convenient or uniform size, and cannot, therefore, be packed so closely in the cart in which they are carried; while it would be difficult to avoid occasions for dispute if the boxes belonged to private individuals; besides, they can be supplied more cheaply in large numbers than singly.* The byelaws may, therefore, properly provide—

That ashes and other kinds of refuse shall be placed ready for removal at the times appointed, such refuse being put into a convenient receptacle, ready to be given to the dustman when the dust-cart passes by.

That no dust or dirt shall be thrown on the surface of any court, yard, or passage, or out upon the footpath, or swept into the street during the day, after such shall have been cleansed, persons being required to retain all such refuse until the next time the scavenger passes.

In respect to the cleansing of stables, a provision for the constant removal of dung should be made, similar to that for the removal of house refuse. Mews and quarters where horses and cattle are kept in towns, are often what have been properly called "fever nests," to which the attention of the General Board has been strongly directed, and evidence has been received from eminent veterinary surgeons that frequent and complete cleansing, and other sanitary measures, are as important and economical for cattle as for human beings. The stable-keeper who permits stable-dung to accumulate and rot in or near the stables, until he can dispose of it in a heap, is generally guilty of a false economy. Late reports of agricultural associations have incontestably proved that disease and epidemics amongst cattle are most rife in filthy, close, ill-cleansed, and ill-ventilated byres and stables. The pallid complexion and low health so

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* A dust-shaft, or even box, beneath the ashpit of the kitchen fire, covered by a grid to prevent the entrance of coals or cinders, saves fuel considerably, and prevents much of the annoyance of dust-bins. It has been proposed to add to this a receptacle in which vegetable refuse may be placed to dry, the vapours from which would pass up the dust-flue into the chimney, and the dried remains might be burnt. Such arrangements would greatly reduce the quantity and the offensiveness of refuse to be carried away. It would be wise for those who keep horses at livery to be more careful than they usually are in choosing stables which are kept in a salubrious condition.

common among stable-keepers denote the unwholesomeness of the atmosphere thus created. Whatsoever may be the farmer's usual practice as to the fetching of dung, its accumulation in the vicinity of crowded dwellings should be rigorously prevented, and provision should be made for its due removal by the scavengers appointed under the Local Board. The detention of dung until it dries, giving off offensive gas, to the pollution of the air, is moreover injurious to the dung itself, for many farmers have now become aware that recent, or, as they call it, "fresh dung," is the most powerful as manure, and they will therefore pay more for it.

But were the interest of stable-keepers, in having perfect cleansing, less in accordance with that of the town, as no one has any right so to conduct his business as to make it annoying and injurious to others; no accumulations of dung near dwellings ought, therefore, to be permitted beyond what can be contained in a covered receptacle of limited dimensions, provided with a trapped drain to carry off the liquid manure, and emptied at short intervals.

The occupiers of stables and slaughter-houses, who are in the habit of what they call "saving" the manure, that is, keeping it a long time, at such real expenses as those adverted to, may object to frequent removals of refuse as interfering with their means of selling it. If they choose to retain such accumulations in disregard of the health of their own servants and the condition of their cattle, they should not be allowed to to do so to the annoyance of other inhabitants and the injury of the public health. But owners of such refuse would, for the reasons already given, find it to their interest to remove it more frequently, and an arrangement might be made with the contractor to make for it a fair allowance.

The retention of decomposing refuse in slaughter-houses, and the neglect by butchers of frequent and complete cleansing, is also proved to be not only dangerous to health, but even, in a pecuniary sense, an error. Offensive odours, and a close and stagnant atmosphere, injure the quality of meat, dispose it to taint, and promote its rapid putrefaction. It has been demonstrated, that meat killed in slaughter-houses where a degree of cleanliness and freshness is maintained above the average, "keeps" beyond the ordinary time; whilst meat killed in slaughter-houses where there is excessive filth and closeness, becomes sooner tainted, occasioning great loss. Professor Owen has pointed out that,—

"Another advantage (of well-conducted slaughter-houses) was, that the butcher, getting the meat in better condition, was able to keep it fresh much longer than it could generally be kept in London. I have seen in Clare Market fine joints of meat thrown on the offal heap, and carted away in thirty hours after the slaughter of the animal; this had been the case with carcases which had been suspended for only one night in the tainted atmosphere of the slaughter-house. The owners of these places appeared not to know that a piece of fresh meat placed within the atmosphere of tainted meat would rapidly partake of the corruption, and seemed also not to be aware that their filth and ignorance combined to make them pay a large fine out of their own pockets, in the shape of meat thrown away, if it could not be forced by its cheapness on the poor inhabitants of the district."

The dung in slaughter-houses, the blood, and much of the garbage heretofore removed by hand, might be removed by convenient apparatus on the principle of a water-closet. For this purpose arrangements should be made for easy access to one of the branch or main lines of sewer, having an adequate flow of water, for the removal of most of the manure which is now collected and removed by cartage. By such arrangement, almost all, if not literally all, filth liable to decomposition, that is, liable to become annoying and injurious, might be at once got rid of, leaving scarcely anything but coal-ashes and perfectly dry substances to be removed by hand.

Similar means would be applicable, to a considerable extent, for the removal of the remains of fish and other garbage, and the cleansing of markets, as well as for the removal of dung and the cleansing of stables.

It should be the duty of the inspector of nuisances, or of some other officer under the direction of the surveyor, to communicate information to stable-keepers, fishmongers, and other inhabitants as to the conveniences available for such purposes, and to give instruction as to their use; the object being not to increase labour and trouble, but to diminish them as much as possible. All practicable conveniences should be provided, and full information given, before attempts for the enforcement of a change by means of penalties are resorted to.

The Local Board may fairly provide, as a byelaw, that the cleansing of the interior of all yards and premises whatever shall be so frequent and complete as to prevent any offensive odours being diffused, so as to be perceptible to the neighbours or passers-by.

### *Public Conveniences.*

It will be the duty of Local Boards of Health to provide public water-closets and public urinals, as important means of preventing the deposit of filth on the surface of the streets or on walls. Such conveniences may be considered as indirect means of surface cleansing, and should be erected near markets and places of large resort, as good at least as those provided at railway stations, or with improved construction, giving more light and air, and better means of cleanliness, and placed under proper care. Public water-closets should be examples of the most perfect cleanliness and freedom from offensive odour. In some places an arrangement has been sanctioned of a small payment for a superior order of accommodation.

### *The Surface cleansing of Streets and Edifices.*

One important mode of applying the principle of the removal of all town refuse in suspension in water, is that of cleansing streets by means of the jet d'eau.

The broom without water loosens and removes a large proportion of the indurated filth; but in some states of weather it smears and spreads ordure, and increases the surface evaporation from it, leaving the filth between the interstices of stones untouched. In dry weather, it raises dust; and the operation of street cleansing by sweeping alone is very incomplete.

The cleansing by jet is, on the contrary, complete; it cleans interstices and removes everything. Slight showers soften the surface dung and dirt of streets, and render it adhesive. A proper jet scours and clears all perfectly away. Properly applied, it leaves neither loose mud nor puddles of stagnant water; it moreover scours away the filth from side walls,* and may be used to

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* Mr. Seymour Tremenheere, in his Notes on Public Subjects in the United States, p. 108, thus describes the improvements in the supply of water in American towns, and the usual process of applying the jet:— "The luxury of cold water is one which certain of the great companies seem to think unnatural to man; of cold water, at least, in abundance and purity. It is rather tantalizing to one who leaves London in the beginning of August to find himself in ten days in cities across the Atlantic where bath-rooms are almost as numerous as bed-rooms in every private house of any pretensions to comfort, that even a moderate competency can command, and where the purest water is let in at the highest habitable part of every building in unlimited quantity and for a most moderate payment. It is somewhat amusing, too, to see the Irish maidens in Philadelphia (in their usual vocation of housemaids there as elsewhere) tripping out in the early morning upon the broad brick foot-pavements, and screwing a small hose of an inch in diameter to a brass cock concealed under a little iron plate near the kerbstone; then, with an air of command over the refreshing element,

clean the fronts of houses. When applied by means of fire-engines, during the prevalence of cholera, to the cleansing of close courts and alleys, there was a decided check given to the virulence of the disease. When used in such courts and alleys in sultry weather, the effect is most grateful to the senses. The operation of cleansing by the jet is far more rapid than by hand-sweeping, or even than sweeping by machine, and is less expensive by nearly one half than hand-sweeping. The apparatus is, moreover, available for the extinction of fires in towns more rapidly and effectually than by any other known means; and where skill in its use has been acquired, losses and risks from fires have been diminished more than one half. The hose and jet is also an important means of removing any stoppages from house-drains and pipe-sewers.

For such cleansing, no less than for the proper sanitary condition of the dwellings, the existence of a good surface pavement is presumed. The available experience for the construction and pavement of courts, alleys, streets, and roads, will form the subject of separate minutes of information; but it may be observed here, that unpaved and uncleansed surfaces near crowded habitations, especially in closed courts, back-yards, passages, and other close and ill-ventilated localities, are often more noxious in their influence on the health of the population, even than cesspools. Where the surface is unpaved, it becomes the depository of

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directing a copious shower against the windows, shutters, front door, white marble steps, elegant iron railing, green shrubs, small and much-cherished grass-plot, heavy-blossomed creepers hanging on neat trellis-work, and finally upon the graceful acacias, or the silver maple, or the alanthus, or the mountain-ash above her head. Next advances a graver character, whose business is to 'lay the dust.' He drags after him a snake-like hose, some 50 feet long, one end of which he has screwed upon the stop-cock fixed by the side of the pavement, while from the brass pipe of the other end he throws a strong jet over the street, and to a considerable distance beyond the point at which he has arrived when he has come 'to the end of his tether;' he then removes the screw-end to the next cock, which is at the proper distance to enable him to reach by the jet from the hose the point where he left off. The jet is also eminently serviceable in cleansing streets, courts, and alleys, which can never be sufficiently purified by mere sweeping, and also for clearing out drains and sewers, and preventing accumulations which cause offensive and noxious exhalations. It is recommended for that purpose in the Report of the General Board of Health on the Supply of Water to the Metropolis (London, 1850, page 231), and experiments with it are adverted to which had been made at Sheffield and elsewhere, apparently without a knowledge of the fact of its successful and very popular use in the United States." He speaks emphatically, and in concurrence with other witnesses, of the superior "comfort and luxury of an abundant supply of fresh, sparkling, cool, and what is of more consequence than all, most agreeably soft water, in the hotels and private houses."

ordure, of animal and vegetable matter, as well as of slops and waste water. Although the emanations from the foul, wet, and miry surfaces thus occasioned are less intense than those from cesspools and drains of deposit, yet the people, and especially children, are longer exposed to them, and the evaporating surface is much wider. The most marked improvements of the general health and habits of the inhabitants of the poorest classes of houses have followed the substitution of good pavement for such miry surfaces. The surfaces should be properly levelled for surface drainage, and also channelled where necessary; but channelling is not an advantage where there is sufficient fall to the street. Impermeability to moisture, or non-absorbency, is an important quality for surface cleansing and surface washing.

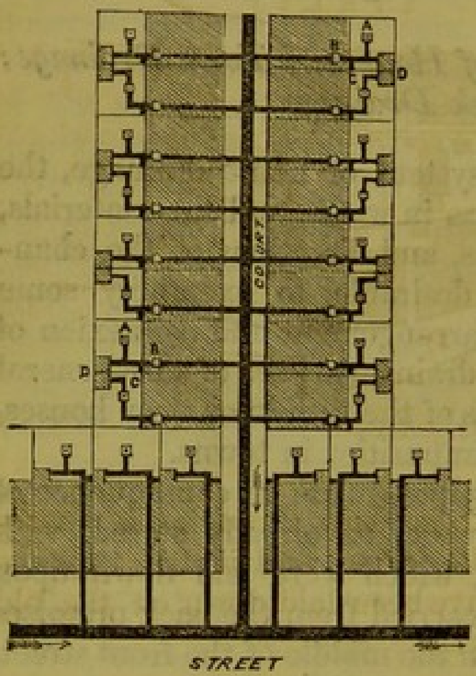
### *General View of combined Works of House and Town Drainage; Principle of Back Drainage.*

Having described the tubular system of house drainage, the apparatus for the reception of refuse in water, and the materials, forms, sizes, inclinations, junctions, and directions of the channels for its removal, it is now desirable to exemplify some important improvements in the arrangement and connexion of branch-pipe drainage with house-drains, as part of one general system to abolish the chief sources of the filth in or near houses, and to prevent gaseous or aërial impurities in towns.

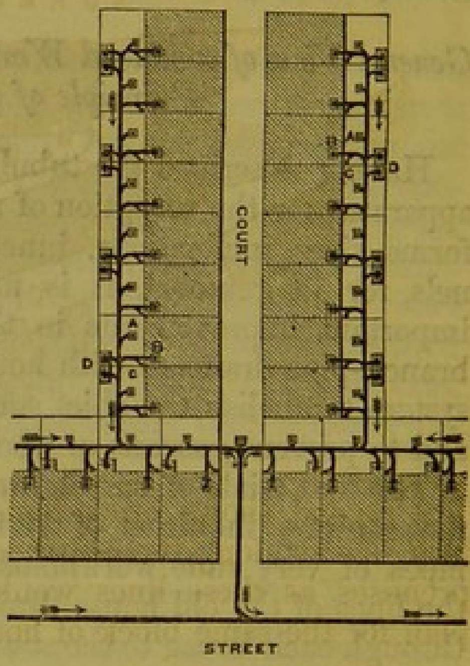
The first trials of earthenware pipes, made in consequence of the sanitary inquiries of 1842, were, as already stated, with pipes of very rude workmanship, which were laid down upon the lines of the old house-drains, carried from the back premises through each house to the sewer in the middle of the front street. Now, although the impermeable pipes (which, as first used, were more than double the proper size, and were also of unnecessary lengths and with defective falls) remove what the old permeable brick-drains detain, and keep themselves clear of deposit, without cleansing by flushing or otherwise; yet it appeared on further investigation that considerable economy of material and expense might be obtained by a closer application of the principles herein-before set forth, by adapting the capacity of the pipes to the service they have to perform, by obtaining with the shortest lengths, the best fall, by diminishing the frictional area, by concentrating the flow, and by obtaining the quickest discharge practicable, and therefore the greatest force of sweep.

The economy of materials has indeed been already shown (*vide ante*, pages 41, 42, 43,) from the application of these principles to the drainage of a single house, particularly from bringing the branch sewer itself to the back of the premises, and as near as practicable to the sinks and the several discharge-pipes, instead of taking it to the greatest distance from them, that is to say, into the centre of the streets, as was previously the general practice. The following plans display the arrangements as applied to a block of houses, or a court or alley, in contrast with the practice of the drainage of such a block of houses, or such court or alley, with a brick sewer large enough to enable a man to enter and remove the deposit:—

Old System.




Improved System.

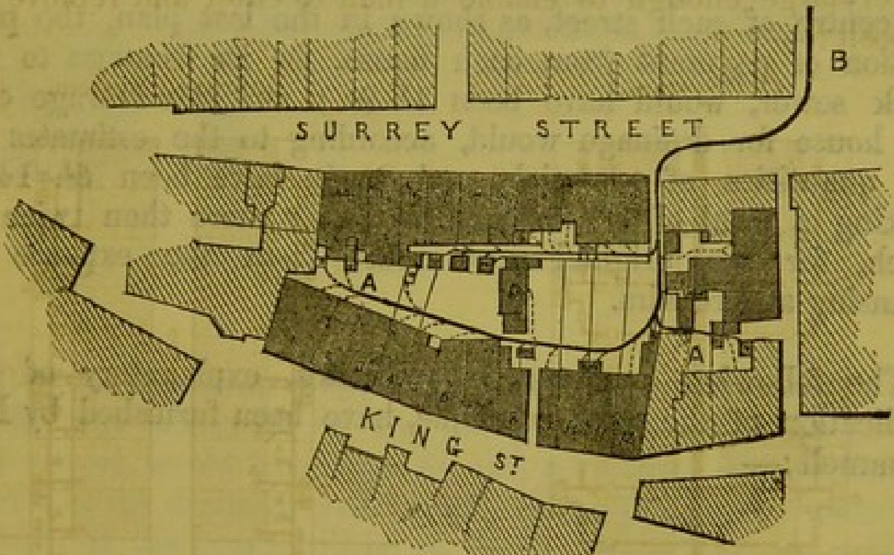



On the measurement of these two methods of house drainage, it appears that by the new arrangements the *lengths* of the whole of the drains would be as 1 to $2\frac{1}{4}$;—the *inclination* of the house-drains would be 10 times greater;—the sectional *area* of the house-drains would be one tenth;—the *inclinations* of the mains would be doubled;—the *area* of the mains would be only one thirtieth;—and the *cubic capacity* of the whole system would be reduced to one thirty-seventh.

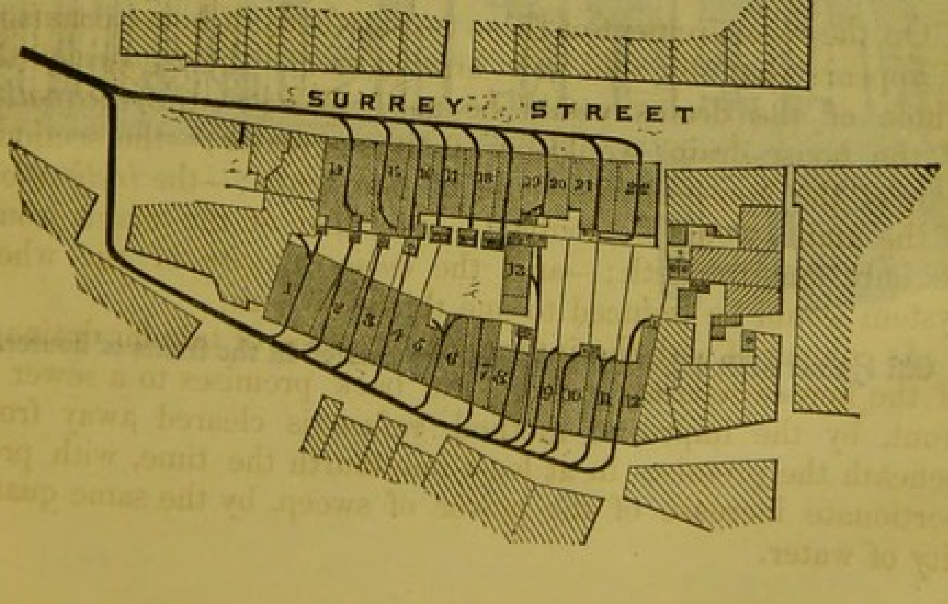
As compared with the intermediate system of tubular drainage of the houses separately, from the back premises to a sewer in front, by the improved method, refuse is cleared away from beneath the premises in at least one fourth the time, with proportionate increase of the power of sweep, by the same quantity of water.

Now, these engineering results, combined with a reduction of nearly four fifths of the previous ordinary rates of expense, are applicable, under proper management, to two thirds of the works needful for complete house and town drainage, and cleansing.

The following are varied exemplifications of this system, as executed under the Public Health Act; the first shows the plan of draining from the backs of houses, adopted for a block of houses at Croydon:—

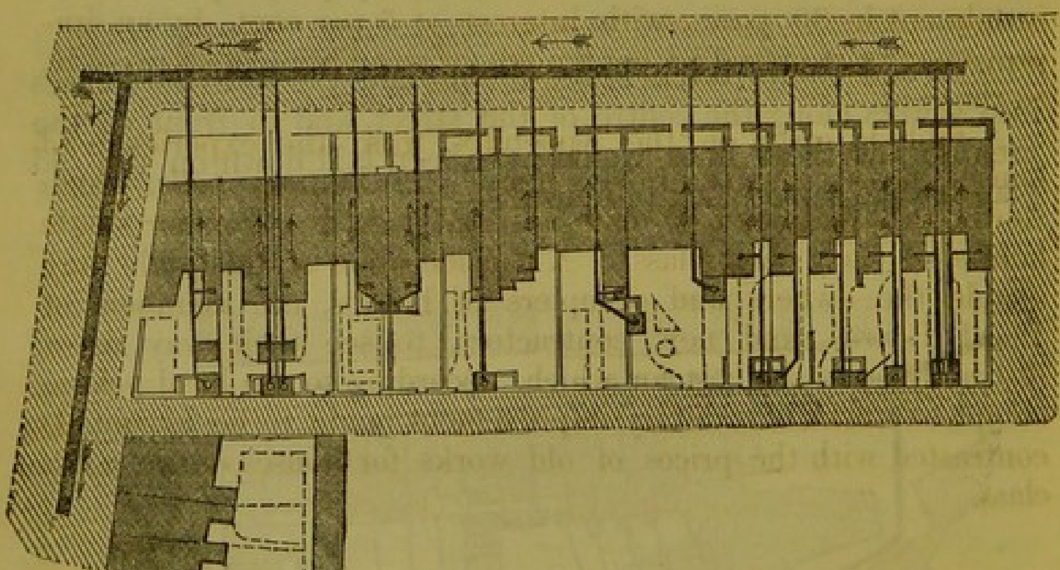



The second shows brick house-drains laid through the houses into sewers along the centre of the street, and in front of the premises, as these lines would have been laid down on the old plan for the same block of houses:—

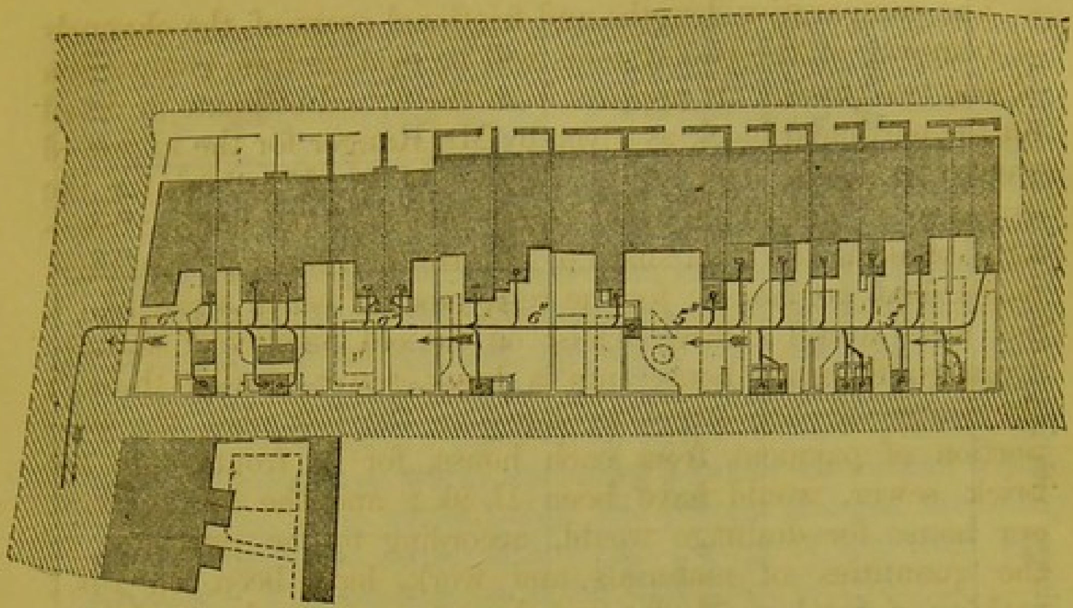


The comparative lengths and frictional areas of the channels of removal of the two systems will be evident from comparison of the two plans. It appears from the actual estimate in detail for the particular block as given by Mr. Ranger for the improved works, that the cost is an average of *2l.* 17*s.* 10*d.* for the drainage of each of these 22 houses, and 11*s.* per house "frontage," making the total share of contribution for pipe sewerage, 3*l.* 8*s.* 10*d.* per house; for the repayment of which a rate of 1*d.* per week would suffice; whilst on the old practice of separate drainage for each house into a brick sewer carried through the centre of each street, as shown in the last plan, the proportion of payment from each house, for its frontage to the brick sewer, would have been 1*l.* 9*s.*; and the average cost per house for drainage would, according to the estimates of the quantities of materials and work, have been 5*l.* 14*s.*; making a total of 7*l.* 3*s.* each house, or more than twice as much, for the original cost, apart from the expense of cleansing and repairs.

The following comparative estimates, explanatory of the application of the same principle, have been furnished by Mr. Rammell:—



Old system of Brick-drains and Sewers carried in the fronts of houses.



Tubular Drainage from the backs of houses.

Here the comparative expense of execution, according to the lengths and quantities on the old plan of front drainage by brick sewers, would have been 8*l.* 10*s.* per house; the estimated expense of the drainage with tubular drains to the pipe-sewer at the back of the house will be 2*l.* 7*s.* 9*d.*, repayable by an annual instalment in 30 years, with interest at 5 per cent., by an improvement rate of 3*s.* 1¼*d.* per annum, or an addition of ¾*d.* weekly, to the rent.

A table is given in the Appendix, from the experience of houses already drained in this manner in the metropolis, which shows the quantities of materials and work required for single houses of each chief class. A consideration of this table may enable the owners and occupiers of houses, the members of Local Boards, and new contracters, to see their way more distinctly as to the cost for which, according to the local prices, complete works of sanitary improvement ought to be executed, contrasted with the prices of old works for houses of the same class.

**Comparison of the Cost of Old separate Works of Water Supply and Brick Drainage with improved Works of Water Supply and Tubular Drainage.**

| — | House and Main Drainage. | | | | Water Supply. | | | | Total cost of Old separate Works and New combined Works of water supply and drainage. | | Average cost of Works for carrying water to and waste water from each additional floor. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Works within the House, including water-closets and sinks. | Proportion of cost of main drains. | Total cost of house and main drainage, per House. | Weekly charge per House. | House apparatus. | Main service. | Total cost of house and main water service. | Weekly charge per House. | Gross charge. | Weekly charge. | |
| | £ s. d. | £ s. d. | £ s. d. | s. d. | £ s. d. | £ s. d. | £ s. d. | d. | £ s. d. | s. d. | £ s. d. |
| 4th Class Cottage— | | | | | | | | | | | |
| Old Works - - | 9 3 0 | 7 2 6 | 16 5 6 | 0 4$\frac{7}{8}$ | 7 0 9 | 0 15 0 | 7 15 9 | 2$\frac{1}{8}$ | 24 1 3 | 0 7$\frac{1}{4}$ | |
| New Works - - | 2 18 8 | 0 17 6 | 3 16 2 | 0 1$\frac{1}{7}$ | 0 17 5 | 0 10 0 | 1 7 5 | 0$\frac{3}{7}$ | 5 3 7 | 0 1$\frac{4}{7}$ | 1 5 9 |
| 3d Class House— | | | | | | | | | | | |
| Old Works - - | 17 15 2 | 8 11 0 | 26 6 2 | 0 7$\frac{7}{8}$ | 19 19 0 | 1 2 6 | 21 1 6 | 6$\frac{1}{8}$ | 47 7 8 | 1 2$\frac{1}{8}$ | |
| New Works - - | 3 8 0 | 2 14 0 | 6 2 0 | 0 1$\frac{4}{5}$ | 2 3 3 | 0 15 0 | 2 18 3 | 0$\frac{7}{8}$ | 9 0 3 | 0 2$\frac{2}{3}$ | 1 5 8 |
| 2d Class House— | | | | | | | | | | | |
| Old Works - - | 24 8 8 | 12 7 6 | 36 16 2 | 0 11 | 27 8 3 | 1 13 0 | 29 1 3 | 8$\frac{3}{4}$ | 65 17 5 | 1 7$\frac{3}{4}$ | |
| New Works - - | 4 12 4 | 4 19 0 | 9 11 4 | 0 2$\frac{7}{8}$ | 2 18 6 | 1 2 0 | 4 0 6 | 1$\frac{1}{4}$ | 13 11 10 | 0 4$\frac{1}{12}$ | 2 5 11 |
| 1st Class Mansions— | | | | | | | | | | | |
| Old Works - - | 35 5 7 | 15 3 9 | 50 9 4 | 1 3$\frac{1}{8}$ | 35 1 9 | 2 0 6 | 37 2 3 | 11 | 87 11 7 | 2 2$\frac{1}{18}$ | |
| New Works - - | 4 18 0 | 6 1 6 | 10 19 6 | 0 3$\frac{1}{4}$ | 3 13 2 | 1 11 6 | 5 4 8 | 1$\frac{1}{2}$ | 16 4 2 | 0 4$\frac{6}{7}$ | 2 15 11$\frac{1}{4}$ |

In respect to the charges for cottages it is to be observed that they include prices much beyond what sufficient works have been executed for on a large scale. For example, in the statement of particulars, 17*s.* 5*d.* is set down for service-pipes and taps; whereas it is reported that where the main has been laid close to a house, a sufficient half-inch service-pipe and tap has been put in upon large contracts for less than half that sum, and that, generally, complete works have been executed for that important class of house at 30 per cent. below the total amount set down. The cost of complete works of water supply for a cottage, (including house service-pipes of block tin instead of lead), and of complete drainage works, including a water-closet and a sink for the house,—the whole public and private charges, including the water rent, are accomplished at a charge of less than 2½*d.* per week. *Vide* particulars in the *Appendix*, p. 166.

As the estimate stands, however, in the above table, the cost of these works may be contrasted with the cost of a common pump and well, and with the original cost of a common cess-pool with its repairs, which are greater in both instances than the charges for the apparatus in question.*

Where from any particular circumstances it has been found to be absolutely necessary to carry the tubular drainage from the back premises to an existing sewer in the centre of the front street, the use of the tubular pipes has generally effected a saving of one half of the former charge for brick drainage, over the same lines.

The expense of an extension of combined works, for providing water-service apparatus, and a sink or return-pipe or drain for each additional floor, is set forth in the table at 1*l.* 5*s.* 9*d.* for a cottage or a fourth-class house. This is an arrangement of great importance to the health and comfort of families occupying flats and model dwellings in towns, and one, indeed, of great economy for the higher class of houses, for which the charges would be double those stated.

Pipes of properly-made vitreous earthenware will be as durable as those found by Mr. Layard at Nineveh, or those at the Collosseum at Rome, and when they are properly laid,

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* A common price for sinking a well eight yards, and steining it, is about 4*l.*; pump and wood frame 7*l.*; stone trough 1*l.*; total 12*l.*; interest and depreciation at 6½ per cent. 15*s.* 7¼*d.* per annum. The expense of wells of brick construction, is frequently 16*l.*; and the total annual expenses 1*l.* 10*d.* The average expense of a common cesspool, including cleansing, repairs, and interest on capital, has been stated at 1*l.* per annum; but the original expense of water-tight cesspools for the middle class of houses is sometimes 25*l.*; and the annual cost, including interest and depreciation, 3*l.* per annum.

there are no accumulations of refuse within them. But on a house-to-house inquiry in the Metropolis, which may be taken as a fair average of the whole (*vide Report on the Supply of Water to the Metropolis*, p. 282), it appeared, in answers from nearly 8,000 householders, that the private expenses per house, (apart from the public sewers rate), upon an average of five years, was (in addition to the expense of making, repairing, and cleansing the brick sewers of deposit) as follows, with the contrast practicable where the Public Health Act is properly executed :—

| | Old System. Annual Expense. | | | Old System. Weekly Expense. | | Under the Public Health Act. |
|---|---|---|---|---|---|---|
| Mending and cleansing brick house-drains | 0 | 19 | $8\frac{3}{4}$ | 0 | $4\frac{1}{2}$ | abolished. |
| Cleansing cesspools - - - | 1 | 0 | 4 | 0 | $4\frac{3}{4}$ | abolished. |
| Repairing water-butts, and cisterns - | 0 | 19 | 2 | 0 | $4\frac{1}{2}$ | abolished. |
| Making house-drains - - | 2 | 0 | 4 | | | |
| Cost of an intermittent water-supply - | 2 | 1 | 9 | 0 | $9\frac{3}{4}$ | |
| Cost of a constant water-supply | - | - | - | - | - | 2*d.* weekly. |

Thus, whilst it is perceived that up to the time of making the official investigations an intermittent supply of inferior water alone cost $9\frac{3}{4}$*d.* per week,—that mending and cleansing defective house-drains cost $4\frac{1}{2}$*d.* per week, the making of them double the sum, and cleansing cesspools $4\frac{3}{4}$*d.* per week,—in the places where combined and improved works have been executed, and the charges distributed over a term of years, on the system adopted under the Public Health Act, cesspools have been filled up, and a soil-pan apparatus substituted, and kept in good action, at little more than half the ordinary expense of cleansing a cesspool. The expense of cleansing the brick house-drains and the cesspools for four or five years, would pay the expense of properly constructed water-closets and pipe-drains for the greater number of old premises.

With respect to the comparative prices of tubular main sewers and brick sewers of the former construction, a practical illustration may be taken from the new main sewers laid down for the town of Rugby. They are of glazed stoneware, of sizes varying from 6 to 20 inches (for the trunk main), laid at depths varying from 3 to 28 feet, the average being 10 feet 6 inches; the total length, converging upon a single outfall below the town, is 6 miles 2,880 feet. The total cost, including all charges whatsoever, was under 3,600*l.*, being at the rate of 2*s.* 1*d.* per lineal foot, or about 550*l.* per mile. Now had that town been drained with brick sewers of deposit, made sufficiently large for men to cleanse them, as arranged by the late surveyor to the City of London, in three classes, and at the contract prices for such sewers as laid down by the Metropolitan Commissioners of Sewers, the following would have been the cost of the system :—

| | £ | s. | d. |
|---|---|---|---|
| 1st. Of brick sewer, large enough for a man to crawl through, 2 feet 6 inches high by 2 feet wide, 11,520 feet at 6*s.* - - - - | 3,456 | 0 | 0 |
| 2d. Of brick sewer, large enough for a man to crouch through, 3 feet 6 inches high by 2 feet 3 inches wide, 11,520 feet at 8*s.* - - - | 4,608 | 0 | 0 |
| 3d. Of brick sewer, large enough for a man to stoop through, 4 feet 6 inches high by 2 feet 6 inches wide, 11,520 feet at 12*s.* - - - | 6,912 | 0 | 0 |
| Total 6 miles 2,880 feet of brick sewer - | £14,976 | 0 | 0 |

But to the annual charges for this outlay, in most cases, must be added the expense of removing the accumulations of deposit, which would be at the rate of 29*l.* per mile per annum, and also the cost of dilapidations, which the subterranean survey of the metropolitan sewers proved to be considerable. Brick sewers are often cheaper in the construction than the larger sizes of tubular earthenware pipes at their present prices; but the brick sewers of the same internal diameter are dearer in action, in consequence of the current expenses attendant upon them, from their liability to choke, and from their permeability and dilapidations, than proper tubular sewers. Assuming, however, the reverse of the fact, that permeable brick and mortar sewers are permanent, and vitreous earthenware pipes perishable, the latter would be the cheaper; and without incurring any greater annual cost than for drains on the old system, the whole of those laid down at Rugby might be pulled up and renewed every four years,* and the house-drains within even a shorter period, and the occupiers would, during their continuance, enjoy an exemption from the noxious emanations arising from drains or sewers of deposit.

The expense of tubular drainage at Rugby as well as at Croydon, has been from various circumstances greater than an average. The town of Barnard Castle contains about 750 houses, and

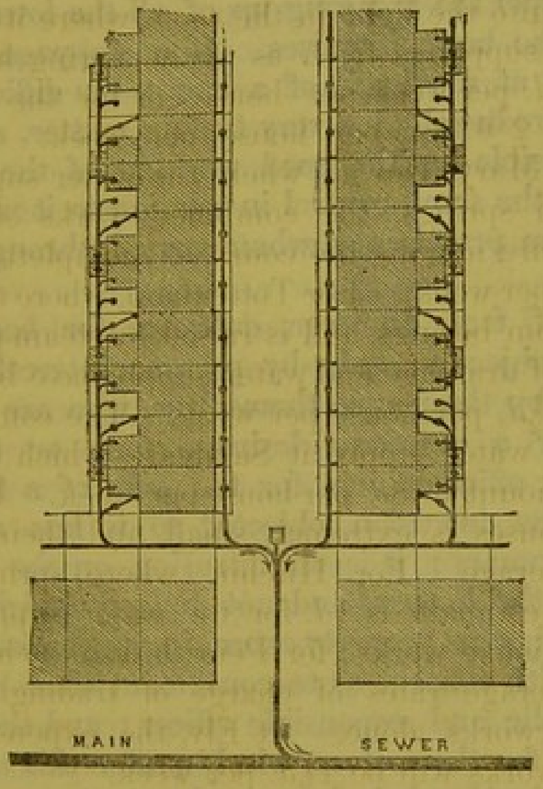
* The annual instalment to repay 14,976*l.*, say 15,000*l.*, in 30 years, with interest at 5 per cent. per annum, is 975*l.*, which sum, added to 300*l.* a year for cleansing and repairs, would amount to an annual charge for sewerage of 1,275*l.* The annual instalment to repay 3,600*l.*, the cost of the pipe sewerage of Rugby, in four years, would be 1,015*l.* 4*s.*, to which if there be added the large sum of 180*l.* a year for repairs, the total annual cost (upon the extravagant supposition of one fourth of the pipes requiring renewal every year) would still be 80*l.* a year less than the large brick drains would cost, which according to the old practice would have been constructed.

covers nearly 120 acres. It is drained under the Public Health Act, by 4 miles of pipe drain sewers, the diameters of which vary from 4 to 15 inches, at one outfall, at an average depth of from 7 to 8 feet; in some parts through rock. The average cost is 1*s.* 8*d.* per lineal foot, or 439*l.* per mile; being at the rate of 2*l.* 6*s.* 10*d.* per house, or $\frac{3}{4}$*d.* per week, for main drainage. The main water supply, instead of being taken from the river Tees, according to the former practice, is collected from soft-water springs nearly five miles distant, and brought to a covered reservoir in an earthenware pipe of 9 inches diameter, and thence to the town in an iron pipe of 7 inches diameter. The water is only brought into the light in the room where it may be drawn, in a constant supply as fresh as at the spring-head. The cost will be 1·37*d.* per week per house, or for the total combined public works 2·032*d.* per house per week. For the town of Ottery St. Mary, Devon, where the water supply is similarly collected from springs, the combined works of drainage and water supply are now in the course of completion, at less than 1*d.* per house per week. For Tottenham, where the water supply is obtained from borings, and is raised by steam power, the combined works of drainage and water supply have been constructed at less than 1$\frac{1}{2}$*d.* per house per week. The combined works of drainage and water supply at Sandgate, which have just been completed, amount to 3*d.* per house per week. In this town the number of houses is extremely small, and their size and value above the average. For Hitchin, where spring sources are obtained, the estimate is 1*d.* for the water supply, and $\frac{3}{4}$*d.* for the public drainage works: for Penrith, a like charge; all being below the average rates of charge of trading companies for separate waterworks alone. At Ely, the expense of the combined public works will be 1$\frac{1}{2}$*d.* per week.

The average estimated expense of other towns drained under the Public Health Act, (and the contracts have hitherto been taken within the estimates,) has been 5*s.* 4$\frac{7}{8}$*d.* per house per annum, or 1$\frac{1}{4}$*d.* per week for combined works, or $\frac{11}{16}$*d.* per week for main drainage works, and $\frac{9}{16}$*d.* per week for a main water supply.

It was however found in the course of the inquiry under the Sanitary Commission, that other inconveniences besides those herein-before recited, were attendant upon the common practice of town drainage; viz., the grievous disadvantages and dangers from stoppages of the public highways for road repairs. At present the perforations of sewers and the breaking up roadways from time to time, for cleansing house-drains, as well as for repairing water-pipes, are liable to be as numerous as the houses. Under the improved system of combined works of tubular back drainage, the perforations into main sewers for the reception of house-drainage, and the occasions for breaking up the carriageway, instead of being proportionate to the number of separate houses, will often be only as the number of the blocks of houses.

Rain-water falling on the surface of the pavement in courts and alleys would be carried away as at present, by a surface channel on the pavement to a grating at the end of the court, and the drainage of sunk areas in front would be accomplished in a continuous line,* as indicated in the following plan:—




SCALE 80 FEET TO 1 INCH

One chief objection to the practice of laying branch sewers

* The arrangement by which a water-main is laid in the centre of a wide street, instead of a small main at each side, or where practicable, at the back of the premises, is illustrative of the expense caused by the separation of what ought to be parts of one arrangement. The trading companies, by laying a pipe in the centre of the street to save a small portion of their capital, occasion a much larger expenditure of capital by the ratepayers. This is exemplified in the course of an examination of Mr. Mylne, Engineer to the New River Company:—"Did the plan of comprehending the tenant's communication-pipes, and the whole machinery under one general system, (*i.e.* a plan for a new supply for Paris,) offer any advantages in respect to economy and sufficiency in laying down the iron pipes?—In a new town there would often be much public economy in laying pipes on both sides, instead of in the centre of the streets; there

at the back of houses, and draining from them, instead of of from the fronts and the centre of the streets is, that in case of the occurrence of a stoppage in a branch-pipe sewer, the stoppage may affect several houses of persons who are not to blame for having caused it. In practice, however, where the pipes have been tolerably well laid, with proper water supply, such stoppages are not found to occur; and they may not be expected to occur, because from the greater falls and more concentrated runs, they are necessarily kept more clear of any deposit or obstruction. If, however, a fault does occur in the line of the house-drain itself, it does not, as at present, affect the interior of the house, or compel the breaking up of all the lower floors, but is confined to the back premises. If a stoppage occurs in the branch sewer at the back of a house, the difficulty in getting it removed is reduced to a very trifling matter, as the surveyor will be responsible for the good working of the branch sewer, and exercise the same control in relation to it when brought to the back of the premises as when carried through to the front street.

In point of fact, however, entrance for back drainage is urged as an objection only by persons interested in existing practices, not by the people themselves, who are not so unwise as to pay for a defective drainage four or five times the expense of an efficient one, for the sake of a fallacious independence. The intrusion objected to is less annoying than that now customary; it is an intrusion on the back premises only, outside the houses, and not by any neighbour or proprietor of contiguous property exercising apparently questionable rights, but (with consent as to convenient times) by a common servant, a public and responsible officer; and the people, when left to choose for themselves, wisely prefer this to the intrusion of bricklayers inside their houses, the ripping up of floors, the cutting of joists, and the disturbance of foundations, followed by heavy bills, and continued intrusions to open up the drains when stopped, or out of repair.

The real intrusion upon privacy is therefore occasioned by the present practice of carrying drains underneath the living-rooms and through the houses; for the workmen must follow them there for repairs as for construction. By restricting their

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would be saving of lead pipes; saving of repairs to these lead pipes; avoidance of inconvenience and expense of breaking up roads for that purpose; saving of inconvenience to tenants in the event of frosts, from there being less of their smaller pipes exposed. In a street of 60 feet wide, the saving of lead pipes would be about 20 feet to each tenant; that is, if the street is built upon each side, there would be 40 feet of leaden pipe saved in a house-frontage of, say, 20 feet; therefore 20 feet of iron extra would avoid the use of 40 feet of lead."

extension to the back yards, or the back offices, intrusions are confined to the parts where they must be least inconvenient and objectionable, and the dangers of accidents from want of skill, as well as the expense and inconvenience, in cutting through the walls and foundations of old houses are avoided. By laying down the drain as well as the water-pipes at the same time, in the same trenches, and carrying both, wherever practicable, through the same openings, double earthwork and other work is saved, and also double annoyances and intrusions of workpeople. By carrying the water-mains to the back premises instead of through the centres of the streets, the saving of the lengths of house service pipes and of the expense of repairs, is proportionately great to the saving of the cost of house-drains. Where soil-pans and pipe-drains, on a proper system, are laid down, and kept in action by due supplies of water, the work and the intrusion in respect to it, and the charges for cleansing and repairs, now constant, will be reduced to a mimimum.

Neither religious duty, nor the existing law, nor private, social, or public morality, recognizes the existence of private rights at the expense of the health and well-being of others. By all the recent general as well as local legislation upon the subject of the removal of filth from private premises in towns through public agency (by dust contractors and scavengers), the law is universally compulsory. It is impossible that any one person should be allowed to retain ordure, or cesspools, or filth of any kind, upon his own premises, in a town, or amidst closely-packed habitations, without polluting the common air, and thereby injuring his neighbours. And although he might be left to injure his own health, he has no right, even if he lived in a detached dwelling, to injure the health of his children, or of others dependent upon him.*

It is, moreover, most to the interest of individual occupiers, that the cleansing should be constant, complete, and to the greatest extent self-acting; that it should be done with complete regularity and economy;—which objects can only be attained by a general system, executed by a responsible and public

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* In many of the Local Acts for the improvement of towns, passed prior to these investigations, the conservation of filth was carried to such an extreme as the following:—"That nothing herein contained shall extend or be construed to extend to any ashes, cinders, dust, *dirt*, manure, ***filth***, soil, *dung*, or rubbish, which any of the inhabitants of the said limits shall have occasion or shall think fit to preserve, or keep within their own respective ***houses***, yards, and gardens." Under the influence, however, of an enlightened public opinion, a great number of such "*Improvement*" Acts, drawn up in the most perfect ignorance of sanitary principles, have already been superseded by the provisions of the Public Health Act.

agency, that is to say, when, as under the Public Health Act, the primary works, the house service-pipes for the common water supply, the channels for the removal of the waste water, the house-drains, as well as the branch and main sewers, are managed and kept in order as parts of one general system.

It was usually the case up to the time of these investigations, and is so now in towns where the Public Health Act has not been applied, that the first notice which a householder or the owner of house property received of the construction of a sewer, intended for the service of all houses without exception, was the raising of a large earthwork in front of his house. Even when time was allowed, no provision having been made for the distribution of the charges of the new works between the various classes of owners, between lessees and tenants-at-will, yearly tenants, or weekly tenants, notices to the owners were of little avail towards voluntary adoption. Joint notices to the occupiers as well as the owners often served only as notices of a dispute between them, which there were no means provided for settling equitably and cheaply, the owner disputing the justice of the requisition for an immediate payment for a new work not expected or stipulated for at the time the tenement was let, and the occupier or the lessee objecting to the payment of the expenses of a work for permanent improvement of premises in which he had only a temporary interest. If the grounds of dispute as to the justice of the charge, or as to the legal liability were settled, separate notices to separate owners, each to drain their respective tenements, would be nevertheless notices to set about a work of which they probably know nothing, and of which, (judging from the defective state of the drainage and the extravagant cost of the drains of large public buildings, and the erroneous doctrines contained in professional books,) it is highly improbable they will be well informed by the common builders. Such notices to private owners are usually notices to them to incur expenses, to which they see no reasonable limit, and of the extent of which they may well be apprehensive.

One main cause of the very small number of house-drains voluntarily joined to the sewers in the metropolis, and in provincial towns, under the practices pursued up to the time of the official investigations, was, besides the fees, and the expenses to which the opening of the roadway and the formation of the junctions gave rise, the costs entailed by the construction of a house-drain itself, and which are yet maintained under the few local or private Acts, which contemplate house-drainage at all. When the newly-constructed sewer has been covered up, the owner or occupier is not only put to the expense of unpaving the footpath and the roadway, and re-opening the ground in order to make his communication with the sewer; but, beyond this, by the position in which the sewer is in the front of the house, and in the middle of the street, he is, often unnecessarily, put to from four to six times more expense than need have been incurred under other arrangements; and in many cases the drainage of cellars, and the foundations of the buildings are impaired, from the length of the drain that would be necessary, while under better arrangements the public drain might have been laid of the same depth, and yet sufficient fall have been obtained to dry the foundations and cellars.

Under these circumstances a small proportion only of the houses in the poorer districts are drained into the sewers; and one of the pecuniary consequences of this restriction is, that the majority of ratepayers, who by these defective arrangements are practically excluded from the chief use of the sewers, are nevertheless compelled to contribute to the expense of the main sewerage works, from which they do not derive benefit proportionate to their share of contribution.

One engineering consequence of such defective administrative arrangement, which excludes a large proportion of the tributaries from the mains, is, that sewers receiving only a small proportion of the house-drainage for which they were intended, are deprived of the force of the sweep of water which would have kept them more clean; they receive mere dribbles; and greater deposit in the sewer is thereby occasioned, so as to increase the extent of surface constantly giving off noxious evaporation.

House-drains of deposit not only occasion smells, but lead to considerable waste of water, used, though seldom effectually, to cleanse them. By re-placing such drains by proper earthenware pipes, in which no deposit will be formed, the excessive expenditure of water for cleansing drains will be prevented, by being rendered unnecessary.

It will be the duty of the Local Board to protect the public health from the noxious influence of defective private works, as well as to protect owners and ratepayers from unnecessary exactions, which are a great source of irritation and local opposition to sanitary improvement. This may be done by the previous preparation of proper plans of house drainage and cleansing works, and previous estimates of the expense at which they may be provided, under common contracts, for private improvement rates, *i. e.* payments by annual instalments of principal with interest. (*Vide Forms* in the *Appendix.*) Such explanations should accompany the orders for filling up cesspools, and for proper drainage and cleansing of houses; and should set forth, that for what is termed a private improvement rate,—of from 1*d.* to 2*d.* per week,—for terms not exceeding thirty years,—and which will be a reduction of existing charges,—cesspools may be filled up, and complete house-drains laid down, and kept in good action and repair. The rates for which combined works may be constructed and maintained upon private premises are properly called improvement rates, for the works have been found to produce improved rentals, as compared with other properties which are destitute of them; and they, moreover, are directly remunerative in the saving of dilapidations. It should also be explained that the owner will be at liberty either to pay off the whole of the immediate outlay, or to construct the works himself, as he may think fit, provided that, before they are covered up, their efficiency in all respects shall be tested by the Board's surveyor, who must be satisfied that they are neither bad from liability to accumulations of deposit, nor from connexion with objectionable cesspools, nor are of an inclination or construction and arrangement, or in other respects, unconformable to a general system.

The policy of the Public Health Act is to diminish individual chargeability and individual trouble; and for the sake of economy, as well as efficiency, to comprehend under one system all works effected by it—works of water-supply from spring-heads to the taps in the house, and works of drainage from house-sinks, or soil-pans, to the outfalls of the trunk line of sewer; the expense of combined works within the house being defrayed by distributed charges under private improvement rates, and those common to several houses by special district rates. Formerly it was the practice to charge as much as practicable of the branch sewers, and first cost of all works carried through private lands, upon private individuals or owners. Under the Public Health Act no such immediate levies should be made, but the whole cost of the works, as in the plan (*ante*, p. 127), from A to B, should fall upon the special district rate, the dotted lines only, which form the actual private house drains, being chargeable to the individual owners.

The term "branch drains" is frequently used in relation to the tubular pipes substituted for the former brick sewers. But these branch drains are, in fact, public sewers, and part of the public system of drainage, though carried through private premises. By the Public Health Act interpretation clause the term "drain" means "any drain used for the drainage of one building only, or of premises within the same curtilage," and would include any pipe, from a single house, communicating with a sewer into which the drainage of two or more buildings or premises, occupied by different persons, is conveyed.

The word "sewer" includes "sewers and drains of every description, except drains to which the word 'drain,' interpreted as aforesaid, applies." It is within the power of Local Boards, sec. 45, to carry their sewers, after reasonable notice in writing, through any lands whatsoever, where it may appear upon the report of the surveyor to be necessary, while the expenses shall be charged upon the special district rate, by which the cost should be equally distributed over a period of years.

*Conclusions.*

In addition to the conclusions set forth in the Report on the Sanitary Condition of the Labouring Population, and confirmed and adopted by the Commissioners for inquiring into the means of improving the Health of Towns, namely,—

That no population living amidst aërial impurities, arising from putrid emanations from cesspools,—drains,—or sewers of deposit, can be healthy, or free from the attacks of devastating epidemics; and

That as a primary condition of salubrity, no ordure and town refuse can be permitted to remain beneath or near habitations;—and, that by no means can remedial operations be so conveniently, economically, inoffensively, and quickly effected as by the removal of all such refuse dissolved or suspended in water; may be enumerated the following:—

That it has been subsequently proved by the result of draining houses with tubular drains, in upwards of 19,000 cases, and by the trial of more than 200 miles of pipe-sewers, that the practice of constructing large brick or stone sewers for general town drainage, which detain matters passing into them in suspension in water, which accumulate deposit, and which are made large enough for men to enter them to remove the deposit by hand-labour, without reference to the area to be drained, has been in ignorance, neglect, or perversion of the above-recited principles.

That whilst sewers so constructed are productive of great injury to the public health, by the diffusion into houses and streets of the noxious products of the decomposing matter detained in them, they are wasteful from the increased expense of their construction and repair, and from the cost of ineffectual efforts to keep them free from deposit.

That the house-drains, made as they have heretofore been of absorbent brick or stone, besides detaining substances in suspension, accumulating foul deposit, and being so permeable as to permit the escape of liquid and gaseous matters, are also false in principle, and wasteful in the expense of construction, cleansing, and repair.

That it results from the experience of works constructed upon the principles developed in these inquiries, that improved tubular house-drains and sewers of the proper sizes, inclinations, and material, detain and accumulate no deposit, emit no offensive smells, and require no additional supplies of water to keep them clear.

That under a proper system of works for water supply combined with house and town drainage, such as is contemplated and sanctioned by the Public Health Act, no ordure is detained so long as to allow it to enter into advanced stages of decomposition, either in the house-drains or in the public sewers; but that all refuse is put in course of constant and inoffensive removal, at a rate of discharge of about three miles an hour.

That where the absence of a natural fall impedes the continuous removal of town refuse, and of surplus rain or spring water, an artificial fall may be obtained by steam power, at a rate of cost (on a scale for a large district) which is inconsiderable compared with the evils it would obviate; and that, at such rate of cost, or from 1*s.* to 2*s.* per house per annum, in many cases, not only may the house-refuse be removed from near habitations, but the foundations of houses and the whole sites of towns may be relieved from the damp of low-lying districts, and the consequent excessive unhealthfulness and decay of habitations thereon diminished.

That all offensive smells proceeding from any works intended for house or town drainage, indicate the fact of the detention and decomposition of ordure, and afford decisive evidence of malconstruction, or of ignorant or defective arrangement.

That the method of removing refuse in suspension in water, by properly combined works, is much cheaper than that of collecting it in pits or cesspools, near or underneath houses, emptying it by hand-labour, and removing it by cartage.

That by a proper system of combined works, and properly adjusted tubular drainage, three districts at the least may, under ordinary circumstances, be drained and supplied with water completely at a rate of expense heretofore incurred in one for imperfect works, which accumulate decomposing deposit, and gave off offensive and injurious smells.

That under ordinary circumstances, where new and combined works are properly executed, the expense of the main water supplies, and the main drainage works have, on the average of the whole town, been less than at the rate of 3*d.* per house per week.

That where combined works have been properly constructed, a service-pipe has been introduced from the water-main for the conveyance of a constant supply of water, a sink and dust-bin provided, the cesspool filled up, and an apparatus of the nature of a water-closet substituted, connected by a house-drain with a main drain or sewer, and put in good action, at a charge under ordinary circumstances, and for the greatest number of habitations, payable by an improvement rate of little more than 3*d.* weekly, being less than the ordinary rates of expense for forming and keeping in repair common pumps, and the expense of cleansing cesspools attached to houses in towns.

That where combined works have been properly executed, the expense of the complete works has not hitherto exceeded the average expense of cleansing and repairing house-drains, and of cleansing cesspools, as declared upon a house-to-house inquiry, including 8,000 houses, in three average parishes of the metropolis.

That it is important, for the sake of economy, as well as for the health of the population, that the practice of the removal of refuse in suspension in water, and by combined works should be applied to all houses, especially to those occupied by the poorest classes.

It is to be hoped that the due consideration of the facts upon which the general conclusions above recited are based will lead to the voluntary adoption and wide practical application of the principles evolved; but it is proper to observe, that, whilst those facts prove the eminent practicability of the chief measures contemplated by the Public Health Act, they equally show the duty of enforcing, in places where the Public Health Act has not been brought into operation, the provisions of the Nuisances Removal and Diseases Prevention Act: in all cases "where it appears that any dwelling-house or building in any city, town, borough, parish, or place, within or over which the jurisdiction or authority of the town council, trustees, commissioners, guardians, officers of health, or other body to whom such notice is given, extends, is in such a filthy and unwholesome condition as to be a nuisance to, or injurious to the health of any person; or, that upon any premises within such jurisdiction or authority there is any foul and offensive ditch, gutter, drain, privy, cesspool or ashpit, or any ditch, gutter, drain, privy, cesspool, or ashpit *kept* or *constructed* so as to be a nuisance to, or injurious to the health of *any* person;"—then, upon proof thereof before two justices, the nuisance may be ordered to be abated, that is to say, the viciously-constructed drain, or other work to be removed; and the neglect to obey such order subjects the owner or the occupier to penalties, while the work may be done by the authorities, and the parties offending may be charged therewith.

The subject is by the common law entitled to protection against anything as a nuisance, which is offensive to the senses, although no injury to the health results from it, nor any other injury than the discomfort of offensive smells, or of filth and other matters offensive to the sight.

House drains, or branch or main drains, which detain and accumulate deposit, can scarcely fail under ordinary circumstances to give off emanations offensive to the senses, which will make them nuisances within the meaning of the act, and such emanations are often fatal, and are always injurious, by lowering the general tone of health, even when they are so diluted as not perceptibly to produce specific disease.

It cannot be too often impressed on Local Boards, that it is their duty to cause such sewers to be made as may be necessary for effectually draining their district for the purposes of the Public Health Act, and that this duty is not discretionary but compulsory. Nor must it be forgotten that a Local Board may incur penal consequences as well from the improper discharge of their duty, as from the "unlawful omission" of it. Whatever discretion the Act may have allowed with respect to the form of works, or their mode of construction, they must be so executed as neither to create a nuisance, nor incur wasteful expenditure,—the very objects which it was the intention of the Statute to prevent. The legislature having charged Local Boards with the duty of executing its beneficent provisions for the protection of the public health, they are subjected not only to moral, but also to legal responsibility for any private or public injuries which they may occasion, whether by their acts of commission or omission. They may create nuisances by constructing bad works, or by allowing nuisances to accumulate in consequence of constructing no works at all, when, by the Statute, they are under legal obligation to provide them. If they allow nuisances to remain, when they are bound to remove them, they incur legal responsibility for neglect of duty, or, in legal phrase, for "nonfeasance;" if, from insufficient attention or culpable negligence, they create nuisances in the attempt at removal, the offence arising unwittingly or from negligence, they incur responsibility for "misfeasance;" and if they create nuisances by wilful neglect or defiance of previous available information and experience, they incur reponsibility for "malfeasance."

Signed by order of the Board.

C. Macaulay, *Secretary.*

*Whitehall, 25th June* 1852.

# APPENDIX.

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(No. 1.)

## Elementary Maxims to be kept in view in the Drainage and Cleansing of Towns.

Ascertain, if practicable, from any existing or previous experience of storms within the district, with what modifications the tables herein-before given may be applied to the district.

Where drainage works have already been laid down, observe the outfalls and the branches, both in the discharge of pipe water and of rain-water, and the quantity of deposit left; and from such observations judge of the corrections requisite in the sizes of tributary pipes.

In laying down main drains or sewers in any street, let it be ordered at the same time that all cesspools on the premises in such street shall be filled up; that tubular house-drains shall be provided, and that a sufficient flow and sweep of water shall be secured to keep such drains free from deposit.

Provide that blood, semi-fluid offal, garbage, and refuse of every description, which may be capable of safe removal in the drains by suspension in water, from slaughter-houses, markets, shambles, stables, cow-houses, or manufactories, be conveyed into the drains on the principle of the soil-pan apparatus, taking care that such refuse be led as directly as possible into those main-pipes which have the largest, quickest, and most constant flow.

Provide such gullies or openings into the sewers that the surfaces of streets, foot pavements, roads, yards, markets, or open spaces where there is much traffic, or droppings from cattle, or other filth, may be promptly cleansed by means of the jet.

Make proper provision for the ventilation of all sewers and drains in such manner that there may be a free current of air through them in the direction of the sewage flow.

To adjust the drains to the service they will be required to perform, calculate for extraordinary storm-waters in those valley or outlet lines only where it will be necessary to accommodate them.

Take care that in laying socket-jointed pipes great caution is used to give the pipes a full bearing, and not to allow the plain ends of the pipes to "*bind*," or rest solely on the socket, as, by doing so, pipes are frequently broken.

Whilst proper provision is made for the discharge of storm-waters in valley lines, where there is a natural descent, do not provide for taking them into the sewers of streets and places where storm-waters can flow on the surface without inconvenience, and thus, at increased cost, incur the certainty of weakening and impeding the ordinary discharges by the use of sewers too large for them.

To provide an efficient drainage where a natural outfall is wanting for a continuous discharge of sewerage, as in the case of lands near tidal rivers and below high-water mark, pumping should be resorted to; but in order to economise power, cut off the upper districts wherever practicable by a line of catch-water sewer for discharge by gravitation, so as to avoid any unnecessary quantity flowing down to a depth whence it must be pumped up again.

Admit into the soil-drains only the surface-drainage of streets, roads, places of traffic, roofs, yards, &c. which discharge foul water.

Lead the under-drainage of garden grounds and all clean waste water, when it is considerable in quantity, into the pipe-drains for the land.

Allow no private tradesman, or irresponsible person, to make junctions with the public sewers, except under proper regulations and strict superintendence.

Prefer always a small drain, with a good inclination, to a large drain with a less inclination.

Make all junctions with the largest curves practicable, and allow no junctions whatsoever at right angles.

Join all vertical pipes into the mains at the side, with a curve.

In vertical junctions let the bottoms of the pipes be level with each other.

Use syphon-traps at all times in preference to flap-traps or bell-traps.

Give a large body of water to all water traps.

Place the syphon-trap low, at a little distance below the opening, so that the force of water may effectually discharge its previous contents.

Take care to put cesspits to all road-side openings to prevent the entrance of stones or solid detritus into the gully-shoots or pipe-drains, and let these cesspits be frequently cleansed by water with the jet, and let the solid matters be regularly removed.

Choose those forms of soil-pan apparatus which keep the pan clean, prevent the ingress of hard solids not smaller than the connecting pipe, and afford a sufficient trap with the least quantity of water.

Allow no supplies of water to water-closets or soil-pans, which have not one form or other of self-closing taps or valves.

Take care to protect the upper ends of all drain-pipes by proper grates, or other means, so as to render it impossible for careless or mischievous persons to choke the pipe by a thoughtless or wilful insertion of large solids.

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The tests of the completeness of all and every part of the general system of drainage works, combined with waterworks, is, that no matter liable to run into decomposition,—no matter whatsoever,—is detained in them, but that all is received in suspension in water, and kept in constant motion until it is discharged at the outfall; and the chief points of comparative superiority in the works are—the great quantity of matter removed in suspension in water—the rapidity and completeness of its removal—and the small quantity of water with which the removal is effected—and the general low rate of expense.

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(No. 2.)

## Special Maxims as to the Application of Water.

Allow no water to be conveyed into any premises until assured that means are provided for removing the waste water, and take care that near to every end of a water-pipe there is a drain or return-pipe, and that under every water-tap there is placed a sink.

Take care that a stop-tap is provided upon the service-pipe in each house, so that in the case of breakage or repairs the water may be at once turned off. The best situation for the stop-tap is immediately withinside the house by the frontage wall.

Take care that all piping in exposed situations be well protected against frost. Half-inch deal-box troughing, about $2\frac{1}{2}$ inches clear in the inside, held to the wall with iron staples, and filled with sawdust, is found to be sufficient.*

Allow no old-fashioned plug-taps, whether bit, stop, or ball, to be made use of, and always reject any tap which can be closed suddenly;—unless this is carefully attended to, the hydraulic shock or ram of water under pressure brought to a sudden state of rest, will not only produce an unpleasant noise, but often ultimately burst the strongest piping. Those taps which are gradually shut by the action of a screw, and called thence "screw-down taps," are the best for domestic purposes.

Look to the adjustments of taps, and of spreaders or valves in soil-pans, to the pressure of water in the lower and upper floors, and at different altitudes.

Allow only those taps which are self-closing to be used for soil-pans and water-closets, unless other means are provided for the prevention of waste of water.

Substitute for lead service-pipes, pipes of tin or of iron protected by enamel; or better still,—as being less subject to oxidation, less liable to breakage from frost, and when air vessels are properly arranged, in less danger of breakage from hydraulic jerks,—well-made earthenware pipes.

Provide air-cushions in the mains at proper stations, where the hydraulic shocks to the general system of pipes might otherwise be severe.

Let the taps be always one eighth of an inch larger in bore than the pipe supplying them; by which means any wire-drawing, or spreading of the water, will be obviated, and the full effect of the discharge of the pipe attained.

Place a fire-plug stand-pipe at every junction of one street with another, and at other points at intervals not exceeding 80 yards. Let the fire-plug boxes or stand pipes be placed close to the curb-stone, and not in either the roadway or footpath, and let the situation of each be indicated by a conspicuous mark.

Let the fronts of public edifices, as well as shop-fronts, and the fronts of houses, be kept clean by jets, at such convenient times as the ratepayers may desire.

For street-cleansing let the same hose and apparatus be used as for the prevention of fires; and let the different sets of apparatus provided, be stationed in different parts of the district, so that a set may always be near at hand in case of fire.

Keep the whole works, house services and waste-pipes, the smallest branches as well as the mains, under one and the same management, and that management a public and responsible one.

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(No. 3.)

## Special Maxims in the case of offensive Smells from Houses.

In case of offensive smells, proceeding from any premises, let the surveyor, on noticing it, or on his attention being called to it, proceed to enforce the byelaw thereon, until the smell is removed.

All smells whatsoever from soil-pans, house-drains, or main-drains, denote neglect or defective engineering arrangements requiring correction.

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* Gutta percha (which is a very slow conductor of heat) being used for pipes, water is little liable to freeze in them, and if it does they yield, and do not burst; neither are such pipes liable to injury from chemical action. They are, however, rather expensive, unless such as those of very small size, described at page 118, are employed.

(No. 4.)

## Byelaws for the Direction of Officers of Local Boards in the execution of New Works.

The following byelaws have been prepared in conformity with the principles herein-before expounded.

With a view to the utmost promotion of these important works of sanitary improvement, it is above all things desirable that every guarantee should be afforded to the public for the permanent efficiency and economy of the necessary works, and that every facility for their execution should be given by removing the pressure of immediate payment.

For the efficiency of the work, and the protection of the householder as well as the public, it should be required that the surveyor, either himself, or by a clerk of the works, shall inspect, without fee, every new house-drain before it is covered in, and see that it is in every respect conformable to the regulations of the Local Board, and the requirements of the Public Health Act. Every care should be taken to select superior workmen of good character, which precaution would remove much of the objection that is felt to the admission of strangers into houses.

Contracts (of which forms of specifications are hereunto annexed) should be obtained for the supply of all materials—drain and water pipes, water-closet basins, taps, sinks, syphons, and other matters, according to specifications ; and on application for the construction of house-drains, estimates should in each case be made of the cost of emptying and filling up cess-pools, putting in drains, laying on water, performing such other works as may be necessary, and making good whatever may be disturbed.

The total cost should, wherever practicable and desired, be distributed over a period of years, and payment obtained, as a private improvement rate, by a fixed annual charge of principal and interest, including the expense of the maintenance of the work, in order that the outlay may press equally and fairly upon all benefited. This annual charge, added to the amount of sewer-rate, would cover all repairs, alterations, or clearances of stoppages that might be necessary, and entirely protect the owner or tenant from any annoyance, cost, or liability from the drains during the period fixed, except from damage or obstruction wilfully or mischievously occasioned, for the reparation of which alone he would be called upon to pay.

By such means the best security would be afforded for the efficient and economical execution of the work, and for its ready adoption by the public.

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(No. 5.)

## Byelaws and Regulations recommended to be observed by the Surveyor in respect to the Preparation of Plans and the Superintendence of Works of House Drainage.

In the case of house-drainage to existing buildings, whether by order of the Local Board, or on the application of private parties, copies of the detail plan and levels of the whole block of buildings of which those in question form a part, should in every instance be supplied from the office ; and if not already obtained, the surveyor should forthwith furnish it.

He should then examine, plan in hand, the whole of the particulars of the property of which a knowledge is required, and report its capabilities for combined or separate drainage, its supply of water or facility for obtaining it, the state of the paving or other surface, the provision of dust-bins and other means of cleansing, adding the information necessary for a decision as to the interests affecting the property.

Being in possession of the complete plan of the particular block in each case, he should determine the plan of drainage most advisable, instead of working by piecemeal with limited information.

In determining the direction and arrangement of the drainage, the surveyor should pay the utmost attention to secure, as far as practicable, the shortest course, the greatest inclination, and the readiest combination of the branch-drains and traps.

Having decided on the most advisable arrangement, he should then compute the area of the surface to be drained, and determine by the table the graduated sizes of the drain. Every inlet to the drains of each house should be accurately marked, and the dimensions of the branches therefrom carefully fixed.

In the execution of the work in public places, the excavations should be securely protected when necessary, and properly lighted and watched.

Excavations of the exact form and depth for each line of drainage should be made and tested before any pipes are laid ; and if any irregularities occur in the foundation, they should be made sound and even with clay, clean gravel, or other approved material well rammed.

When the pipes have been laid, the sides should be carefully filled in, and well rammed to keep them in place before they are covered, and the work of filling in the trenches commenced. The levels and workmanship of the pipe-laying should then be tested before they are covered in. The best materials and workmanship only should be allowed : any imperfection in either must be immediately remedied. The directions of the surveyor as to qualities of materials and workmanship must be strictly attended to, and no other forms or description of materials and apparatus should be permitted without his previous inspection and approval.

No junctions or curves, other than those approved by the surveyor, should on any account be allowed.

No pipe should join another of larger size without one or more intermediate tapering lengths. All openings should be trapped,* and, where practicable, at or near their inlet. As a general rule the syphon should be of the same bore as the drain.

Where syphons are inserted, bell traps should be disallowed ; but where there are good bell-traps with covers securely fixed, syphons need not be added.

Whenever whole socket pipes are used with cement joints, they should be put together "dry," and the joints afterwards filled round with approved cement ; and the utmost care taken that no rubbish or obstruction of any kind be left in the drains.

Every inlet should be securely protected.

All old drains and cesspools, when done with, should at once be emptied and abolished, every care being taken that this work is performed in such a manner, and with such appliances, as to cause as little annoyance as possible.

Their site should be filled in with dry rubbish or earth, well rammed.

Every portion of the work before covering in should be inspected by the surveyor, who should add to the plan his certificate of the work having been so examined, and found to be of proper materials and workmanship, and to be correctly laid in every respect.

A book should be kept in which every application for a drain should be entered ; and another book in which all complaints should be entered.

No private work of drainage should be allowed to be put in connexion with the sewers without a previous examination and certificate by the

* Except rain-water pipes, the openings or heads of which may be so situated that no inconvenience would arise from any effluvium from them. In these cases traps should be omitted, as the pipes would serve as excellent ventilators of the drains.

surveyor, to the effect that it has been properly laid, that the adequate covers to the inlets have been fixed, and that no danger of stoppage or inconvenience is likely to arise from it.

The inclinations and sizes of the drains, and the depth beneath any fixed contiguous point, to which reference can be readily made, should be invariably recorded upon the plan: the name of the contractor or other party executing the work, with the date of its commencement and completion should be also noted thereon, and entered in an office register containing all the particulars of the work. A section of the work, exhibiting the nature of the ground which has been met with in the excavations, should be recorded at every fifty feet distance.

Whenever any new private drainage should not have been completed in every respect according to the rules laid down, or any old drains or cesspools shall not have been removed, the facts should be at once reported to the Local Board, and its directions asked thereon.

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### Byelaws as to the Surveyor's Duties as to Town Drainage.

Before the water-mains or the sewers are carried to their proper points at the backs of houses (or, where unavoidable, through the streets), the surveyor should make a house-to-house inquiry, and ascertain the state of the respective houses with relation to their water supply and conveniences for cleansing. He should do this by inspection as well as by inquiry of the occupiers, and should give them verbal explanations as to the nature and progress of the main works, and what their own houses require, and as to the contract prices for works executed out of private improvement rates. He should also, for his report to the Local Board, make entries of the works required for each house, and of works in preparation.

He should next advise with the owners of the worst-conditioned houses as to the works required, and ascertain whether they would prefer to have the works executed by the public contractor or by tradesmen of their own, to whom he should forward instructions as to the particulars of works required by the Local Board.

Having thus ascertained the requisite particulars and made his estimate, he should make his report to the Local Board, obtain their orders thereon, and endeavour to complete the notices and orders to occupiers for the required house works, so that the house-drains and water-services may, as far as possible, be completed with the mains when the trenches are yet open. The expenses of re-opening the trenches and making good the pavement may thus be saved.

A record should be kept at the surveyor's office of the course of house-drains, sufficient to furnish accurate information in the event of stoppages.

When the house-drains are laid down by a private tradesman, a certificate should be signed by him. It is very desirable that Local Boards should in all cases where works are done by private persons, require and preserve a certificate, to be signed by the tradesman that the work has been done by him.

The surveyor, or his officer, should also sign a certificate attesting the fact of a due examination of the work having been made, and that it is sufficient, and stating the time when it was examined.

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### Instruction to Surveyor as to combined Private Works for the Supply of Houses with Water, the Removal of Waste Water, and the general Abolition of Cesspools.

"The general object of the Public Health Act is to ensure that a constant supply of pure water shall be carried into every house, and that means shall be provided, by return-pipes and house-drains, for carrying away all waste foul water from thence, and for preventing damp.

Other main objects of the Act which it is the duty of the Local Board to execute, are, to ensure that no ordure shall remain in or near premises, to abolish all cesspools, and to prevent the saturation of the soil and foundations of dwellings with foul matter, so as to avoid the creation of noxious vapours to the injury of the health of the inmates of the houses, or the deterioration of the air of the town.

The Local Board have now provided the main public works to facilitate the accomplishment of these objects for the service of the inhabitants. A proper supply of water has been obtained, and will be brought in mains, laid in a convenient direction for all the premises in the street where your house is situated, for the delivery of a constant supply into your house, by a service pipe and proper tap. This supply will serve for all domestic purposes, and for the use of a water-closet in the place of the cesspool, which is directed to be filled up. The Local Board have also completed the main drains and public sewers, for the removal of all foul water and refuse discharged by waste-pipes, sinks, water-closets, and house-drains.

For the fulfilment of the objects of the Act, the Board, acting under it, have directed written notices* to be herewith sent on the report of their surveyor, directing you now to lay on a supply of water from the main, by a service pipe, and to put down a sink and a house drain, to fill up cesspools, and to provide a proper water-closet and dust-bin. When these requisites are provided, if they are provided at reasonable rates and the work is properly executed, they will be found conducive to the comfort, health, and respectability of the inmates, and they will be in reduction of the occupier's present charges. As the works prescribed will be additions to the premises, some addition of rent will be equitably due from the occupier for them. Should neither the owner nor the occupier be prepared to provide the required works, the Local Board will direct a proper and responsible contractor to execute them, at such time as will be the least inconvenient to the occupier ; and in this case immediate payment for the outlay will not be required, but the works will be paid for by an improvement rate, distributed over a term of years, unless the owner should prefer paying the expense at once.

The cost of the work to be executed on your premises, if repaid by annual instalments of principal and interest, will not exceed a charge of            per week, or            quarterly.†

Owners or occupiers may get these works done themselves, on giving due notice, provided they are done to the satisfaction of the surveyor.

If a service-pipe, tap, sink, and return-pipe be fixed in each floor, the same expense will, of course, be incurred in each case.

The drains must be impermeable, and of the specified size and inclination ; the water-closet apparatus and arrangements must be such as will detain and accumulate no deposit. The water-pipes must be of the specified diameter, and of sufficient strength, and the water taps or valves must be such as will not be liable to waste. Beyond such points as these, which must be attended to for the protection of the general service of the town, owners and occupiers may choose such descriptions of apparatus and sinks as they please. The Board have entered into contracts for the execution of such works, in order to protect the ratepayers from exorbitant charges for irregular and defective works.

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* These notices may be issued to any premises in the district as the works proceed, as soon as a public sewer has been brought to within 100 feet of such premises, without waiting until the whole of the public works have been carried out. Much time and trouble may thus often be saved in the execution of the private works.

† The charge for the public works and water supply and drainage will be in addition, and the whole expense will be less than the ordinary cost for mere cleansing.

The surveyor is required to consult the convenience and the wishes of the occupiers as much as he can, and to give them full information.

The water mains and the main drains have been directed to be brought up to the back premises, wherever possible, and as near as practicable to the sink and water-closet, to prevent annoyance, and three or four fold expense of breaking up the floors of the house to carry the service-pipe and the drains to mains laid in the centre of the streets. Though this may require the occasional admittance of the surveyor or other responsible person to the back premises (at reasonable times) to remove stoppages or make repairs, the occupiers will be saved the necessity of admitting workmen to take up their floors, while they altogether escape danger and annoyance from the passage of offensive and noxious matter through the house itself.

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FORMS of NOTICES for PRIVATE IMPROVEMENT WORKS for WATER SUPPLY; the ABOLITION of CESSPOOLS, and for HOUSE DRAINAGE and CLEANSING.

(NOTICE to construct DRAIN.)

*Local Board of Health for the District of* ________________

To[1] the[2] of the house situated at[3]

Whereas our surveyor, hath by his report bearing date the day of , made it appear to us that the house situated at[4] within our district, of which you are the[2] is without any drain,[5] and that a sewer[6] is within one hundred feet of some part of such house:

And whereas by the said report it appears to us that[7] covered drain of[8] and at a level of[8] and with a fall of[8] is[9] necessary:

We do hereby require you, within the space of from the date hereof, to construct and lay down such covered drain[10] in connexion with such house, and[11] of the materials and size, at the level, and with the fall.

And if this notice be not complied with, we shall do the works referred to herein, and recover the expenses from the owner of the said house in a summary manner; or declare the same to be Private Improvement Expenses, as set forth in the Notification hereunto annexed.

Given this day of 185 .

[1] Insert, if known, name of owner or of occupier.
[2] Insert whether owner or occupier.
[3] Insert name of surveyor.
[4] Describe situation of the house.
[5] Or, without such a drain or drains communicating with the sea, or a sewer, as is or are sufficient for the proper and effectual drainage of the same and its appurtenances.
[6] Belonging to us, or which we are entitled to use, or the sea.
[7] State one or more, as the case may require.
[8] Insert the materials to be used, the size, the level, and the fall.
[9] Or, are.
[10] Or, drains.
[11] Here insert the means of drainage according to note 5, that is, our sewer, or the sewer which we are entitled to use, or the sea.

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[In a non-corporate district, this notice must be under the seal of the Local Board, and the hands of five of its members; in a corporate district, under the common seal only.]

(NOTICE of LOCAL BOARD to OCCUPIER when WATER can be supplied at a rate not exceeding 2*d.* a week.)

*Local Board of Health for the District of*______________

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To occupier of a house, situate at within the district of the Local Board of Health.

Whereas surveyor to the Local Board for the district of has reported to the said Board that the house of which you are the occupier is without a proper supply of water, and that such a supply of water can be furnished thereto at a rate not exceeding twopence a week :

The said Local Board do hereby require you, within the space of from the date hereof, to obtain a proper supply of water for the said house, and to do all such works as may be necessary for that purpose (as described in the Notification hereunto annexed) ; and in your default the said Local Board will do such works and levy water rates upon your premises, not exceeding in the whole the rate of twopence per week, and the expenses of such works will be private improvement expenses, and be recoverable as such in the manner provided in the said Act.

Given this day of 185 .

[In a non-corporate district, this notice must be under the seal of the Local Board, and the hands of five of its members ; in a corporate district, under the common seal only.]

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The following forms are those in use when Improvement Rates are to be levied by the Local Board of St. Thomas, Exeter :—

ST. THOMAS, NEAR EXETER.

July 1852.

SIR,

I am instructed by the Local Board of Health to serve on you the accompanying notice , and at the same time to acquaint you that the Board are desirous of rendering you every assistance in carrying out the requirements of the Public Health Act in the most effectual manner, and at the least possible cost.

On application at the offices of Messrs. Robert Dymond and Sons, surveyors, No. 10, Bedford-circus, Exeter, a plan, showing the details of the proposed works in connexion with your premises, will be exhibited to you, and every information as to their cost, &c. will be readily afforded.

The great attention that has of late been paid to the subject of sewerage works in the Metropolis and elsewhere has shown that no system of drainage is so cheap or effectual as that by means of glazed stoneware pipes. The Local Board having resolved on the adoption of this system have contracted with manufacturers for the supply of a large quantity of pipes, junctions, closet pans, sinks, &c. of the best quality and forms. They are consequently enabled to supply such as may be required in your case at the wholesale price.

Two methods of complying with the requirements of the notice are open to your choice, namely, by having the works carried out to the satisfaction of the surveyor of the Board, by parties employed by yourself, or the Board will undertake the works at an economical rate through their contractor, and under the superintendence of their surveyor, levying the expense as a private improvement rate, of such amount as will be sufficient to discharge such expense, together with interest thereon at 5*l.* per cent., in such period not exceeding thirty years, as the Board may determine.

You will therefore be pleased to fill up, sign, and return to me one of the enclosed forms, stating which of these methods you prefer.

I am, Sir,
Your obedient servant,
W. M. Benison, *Clerk.*

---

St. Thomas.

185 .

Sir,

I beg to acknowledge the receipt of your notice, dated 185 , and to inform you, that I am willing to undertake the construction of the required works to the satisfaction of the surveyor of the Local Board, by parties employed by myself.

I am, Sir,
Your obedient servant,

*To Mr. W. M. Benison,*
*Clerk to the St. Thomas Local Board of Health.*

---

St. Thomas.

185 .

Sir,

I beg to acknowledge the receipt of your notice, dated 185 , and to inform you, that I am desirous that the Local Board should undertake the construction of the required works, levying the expense of the same in the manner directed by the Public Health Act, 1848.

I am, Sir,
Your obedient servant,

*Mr. W. M. Benison,*
*Clerk to the St. Thomas Local Board of Health.*

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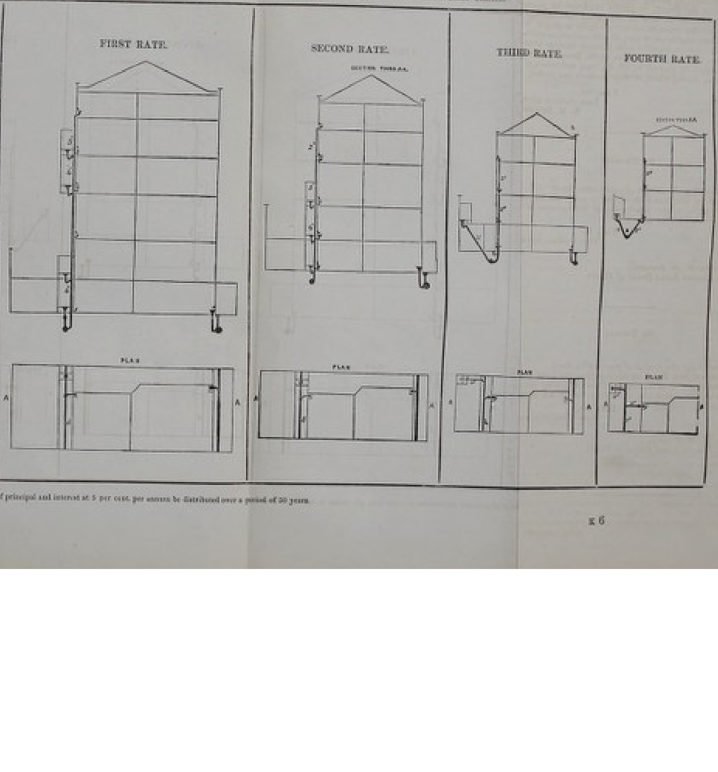
(No. 6.)

TABULAR VIEW of the QUANTITIES of MATERIALS and AVERAGE COST of improved Works for the Supply of Water (on the Constant System), for Water-closets, Sinks, and House-drains; for Habitations of the several under-mentioned Chief Classes.

| Description of Materials. | Unit of Measurement. | Rate of Cost. | 1st-rate House. Sinks and water on one floor and water-closets on two floors. | | | 2d-rate House. Sinks and water on one floor and water-closets on two floors. | | | 3d-rate House. Sinks and water on one floor and water-closet in yard at back. | | | 4th-rate House. Sink and water on one floor and water-closet in yard at back. | | | Labourer's Cottage. Sink and water in back room and water-closet in yard at back. | | | Average cost of drainage and water supply per floor additional. | Proportion of cost of sewer and water sub-mains on frontage of Houses. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Cost. | Gross. | Per Week. | Per ann. |
| DRAINAGE.— | | s. d. | | £ s. d. | | | £ s. d. | | | £ s. d. | | | £ s. d. | | | £ s. d. | | £ s. d. | £ s. d. | d. | s. d. |
| Drains, stoneware, 4 inch | Feet | 0 7 | 34 | 0 19 10 | | 30 | 0 17 6 | | 14 | 0 8 2 | | 6 | 0 3 6 | | 6 | 0 3 6 | | | | | |
| — — 3 — | — | 0 5 | 12 | 0 5 0 | | 8 | 0 3 4 | | 8 | 0 3 4 | | 7 | 0 2 11 | | 7 | 0 2 11 | | | | | |
| — — 2 — | — | 0 4 | 8 | 0 2 8 | | 5 | 0 1 8 | | 5 | 0 1 8 | | 4 | 0 1 4 | | 4 | 0 1 4 | | | | | |
| Water-closet pans complete, superior | No. | 25 0 | 1 | 1 5 0 | | 1 | 1 5 0 | | 1 | 1 5 0 | | | | | | | | | | | |
| — — common | — | 12 0 | 1 | 0 12 0 | | 1 | 0 12 0 | | - - | - - | | 1 | 0 12 0 | | 1 | 0 12 0 | | | | | |
| Sinks in houses | — | 10 0 | 2 | 1 0 0 | | 2 | 1 0 0 | | 2 | 1 0 0 | | 1 | 0 10 0 | | 1 | 0 10 0 | | | | | |
| — yards | — | 2 3 | 2 | 0 4 6 | | 2 | 0 4 6 | | 2 | 0 4 6 | | 1 | 0 2 3 | | 1 | 0 2 3 | | | | | |
| Syphons for sinks, 2 inch | — | 1 3 | 4 | 0 5 0 | | 4 | 0 5 0 | | 4 | 0 5 0 | | 2 | 0 2 6 | | 2 | 0 2 6 | | | | | |
| Holdfasts to pipes | — | 0 4 | 12 | 0 4 0 | | 10 | 0 3 4 | | 1 | 0 0 4 | | 2 | 0 0 8 | | 2 | 0 0 8 | | | | | |
| Digging, &c. | Yds. cube. | 1 0 | - - | - - | | - - | - - | | - - | - - | | 10½ | 0 10 6 | | 10½ | 0 10 6 | | | | | |
| Paving and flooring made good | Ft. super. | 0 2 | - - | - - | | - - | - - | | - - | - - | | 78 | 0 13 0 | | 78 | 0 13 0 | | | | | |
| 1st-rate House | - - | - - | - - | 4 18 0 | d. 1½ | - - | - - | | - - | - - | | - - | - - | | - - | - - | | 1 17 3½ | 6 1 6 | 1½ | 6 6 |
| 2d — | - - | - - | - - | - - | | - - | 4 12 4 | d. 1½ | - - | - - | | - - | - - | | - - | - - | | 1 9 4 | 4 19 0 | 1¼ | 4 4 |
| 3d — | - - | - - | - - | - - | | - - | - - | | - - | 3 8 0 | d. 1 | - - | - - | | - - | - - | | 0 16 8 | 2 14 0 | 0¾ | 3 0 |
| 4th — | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | 2 18 8 | d. 0⅞ | - - | - - | | 0 16 6 | 0 17 6 | 0¼ | 1 2 |
| Labourer's Cottage | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | - - | | - - | 2 18 8 | d. 0⅞ | - - | 0 17 6 | 0¼ | 1 2 |
| WATER SUPPLY:— | | | | | | | | | | | | | | | | | | | | | |
| Services, lead, ½ inch | Feet | 0 5 | 70 | 2 0 10 | | 35 | 0 14 7 | | | | | | | | | | | | | | |
| — — ⅜ — | — | 0 5 | 6 | 0 2 6 | | 36 | 0 15 0 | | 36 | 1 3 4 | | 16 | 0 6 8 | | 16 | 0 6 8 | | | | | |
| Cock, superior, ½ — | No. | 4 0 | 1 | 0 4 0 | | 1 | 0 6 0 | | | | | | | | | | | | | | |
| — common ½ — | — | 3 6 | 1 | 0 3 6 | | 1 | 0 3 6 | | | | | | | | | | | | | | |
| — — ⅜ — | — | 3 0 | 2 | 0 6 0 | | 2 | 0 6 0 | | 5 | 0 9 0 | | 2 | 0 6 0 | | 2 | 0 6 0 | | | | | |
| Solder-joints ½ — | — | 1 4 | 9 | 0 12 0 | | 6 | 0 8 0 | | | | | | | | | | | | | | |
| — ⅜ — | — | 1 0 | 1 | 0 1 0 | | 1 | 0 1 0 | | 10 | 0 10 0 | | 4 | 0 4 0 | | 4 | 0 4 0 | | | | | |
| Putty-joints | — | 0 6 | 2 | 0 1 0 | | 2 | 0 0 6 | | 1 | 0 0 6 | | 1 | 0 0 6 | | 1 | 0 0 6 | | | | | |
| Wall-hooks | — | 0 1 | 4 | 0 0 4 | | 5 | 0 0 5 | | 3 | 0 0 3 | | 3 | 0 0 3 | | 3 | 0 0 3 | | | | | |
| 1st-rate House | - - | - - | - - | 3 13 2 | d. 1½ | - - | - - | | - - | - - | | - - | - - | | - - | - - | | 0 19 8 | 1 11 6 | 0⅝ | 1 2 |
| 2d — | - - | - - | - - | - - | | - - | 2 16 6 | d. 0⅞ | - - | - - | | - - | - - | | - - | - - | | 0 16 7 | 1 2 0 | 0⅜ | 1 0 |
| 3d — | - - | - - | - - | - - | | - - | - - | | - - | 2 3 3 | d. 0⅝ | - - | - - | | - - | - - | | 0 9 0 | 0 12 0 | 0⅜ | 0 10 |
| 4th — | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | 0 17 5 | d. 0⅜ | - - | - - | | 0 9 3 | 0 10 0 | 0⅜ | 0 8 |
| Labourer's Cottage | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | - - | | - - | 0 17 5 | d. 0⅜ | - - | 0 10 0 | 0⅜ | 0 8 |
| DRAINAGE & WATER SUPPLY. TOTAL:— | | | | | | | | | | | | | | | | | | | | | |
| 1st-rate House | - - | - - | - - | 8 11 2 | d. 2⅝ | - - | - - | | - - | - - | | - - | - - | | - - | - - | | 2 16 11½ | 7 13 0 | 2½ | 5 8 |
| 2d — | - - | - - | - - | - - | | - - | 7 10 10 | d. 2¼ | - - | - - | | - - | - - | | - - | - - | | 2 5 11 | 6 1 0 | 1¾ | 5 6 |
| 3d — | - - | - - | - - | - - | | - - | - - | | - - | 5 11 3 | d. 1⅝ | - - | - - | | - - | - - | | 1 5 8 | 3 6 0 | 1 | 3 10 |
| 4th — | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | 3 16 1 | d. 1¼ | - - | - - | | 1 5 9 | 1 7 6 | 0½ | 1 10 |
| Labourer's Cottage | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | - - | | - - | 3 16 1 | d. 1¼ | - - | 1 7 6 | 0½ | 1 10 |




The figures indicating the rate per week show the payment per week by each class of house, supposing the repayment of principal and interest at 5 per cent. per annum be distributed over a period of 30 years.

(No. 7.)

TABLE showing the QUANTITIES and the AVERAGE COST of OLD WORKS in BRICK HOUSE DRAINS of DEPOSIT, &c.

(No. 7.)

TABLE showing the QUANTITIES and the AVERAGE COST of OLD WORKS in BRICK HOUSE DRAINS of DEPOSIT, &c.

| Description of Materials, &c. | Unit of Measurement. | Rate of Cost. | 1st-rate House. Sinks and water on one floor and water-closets on two floors. | | | 2d-rate House. Sinks and water and water-closets on two floors. | | | 3d-rate House. Sinks and water on one floor and water-closet in yard at back. | | | 4th-rate House and Labourer's Cottage. Sink and water on one floor and water-closet in yard at back. | | | Proportion of cost of sewer and water-mains on frontage of Houses. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Quantities. | Cost. | Per Week. | Gross. | Per Week. | Per ft. run. |
| DRAINAGE:— | | £ s. d. | | £ s. d. | | | £ s. d. | | | £ s. d. | | | | | £ s. d. | | s. d. |
| Sewers 5×3 and 5×2, 6 upright sides | Feet | - - | 27 | - - | | 22 | - - | | 18 | - - | | 15 | | | | | |
| " bricks in | No. | - - | 7,128 | - - | | 5,808 | - - | | 4,330 | - - | | 3,608 | | | | | |
| " digging to | Yds. cube | - - | 96 | - - | | 73½ | - - | | 58⅔ | - - | | 30⅔ | | | | | |
| Drains, of brick, 12 inch | Feet | 0 3 0 | 105 | 15 15 0 | | | | | | | | | | | | | |
| " " 9 " | " | 0 1 4 | 4 | 0 5 4 | | 70 | 4 13 4 | | 80 | 5 6 8 | | 43 | 2 17 4 | | | | |
| " bricks in | No. | - - | 6,162 | - - | | 630 | - - | | 720 | - - | | 387 | | | | | |
| " digging to | Yds. cube | 0 1 0 | 48½ | 2 8 6 | | 31½ | 1 11 1¾ | | 44½ | 2 4 6 | | 28⅔ | 1 8 8 | | | | |
| " paving and flooring made good | Ft. super. | 0 0 2 | 327 | 2 14 6 | | 210 | 1 15 0 | | 240 | 2 0 0 | | 129 | 1 1 6 | | | | |
| Water-closets, complete, superior | No. | 5 0 0 | 1 | 5 0 0 | | 1 | 5 0 0 | | | | | | | | | | |
| " " medium | " | 3 10 0 | - - | - - | | - - | - - | | 1 | 3 10 0 | | | | | | | |
| " " common | " | 1 10 0 | 1 | 1 10 0 | | 1 | 1 10 0 | | - - | - - | | 1 | 1 10 0 | | | | |
| " lead soil-pipe to, 4½ inch | Feet | 0 3 6 | 14 | 2 9 0 | | 14 | 2 9 0 | | 2 | 0 7 0 | | 2 | 0 7 0 | | | | |
| Sinks in houses | No. | 1 10 0<br>1 0 0 | 2 | 3 0 0 | | 3 | 4 10 0 | | 2 | 2 0 0 | | 1 | 1 0 0 | | | | |
| " in yards and areas | " | 0 6 0 | 2 | 0 12 0 | | 2 | 0 12 0 | | 2 | 0 12 0 | | 1 | 0 6 0 | | | | |
| " lead pipe to, 2½ inch | Feet | 0 1 9 | 7 | 0 12 3 | | 13 | 1 2 9 | | 12 | 1 1 0 | | | | | | | |
| " " 2 " | " | 0 1 3 | - - | - - | | - - | - - | | - - | - - | | 6 | 0 7 6 | | | | |
| Bell-traps, brass | No. | 0 6 6<br>0 4 6<br>0 3 0 | 2 | 0 13 0 | | 3 | 0 19 6 | | 2 | 0 9 0 | | 1 | 0 3 0 | | | | |
| " iron | " | 0 3 0<br>0 2 6<br>0 2 0 | 2 | 0 6 0 | d. | 2 | 0 6 0 | | 2 | 0 5 0 | | 1 | 0 2 0 | | | d. | |
| 1st-rate House | - - | - - | - - | 35 5 7 | 10⅝ | - - | - - | d. | - - | - - | | - - | - - | | 15 3 9 | 4 9/16 | 11 3 |
| 2d " | - - | - - | - - | - - | | - - | 24 8 8¼ | 7¼ | - - | - - | d. | - - | - - | | 12 7 6 | 3¾ | 11 3 |
| 3d " | - - | - - | - - | - - | | - - | - - | | - - | 17 15 2 | 5¼ | - - | - - | d. | 8 11 0 | 2 9/16 | 9 6 |
| 4th " and Labourer's Cottage | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | 9 3 0 | 2¾ | 7 2 6 | 2⅛ | 9 6 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WATER SUPPLY:— | | | | | | | | | | | | | | | | | |
| Mains, 5 inch | Feet | - - | 27 | - - | | 22 | | | | | | | | | | | |
| „ 4 „ | „ | - - | - - | - - | | - - | - - | | 18 | | | | | | | | |
| „ 3 „ | „ | - - | - - | - - | | - - | - - | | - - | - - | | 15 | | | | | |
| Cisterns, kitchen | No. | 15 0 0<br>12 0 0<br>8 0 0 | 1 | 15 0 0 | | 1 | 12 0 0 | | 1 | 8 0 0 | | 1 | 3 0 0 | | | | |
| „ closet | „ | 6 0 0<br>5 0 0<br>4 0 0<br>3 0 0 | 1 | 6 0 0 | | 1 | 5 0 0 | | 1 | 4 0 0 | | | | | | | |
| Services, wastes, &c. 1¼ inch | Feet | 0 1 2 | 10 | 0 11 8 | | | | | | | | | | | | | |
| „ „ 1 „ | „ | 0 0 11 | 145 | 6 12 11 | | 23 | 1 1 1 | | 15 | 0 13 9 | | 6 | 0 5 6 | | | | |
| „ „ ¾ „ | „ | 0 0 7 | 82 | 2 7 10 | | 183 | 5 6 9 | | 140 | 4 1 8 | | 64 | 1 17 4 | | | | |
| Cocks and balls 1 „ | No. | 0 12 6 | 1 | 0 12 6 | | | | | | | | | | | | | |
| „ „ ¾ „ | „ | 0 9 0 | 1 | 0 9 0 | | 2 | 0 18 0 | | 2 | 0 18 0 | | 1 | 0 9 0 | | | | |
| „ bib ¾ „ | „ | 0 3 6 | 2 | 0 7 0 | | 3 | 0 10 6 | | 2 | 0 7 0 | | 2 | 0 7 0 | | | | |
| Ferrules 1 „ | „ | 0 2 0 | 1 | 0 2 0 | | | | | | | | | | | | | |
| „ ¾ „ | „ | 0 1 3 | - - | - - | | 1 | 0 1 3 | | 1 | 0 1 3 | | 1 | 0 1 3 | | | | |
| Washers and wastes, 1¼ „ | „ | 0 3 6 | 1 | 0 3 6 | | | | | | | | | | | | | |
| „ „ 1 „ | „ | 0 2 0 | 1 | 0 2 0 | | 2 | 0 4 0 | | 2 | 0 4 0 | | 1 | 0 2 0 | | | | |
| Solder-joints 1¼ „ | „ | 0 3 0 | 2 | 0 6 0 | | | | | | | | | | | | | |
| „ 1 „ | „ | 0 2 0 | 15 | 1 10 0 | | 4 | 0 8 0 | | 4 | 0 8 0 | | 2 | 0 4 0 | | | | |
| „ ¾ „ | „ | 0 1 4 | 13 | 0 17 4 | *d.* | 29 | 1 18 8 | | 19 | 1 5 4 | | 11 | 0 14 8 | | | *d.* | |
| 1st-rate House | - - | - - | - - | 35 1 9 | 10½ | - - | - - | *d.* | - - | - - | | - - | - - | | 2 0 6 | ⅝ | 1 6 |
| 2d „ | - - | - - | - - | - - | | - - | 27 8 3 | 8¼ | - - | - - | *d.* | - - | - - | | 1 13 0 | ½ | 1 6 |
| 3d „ | - - | - - | - - | - - | | - - | - - | | - - | 19 19 0 | 6 | - - | - - | *d.* | 1 2 6 | $\frac{5}{16}$ | 1 3 |
| 4th „ and Labourer's Cottage | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | 7 0 9 | 2⅛ | 0 15 0 | ¼ | 1 0 |
| DRAINAGE AND WATER SUPPLY. TOTAL. | | | | | *s. d.* | | | | | | | | | | | *d.* | |
| 1st-rate House | - - | - - | - - | 70 7 4 | 1 9⅛ | - - | - - | *s. d.* | - - | - - | | - - | - - | | 17 4 3 | $5\frac{3}{16}$ | 12 9 |
| 2d „ | - - | - - | - - | - - | | - - | 51 16 11¼ | 1 3½ | - - | - - | *d.* | - - | - - | | 14 0 6 | 4¼ | 12 9 |
| 3d „ | - - | - - | - - | - - | | - - | - - | | - - | 37 14 2 | 11¼ | - - | - - | *d.* | 9 13 6 | 2⅞ | 10 9 |
| 4th „ and Labourer's Cottage | - - | - - | - - | - - | | - - | - - | | - - | - - | | - - | 16 3 9 | 4⅞ | 7 17 6 | 2⅜ | 10 6 |

(No. 8.)

## Tables showing the actual Cost of Private Works for the Water Supply and Drainage of Cottages in Rugby, Croydon, Barnard Castle, and Tottenham.

### I.—Table showing the actual Cost of Private Works for the Water Supply and Drainage of Six Cottages in Little Pennington-street, Rugby, the Property of James Atty, Esq., laid on from the Water Mains and to the Drainage Pipes of the Local Board of Health.

*Work executed in January* 1852.

| | £ | s. | d. | | Per Cottage. £ | s. | d. |
|---|---|---|---|---|---|---|---|
| *Water Supply—* | | | | | | | |
| 95 lineal feet of 1-in. and ¾-in. iron pipe, with bends, &c. - - - - - | 1 | 15 | 5½ | - | 0 | 5 | 11 |
| 75 lineal feet of ¾-in., ½-in., and ⅜-in. block-tin pipe - - - - | 1 | 8 | 9 | - | 0 | 4 | 9½ |
| One 1-inch iron stop-cock on main-branch - | 0 | 5 | 0 | - | 0 | 0 | 10 |
| Seven brass bib-cocks, 4 of ⅜-inch, and 3 of ½-inch diameter - - - - | 1 | 10 | 0 | - | 0 | 5 | 0 |
| Three water-closet pans, with traps, valves, and fans - - - - | 2 | 14 | 0 | - | 0 | 9 | 0 |
| Laying iron pipes, and making good surface of ground; fixing tin pipes and bib-cocks, and forming connexions with water-closet pans - | 2 | 4 | 4 | - | 0 | 7 | 4⅚ |
| Total for water supply - - | 9 | 17 | 6½ | | | | |
| or per house - - - - - | - | | - | | 1 | 12 | 11 |
| *Drainage—* | | | | | | | |
| Sixty-three straight stoneware pipes (each 2 ft. long), 5, 4, and 3 inches diameter - - | 1 | 18 | 0 | - | 0 | 6 | 4 |
| Twenty-seven curved and junction pipes and syphon-traps, of 4 and 3 inches diameter - | 2 | 3 | 1 | - | 0 | 7 | 2⅙ |
| 113 lineal feet, laying pipes at an average depth of 5 ft., and making good surface - | 2 | 0 | 0 | - | 0 | 6 | 8 |
| 41 lineal feet, laying pipes at an average depth of 4 ft., and making good surface - - | 0 | 11 | 11½ | - | 0 | 2 | 0 |
| Emptying 3 old cesspools - - - | 0 | 9 | 0 | - | 0 | 1 | 6 |
| Bricklayer, setting 3 water-closet pans, making good walls adjoining old cesspools, and setting iron gratings in yards - - - | 1 | 8 | 6 | - | 0 | 4 | 9 |
| Three new iron gratings for yards - - | 0 | 6 | 0 | - | 0 | 1 | 0 |
| Total for drainage - - | 8 | 16 | 6½ | | | | |
| or per house - - - | - | | - | | 1 | 9 | 5⅙ |
| Total cost of both classes of private works - | 18 | 14 | 1 | - | 3 | 2 | 4⅙ |

[Each cottage has a separate water-tap carried within doors; there are 3 water-closets to the 6 cottages.*]

The cost of the public works of water supply and drainage will be defrayed by a special district rate of 10*d.* in the pound upon the rateable value of the house property in the town of Rugby.

* This is deemed an objectionable arrangement for new cottages; the extra expense of a water-closet for each would have been about 15*s.* per cottage, involving an extra annual charge, calculated as above, of 10¼*d.* per cottage.

The present water rate charged by the Local Board is 4*d.* in the pound.

Deducting one fifth from the actual rental, the gross rateable value of the six cottages in question will amount to 33*l.* 4*s.*

The total account for public and private works of water supply and drainage will therefore stand thus:—

| | £ | s. | d. | | Per Cottage. £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Special district rate for public works of water supply and drainage, at 10*d.* in the pound | 1 | 7 | 8 | - | 0 | 4 | 7 |
| Water rate, at 4*d.* in the pound | 0 | 11 | 0¾ | - | 0 | 1 | 10⅛ |
| Private improvement rate, at 7¾*d.* in the pound | 1 | 1 | 5 | - | 0 | 3 | 7 |
| Giving a total annual charge for the 6 cottages of | 3 | 0 | 1¾ | - | 0 | 10 | 0⅛ |

or a weekly charge per cottage of 2⅓*d.*

14th June 1852. T. W. Rammell.

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II.—Table showing the actual Cost of Private Works for the Water Supply and Drainage of *One* Cottage, being the average of Ten Cottages numbered 48 to 51, and 56 to 61, Old Town Croydon,* laid on from the Water Main and to the Sewers of the Local Board of Health.

*Memorandum.*—No private improvement rates have been mortgaged by the Croydon Board, but the following actual cost of carrying supplies of water into cottage tenements, and of carrying away the waste and soil-water has been ascertained. The works having been done by private contract for immediate payment.

*The Works were executed in March* 1852.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| *Water Supply—* | | | | | | |
| Drilling and tapping main, and providing and fixing stop-cock, &c. | 0 | 4 | 0 | | | |
| Providing and fixing 28 feet of ½-inch iron service pipe, bends, &c. | 0 | 14 | 0 | | | |
| Providing and fixing one bib-cock | 0 | 3 | 6 | | | |
| Providing and fixing one gool-cock, with plumber's time, making the connexion to water-closet | 0 | 7 | 6 | | | |
| Providing and fixing stoneware water-closet pan and syphon-trap, set in brickwork | 0 | 11 | 0 | | | |
| | | | | 2 | 0 | 0 |
| *Drainage—* | | | | | | |
| Junction with sewer | 0 | 2 | 3 | | | |
| Providing and laying 22 feet of 4-inch drain-pipe, at 10*d.* | 0 | 18 | 4 | | | |
| Providing and fixing small kitchen sink of about 3 feet super., with brass grating and iron pipe to drain | 0 | 10 | 0 | | | |
| Providing and fixing one syphon-trap, and making connexion to sink | 0 | 3 | 0 | | | |
| Providing and fixing one syphon-trap, and 12-inch iron grating to yard sink, with small gully-hole | 0 | 4 | 6 | | | |
| Emptying and filling small cesspool or privy-pit | 0 | 15 | 0 | | | |
| Taking up and refixing water-closet seat and floor | 0 | 5 | 0 | | | |
| | | | | 2 | 18 | 1 |
| Total cost | | | | 4 | 18 | 1 |

* In this situation the Board have a branch sewer and water-pipe at the back of the houses at about 23 feet from them.

The outlay for the public works of water supply and drainage has made a special district rate of 1*s.* in the pound upon the rateable value necessary, for the first two years.

The water rate charged by the Board on cottages not exceeding 5*l.* 10*s.* on the rateable value is 1*d.* per week.

The rateable value of the above cottage is about 4*l.*, for I find that 19 cottages are rated at 74*l.* 10*s.*

The total cost per cottage will therefore stand thus :—

| | £ | *s.* | *d.* |
|---|---|---|---|
| Special district rate for public works of water supply and drainage, at 1*s.* in the pound - - - - - | 0 | 4 | 0 |
| Water rate, at 1*d.* per week - - - - - | 0 | 4 | 4 |
| The present outlay of 4*l.* 18*s.* 1*d.* would require an equal annual payment of 4*s.* 8¼*d.* to pay off principal, and at 5 per cent., interest, in 22 years - - - - - - | 0 | 4 | 8¼ |
| Giving a total annual charge of - - - - | 0 | 13 | 0 |

or 3*d.* per week per cottage.

Croydon, 24th June 1852. THOMAS COX, *Surveyor.*

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III.—TABLE showing the actual COST of PRIVATE WORKS for the Water Supply and Drainage of Eleven Cottages in Baliol-street, BARNARD CASTLE, laid from the Water Mains and to the Drainage Pipes of the Local Board of Health.

*Work executed in* 1852.

| | £ | *s.* | *d.* |
|---|---|---|---|
| *Water Supply—* | | | |
| 120 lineal feet of 1½-inch iron pipe, with bends, &c., including laying, fixing, stop-cocks, &c. - - - - - | 5 | 0 | 0 |
| House service lead pipe, ½-inch, and ⅜, the half inch, water-closet supplied, and then ⅜ for supply of house-bib, and turning privies into water-closets, inclusive of pans, taps, valves, stop-cocks, bibs, and other fittings, and fixing - | 16 | 0 | 0 |
| Total for water supply - - - | 21 | 0 | 0 |
| or per house - - - - | 1 | 18 | 2½ |
| *Drainage—* | | | |
| Straight stoneware pipes (each 2 ft. 6 in. long), and 6 inches diameter, including curved and junction pipes - - | 3 | 17 | 0 |
| 120 lineal feet, laying 6-inch pipes at an average depth of 4½ feet, and making good surface - - - - - | 1 | 8 | 5 |
| 216 lineal feet, laying 4-inch pipes at an average depth of 4½ feet, including cement and making good surface, and finding 4-inch pipes with junctions - - - | 6 | 18 | 0 |
| 11 syphon-traps for yard sinks and fixing - - - | 2 | 4 | 0 |
| New iron gratings for yards and stone covers for sinks - | 1 | 2 | 0 |
| Total for drainage - - - | 15 | 9 | 5 |
| Or per house - - - - - | 1 | 8 | 1 |
| Total cost of both classes of private works - - | 36 | 9 | 5 |

[Each cottage has a separate water-tap carried within doors ; there are water-closets erected or erecting for all the cottages.]

The cost of the public works of water supply and drainage will be defrayed by a special district rate of 1*s*. 6*d*. in the pound upon the rateable value of the house property, in the parts over which the works extend in the district.

The present water rate charged by the Local Board is 1*d*. in the pound; deducting nearly one third from the actual rental, after the usual deductions are made, the gross rateable value of the 11 cottages in question will amount to 34*l*. 2*s*., according to the poor rate assessment.

The total account for public and private works of water supply and drainage will therefore stand thus :—

| | £ | s. | d. |
|---|---|---|---|
| Special district rate for public works of water supply and drainage, at 1*s*. 6*d*. in the pound - - - | 2 | 18 | $1\frac{3}{4}$ |
| Water rate, at 1*d*. in the pound - - - - | 0 | 2 | 10 |
| Private improvement rate - - - - - - | 2 | 17 | $6\frac{1}{4}$ |
| Giving a total annual charge for the cottages of - - | 5 | 8 | 6 |
| Annual charge per cottage - - - - - - | 0 | 9 | $10\frac{1}{2}$ |

or a weekly charge per cottage of about $2\frac{1}{4}$*d*.

Charges actually incurred for laying water into 7 cottages in King-street, which cottages are known by the name of Heckler's-row, and belong to Thomas Deighton and others.

| | £ | s. | d. |
|---|---|---|---|
| 90 ft. 6 in. of $\frac{1}{2}$-inch lead pipe - - - - | 2 | 5 | 3 |
| 34 feet of $\frac{3}{8}$-lead pipe - - - - - - | 0 | 14 | 3 |
| Seven $\frac{3}{8}$-inch Lambert's taps - - - - - | 1 | 1 | 0 |
| One $\frac{1}{2}$-inch stop-tap - - - - - - | 0 | 4 | 6 |
| Wall-hooks - - - - - - - - | 0 | 2 | 0 |
| 18 plumbers joints - - - - - | 0 | 9 | 0 |
| Masonry - - - - - - - - | 0 | 4 | 0 |
| Smith's work, ferrule and insertion - - - | 0 | 1 | 6 |
| | 5 | 1 | 6 |

Or per cottage, 14*s*. 6*d*.

This includes all excavation and masonry; a half-inch lead pipe passes through the back pantry of each house, from which a $\frac{3}{8}$ service pipe was taken. Both the $\frac{1}{2}$-inch lead pipe and the $\frac{3}{8}$ was laid as private work, and are included in the above.

The cottages let for about 4*l*. 10*s*. each.

They are rated in the rate book at 2*l*. 1*s*. each; water-closets remain yet to do and drainage.

Charges for Private Works in Barnard Castle District.

*Drainage.*

Excavating for and laying drainage pipes, &c., junctions with appendages, including joint-holes, filling, and restoration of surface to its original state, whether flagged, paved, or macadamized, and every other work relating thereto, exclusive of cement and pipes. Pipes laid to be any diameter not *exceeding* six inches :—

| | | £ | s. | d. |
|---|---|---|---|---|
| Where depth averages not more than 5 feet - | per yard | 0 | 0 | $8\frac{1}{2}$ |
| " " " 7 " - | " - | 0 | 1 | 0 |
| " " " 10 " - | " - | 0 | 1 | 6 |
| " " " 13 " - | " - | 0 | 2 | 7 |

*Drainage*—continued.

| | | £ | s. | d. |
|---|---|---|---|---|
| Pipes, vitrified, impermeable, 4 inches diameter | per yard | 0 | 1 | 0 |
| " " " 6 " - | " - | 0 | 1 | 6 |
| Cement for 4-inch pipes - - - - | " - | 0 | 0 | 1¾ |
| " 6-inch " - - - - - | " - | 0 | 0 | 2 |
| Turning existing privies into water-closets, including common pan, syphon trap, 1 yard of internal pipe, ½-inch or ⅝, tap, cleansing old place, fixing, walling up, and every other labour - - - - - - | each | 1 | 1 | 0 |
| Yard sinks, and stone taps, including all labour in fixing and materials - - - - - - | each | 0 | 5 | 0 |

All disputes to be *decided solely and finally* by the Local Board.

*Plumber's Work.*

| Lead Pipe. | Weight per yard. | Charge for laying, including Pipe. s. | d. | |
|---|---|---|---|---|
| ⅜-inch - | 5 lbs. - - | 1 | 2 | per yard. |
| ½ " - | 6 lbs. - - - - | 1 | 4 | " |
| ⅝ " - | 7 lbs. - - | 1 | 6 | " |
| ¾ " - | 9 lbs. - - - - | 2 | 0 | " |
| 1 " - | 13 lbs. - - | 2 | 9 | " |

Extra for every plumber's joint.

The parties to find excavator, and also to fill up ground, and restore after pipe laid. Plumber to do the rest.

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IV.—Table showing the actual Cost of Private Works for the Water Supply and Drainage of Six Cottages in Tottenham, the Property of Thomas Tilley, laid on from the Water Mains and to the Drainage Pipes of the Local Board of Health.

*Works executed in August 1852.*

| *Water Supply* (all as fixed)— | £ | s. | d. | Per Cottage. £ | s. | d. |
|---|---|---|---|---|---|---|
| 95 lineal feet of ¾-in. galvanized wrought-iron pipe, with bends, &c. - - - | 4 | 9 | 3¼ | 0 | 14 | 10½ |
| 93 lineal feet of ½-in. ditto ditto - | 3 | 10 | 2¼ | 0 | 11 | 8½ |
| Two ¾-inch brass stop-cocks on main branch - | 0 | 7 | 0 | 0 | 1 | 2 |
| Six brass bib-cocks (screw-down), of ⅜-inch diameter - - - - | 0 | 12 | 6 | 0 | 2 | 1 |
| Two self-closing cocks - - - | 0 | 18 | 0 | 0 | 3 | 0½ |
| Four common lever stop-cocks, ¾-inch way - | 0 | 15 | 2 | 0 | 2 | 6 |
| Six water-closet pans, with traps, &c. - - | 1 | 7 | 0 | 0 | 4 | 6 |
| Four water-waste preventers - - - | 3 | 12 | 0 | 0 | 12 | 0 |
| Total for water supply - - | 15 | 11 | 1½ | | | |
| or per house - - - - - | | | | 2 | 11 | 10½ |

| *Drainage—* | £ s. d. | Per Cottage. £ s. d. |
|---|---|---|
| 135 feet straight stoneware pipes (each 2 feet long), 4, 3, and 2 inches diameter, and curved and junction pipes and syphon-traps, of 2 and 4 inches diameter - - - | 2 10 6 | - 0 8 5 |
| 135 lineal feet, laying pipes at an average depth of 4 ft., and making good surface - - | 4 9 9 | - 0 14 11½ |
| Emptying 6 old cesspools (and filling up) - | 1 10 0 | - 0 5 0 |
| Bricklayer, setting 6 water-closet pans, making good walls adjoining old cesspools, &c. - | 3 0 0 | - 0 10 0 |
| Six new sinks and traps for wash-houses and yards - - - - - | 0 15 0 | - 0 2 6 |
| Total for drainage - - | 12 5 3 | |
| or per house - - - - - | | - 2 0 10½ |
| Total cost of both classes of private works - | 27 16 4½ | - 4 12 8½ |

[Each cottage has a separate water-closet; and also a separate tap for water, carried within doors.]

The cost of the public works of water supply and drainage will be defrayed by a special district rate of 4½*d.* in the pound upon the rateable value of the house property in the town of Tottenham.

The present water rate charged by the Local Board is as under :—

| | In the Special District Rate Assessment. Above £ s. d. | And not exceeding £ s. d. | Water Rate, per Week. £ s. d. | Water Rate, per Annum. £ s. d. |
|---|---|---|---|---|
| On Premises assessed - - | - - - | 10 0 0 | | 0 2 6 |
| " " | 10 0 0 | 15 0 0 | | 0 3 9 |
| " " | 15 0 0 | 20 0 0 | | 0 5 0 |
| " " | 20 0 0 | 25 0 0 | | 0 6 3 |
| " " | 25 0 0 | 30 0 0 | | 0 8 0 |
| " " | 30 0 0 | 40 0 0 | | 0 11 0 |
| " " | 40 0 0 | 50 0 0 | | 0 14 0 |

And 3*s.* for every additional sum of 10*l.*

The gross rateable value of the six cottages in question is 60*l.*

The total account for public and private works of water supply and drainage will therefore stand thus :—

| | £ s. d. | Per Cottage. £ s. d. |
|---|---|---|
| Special district rate for public works of water supply and drainage, at 4½*d.* in the pound - | 1 2 6 | - 0 3 9 |
| Water rate, at 2½*d.* in the pound - - - | 1 1 0 | - 0 3 6 |
| Private improvement rate, at 6*d.* in the pound - | 1 10 0¾ | - 0 5 0⅛ |
| Giving a total annual charge for the 6 cottages of | 3 13 6¾ | - 0 12 3⅛ |

or a weekly charge of 2·83*d.*

The foregoing costs included the "water-waste preventer," laid to four cottages out of the six, which ensures the fullest possible flush of water to the closet, at the same time prevents either wilful or accidental waste, from leaving the cocks open, or injury to the same.

James Pilbrow, *Engineer.*

SUMMARY of foregoing Returns.

| Name of Town. | Rateable Value of Cottage. | Annual payment per cottage for Public General Works and Mains. | | *Annual* payment per cottage for combined Public General Works for Water Supply and Drainage. | *Weekly* payment per cottage for combined Public Works for Water Supply and Drainage. | Annual payment per cottage for Private Improvement Works, *i.e.* Service-water Pipes, Sinks, Water-closets, and House Drains. | | Annual payment per cottage for combined Private Improvement Works of Water Supply and Drainage. | Weekly payment per cottage for combined Private Improvement Works of Water Supply and Drainage. |
|---|---|---|---|---|---|---|---|---|---|
| | | Water Supply. | Drainage. | | | Water Supply. | Drainage. | | |
| | £ *s.* *d.* | *s.* *d.* | *s.* *d.* | *s.* *d.* | *d.* | *s.* *d.* | *s.* *d.* | *s.* *d.* | *d.* |
| Rugby - | 5 10 8 | 3 1 | 1 $6\frac{1}{2}$ | 4 $7\frac{1}{2}$ | $1\frac{1}{16}$ | 1 $8\frac{1}{2}$ | 1 $6\frac{1}{2}$ | 3 3 | $0\frac{3}{4}$ |
| Croydon - | 4 0 0 | 2 2 | 1 10 | 4 0 | $0\frac{12}{13}$ | 2 $7\frac{1}{2}$ | 3 9 | 6 $4\frac{1}{2}$ | $1\frac{1}{2}$ |
| Barnard Castle | 3 2 0 | - - | - | 4 8 | $1\frac{1}{13}$ | 2 $5\frac{1}{4}$ | 1 $8\frac{1}{4}$ | 4 $1\frac{1}{2}$ | $0\frac{12}{13}$ |
| Tottenham - | 10 0 0 | - - | - - | 3 9 | $0\frac{6}{7}$ | 3 $0\frac{1}{2}$ | 2 5 | 5 $5\frac{1}{2}$ | $1\frac{1}{4}$ |
| Average - | 5 13 2 | 2 $7\frac{1}{2}$ | 1 $8\frac{1}{4}$ | 4 $3\frac{1}{8}$ | 1 | 2 $5\frac{1}{2}$ | 2 $4\frac{1}{4}$ | 4 $9\frac{3}{4}$ | $1\frac{1}{10}$ |

(No. 9.)

## Specification for Drainage Pipes.

*Local Board of Health of*

Contract No.

1. *Extent of contract. Power for alterations.*—The description and quantities of the drainage pipes required by the Local Board of Health to be furnished by the contractors are set forth in the schedule No. 1, annexed to the accompanying form of tender, the figures inserted being the nearest practicable approximations to the whole quantities that will be actually required. The engineer, however, shall have power to make, within reasonable limits, any additions to or deductions from these quantities that may appear to him to be expedient or proper; and the amount in value of all such additions and deductions shall be calculated upon the basis of the schedule of prices annexed to the contractor's tender.

2. *Description of pipes given in drawings and specification.*—The whole of the pipes shall be of the forms, dimensions, and thicknesses shown in the drawings deposited at the office of the Local Board, as described in this specification and accompanying schedules, but should any discrepancies exist between the wording of the specification and the dimensions written on the drawing, or between the dimensions written on the drawing and the diagrams they refer to, in all cases the contractor shall be regulated by the wording of the specification in preference to the written dimensions, and by the written dimensions in preference to the diagrams they refer to.

*Samples to be submitted.*—The samples submitted with the contractor's tender will be retained and regarded as fair average specimens with regard to material, quality, and workmanship, of the whole of the pipes to be furnished.

3. *Quality of pipes.*—They shall be sound, and well burnt throughou their thickness, impermeable to moisture, and of smooth interior surface, the joinings of the parts perfectly sound, and the pipes free from cracks, flaws, blisters, and all other imperfections; circular in the bore, of true form in length, whether straight or curved, internally of the full specified diameter, and of uniform thickness, not less than one twelfth of the diameter.

4. *Engineer at liberty to test pipes and reject those of defective quality.*—The engineer or surveyor shall have power at any time to examine and test the impermeability or the strength of any of the pipes, to the extent to which the contractor shall have stated in the particulars accompanying his tender, that they will resist moisture, or will bear external and internal pressure; and shall be at liberty to reject all pipes which in his opinion are of an inferior quality of material to the sample submitted, or defective in any other respect, or which in his opinion vary in too great a degree from the forms, dimensions, and thicknesses, shown in the drawings before referred to; and he may direct the immediate removal of any such rejected pipes at the contractor's expense.

5. *Places and periods of delivery of pipes.*—The whole of the pipes shall be delivered, at the contractor's expense, in sound condition, at such place or places within the district of the Local Board as the engineer or surveyor may from time to time determine, and at the several dates specified in the accompanying schedule No. 3; and in case the contractor shall fail or neglect to deliver any of the above-mentioned quantities of pipes within the respective times mentioned, he shall forfeit and pay for every week afterwards elapsing until such pipes are delivered, the sum of pounds, together with all losses and damage for which

the Local Board of Health may be liable for the non-fulfilment of contracts or works which may be dependent upon such deliveries. The Local Board of Health shall also in such case be at liberty to contract with any other maker for the whole on any portion of the pipes, and charge the excess of cost, if any, and all expenses arising therefrom, to the contractor.

6. *No extras allowed, unless upon certificate.*—No extra charges or additional claims of any kind will be allowed, unless upon the certificates in writing of the engineer or surveyor to this effect.

7. *Differences to be decided by engineer.*—Should there arise any misunderstanding as to the meaning of anything contained in this specification during the progress of the works, the decision of the engineer or surveyor to the Local Board of Health for the time being shall be conclusive and binding.

8. *Payments.*—The contractor shall be entitled to receive payment for the quantities of pipes actually delivered at the expiration of two months after the respective periods mentioned, such payments being made upon the certificate of the engineer or surveyor, subject to a deduction of twenty-five per cent. from the full ascertained value; which deduction will be retained by the Local Board until three months after the last time of payment. All payments will likewise be subject to deduction for any penalties that may accrue by reason of the improper or imperfect performance of the contract.

9. *Sureties.*—The contractor shall (when required) find two good and sufficient sureties, in a sum equal to one fourth the amount of his tender, for the full and complete performance of his contract.

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## Contract for Drainage Pipes.

### Conditions to be observed by Contractors tendering.

1. The tender must be made upon a printed form annexed to the specification, and must be signed by a principal, or by a declared agent acting in his behalf.

2. The blank schedule of prices annexed to the form of tender must be filled up.

3. A sample of straight lengths of pipe and of curves or junctions, each of 4 inches, 9 inches, and the largest diameter comprised in the contract respectively, must be submitted with the tender.

4. Full particulars must accompany the tender as to the place where the pipes are intended to be manufactured, the description of clay to be used, and the processes of manufacture to be adopted; the weight in pounds per foot run of each size of pipe when dry, and after 48 hours saturation, and the pressure of pounds on the square inch which pipes of the various sizes are capable of resisting externally and internally.

5. Should the contractor have any doubt as to the meaning of any portion of the specification, he must set forth the particulars of such doubt in writing, and submit the same with his tender, in order that it may be formally settled before his tender is accepted.

6. Tenders must be delivered at the office of the Local Board on or before the            day of                    , endorsed "Tender for Drainage Pipes," and addressed "To the Chairman of the Local Board of Health of                ."

7. The Local Board do not bind themselves to accept the lowest or any other tender; and no tender will be entertained in which these conditions are not complied with.

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TENDER for DRAINAGE PIPES.

185 .

*To the Local Board of Health of*

Gentlemen,

do hereby engage to make and supply you, the Local Board of Health of with the required drainage pipes, in the quantities and of the description set forth in the annexed schedule No. 1, in conformity with the terms and conditions contained in the foregoing specification, and with the drawings deposited in your office; and to deliver the same in the quantities and at the several dates named in the annexed schedule No. 2, for the sum of ; and also to supply any further quantities that may be required, at the prices marked in the annexed schedule No. 3; and do undertake to execute an agreement (to be prepared by and at the expense of the Local Board), for the due performance of the contract.

And propose , of and of , as the two parties who are each willing to become security for the due and proper performance of contract, in the penal sum of , being one fourth of the gross amount of tender.

, Gentlemen,
Your obedient servant,

| | |
|---|---|
| Name of place where pipes are to be manufactured | Particulars. |
| Description of clay to be used | |
| Processes of manufacture to be adopted | |

Weight of each size of pipe when dry, and after 48 hours saturation.

| | Diameter of Pipe. | Lbs. per foot run. | | |
|---|---|---|---|---|
| | | When dry. | When saturated. | |
| | | | | |

Pressure which each size of pipe is warranted to resist.

| | Diameter of Pipe. | Lbs. per square inch. | | |
|---|---|---|---|---|
| | | Externally. | Internally. | |
| | | | | |

REMARKS.

*Local Board of Health of*

Contract for Drainage Pipes.—Schedule No. 1.

Quantities.

| Straight Pipes. | | Curved Pipes. | | Straight Junction Pipes. | | Taper Junction Pipes. | | |
|---|---|---|---|---|---|---|---|---|
| Internal Diameter. | Lengths when laid. | Internal Diameter. | No. | Internal Diameter. | No. | Internal Diameter of Taper. | Internal Diameter of Junction. | No. |
| Inches. | Feet. | Inches. | | Inches on Inches. | | Inches to Inches. | Inches. | |

*Local Board of Health of*

Contract for Drainage Pipes.—Schedule No. 2.

Rates of Delivery.

| Dates. | Straight Pipes. | | ——— |
|---|---|---|---|
| | Sizes. | Lengths when laid. | |
| | Inches Diameter. | Feet. | The quantities of curved pipes, and straight and taper junction pipes of the various sizes accompanying each delivery, shall be in the same proportion to the whole. |

*Local Board of Health of*

Contract for Drainage Pipes.—Schedule No. 3.

Prices.

| Straight Pipes. | | Curved Pipes. | | Straight Junction Pipes. | | Taper Junction Pipes. | | |
|---|---|---|---|---|---|---|---|---|
| Internal Diameter. | Price per foot length when laid. | Internal Diameter. | Price per Pipe. | Internal Diameter. | Price per Pipe. | Internal Diameter of Taper. | Internal Diameter of Junction. | Price per Pipe. |
| Inches. | *s.* *d.* | Inches. | *s.* *d.* | Inches on Inches. | *s.* *d.* | Inches to Inches. | Inches on Inches. | *s.* *d.* |

(No. 10.)

## SPECIFICATION for EARTHWORK and for laying DRAINAGE PIPES.

*Local Board of Health of*

Contract No.

*Extent of contract.*—The contract comprises the excavation for and the laying of the several lines of drainage shown on the accompanying plans and sections, Nos. , and such others as may be deemed, from time to time, necessary during the progress of the works, and in accordance with the conditions contained in this specification. The drawings and specification are intended to be explanatory of each other, but should any discrepancies appear, or any misunderstanding arise as to the import of anything contained in either the drawings or specification, the explanation of the engineer or surveyor of the Local Board shall be considered final and binding upon the contractor. The dimensions written on the drawings shall be taken in all cases in preference to the scale; and the wording of the specification in preference to written dimensions. In the absence of the engineer or surveyor the instructions of the clerk of the works or other officer who may be appointed to superintend the works shall be followed with respect to them.

*Dismissal of incompetent persons.*—If any person employed by the contractor on the works should appear to the engineer to be incompetent or to act in an improper manner he shall be at full liberty to discharge him, and such person shall not be again allowed to be employed upon them without permission.

*Contractor responsible for errors in plans, &c.*—The levels of the plans and sections and the bench marks are believed to be accurate; and any others that may be required shall be given to the contractor, and every assistance in setting out the works; but as the contractor will be held responsible for the consequences of any error, it will be for him to verify all data with which he may be furnished, should he so think fit.

*Notices.*—The contractor shall not commence the works until due notice in writing has been given to him. He shall give all necessary notices in writing to all persons having authority over roads, pavements, pipes, or other property or works liable to be affected by the execution of his contract of the period of commencement of the works.

*Power to vary works.*—The works shall be carried on in such portions as the engineer shall direct, and he shall have power also to vary, extend, or diminish the quantities of work, within reasonable limits, during its progress, without vitiating the contract; but no part of the works shall be altered by the contractor from that shown on the drawings, or described in the specification, without the express sanction of the engineer.

*Work not to be underlet.*—The contractor shall not assign, underlet, or make a sub-contract for the execution of any portion of the work, unless with the consent of the engineer.

*Pipes to be provided by Local Board.*—The drainage pipes will be provided by the Local Board; but when given into the custody of the contractor, he shall be held responsible for their safety. They will be deposited at places as convenient as practicable for use; but all further cartage or removal that may be necessary shall be done at the contractor's expense.

*Materials, implements, and labour provided by contractor.*—All materials to be provided by the contractor shall be of the best description; and he shall furnish all efficient labour and implements necessary for the full and complete performance of his contract; he shall provide and maintain all necessary hoarding, fences, and bridgeways for the traffic, and shall furnish lights and watchmen whenever required for the safety of the public, or for the protection of properties. If any materials or implements should be brought to the ground which the engineer may deem to be of inferior description, or improper to be used in the work, the same shall be removed forthwith; and if the directions of the engineer are not complied with in 24 hours after written notice, he shall be at liberty to remove the same at the expense of the contractor.

*Mode of excavation.*—The ground shall be excavated in open trenches to the necessary width and depth. The trenches shall be opened at least one foot wider than the diameter of the pipe intended to be laid, the bottom of the trench being hollowed out to the exact form and size of the lower half of the pipe, which will be embedded in it. No tunnelling will, on any account, be allowed, except under circumstances which render it unavoidable, and then only with the express sanction of the engineer in writing, in which case it shall be executed in accordance with his directions; and the drains shall be laid, and the work shall be backed in by a trusty person approved by the engineer.

*Protection of buildings, &c. at contractor's expense.*—The contractor shall, at his own expense, shore up, sling, protect, alter, divert, restore, and make good, as may be necessary, all water pipes, gas pipes, sewers, drains, buildings, walls, fences, or other properties, which may be disturbed or injured during the progress of the work.

*Paving materials, &c. to be preserved.*—In digging the trenches the contractor shall carefully take up and lay aside all paving materials, metalling, gravel, or other surface of roads and places, and all turf and vegetable mould of gardens or other grounds which may have to be disturbed.

*Convenience of traffic, &c. to be considered.*—The material excavated shall be laid compactly on the side of the trench, and kept neatly trimmed up so as to be as little inconvenience as possible to the public traffic or the adjoining tenants.

*Bottom of trenches to suit the shape of pipes.*—The bottoms of the trenches shall be neatly formed to the shape of the pipes to be laid down, so that the whole surface of the under half of the pipes shall have a full and even bearing throughout.

*Pumping, &c.*—The contractor shall, at his own expense, pump out or otherwise remove any water which may exist in the trenches, and shall form all dams or other works necessary for keeping the excavations clear of water during the progress of the works. In cases of running sand or other bad or treacherous ground, the works shall be proceeded with day and night without intermission, if the engineer shall so direct.

*Shoring of excavations.*—The sides of the excavation shall be supported with suitable timber whenever necessary. The contractor will be held responsible for all damage which may happen to neighbouring properties, or in any other way from neglect of this precaution. In any case in which the engineer shall direct that the timbering shall be left and buried in the trench, the cost of the timber will be allowed, unless the necessity for leaving it has arisen from carelessness or neglect in the work, in which case the timber will not be paid for.

*Good foundation to be secured for pipes.*—All irregularities in the trenches shall be filled up with gravel or clay, firmly rammed in; but where the ground would not present a sufficiently firm foundation for the pipes, the contractors shall excavate to such increased depth as may be necessary, and shall make good to the required form and level with concrete, or such other course shall be taken for securing a good foundation as the engineer may see fit to direct under the circumstances, and all increased work arising therefrom will be paid for as an extra.

*Pipes to be fitted before laid.*—Previously to the pipes being lowered into the trenches, they shall be fitted together dry on the surface, and matched, so that when jointed in the trench, they may form the most accurate and truest possible line of tubes.

*Mode of laying pipes.*—The pipes shall be laid truly in line and gradient throughout, according to the plans or directions furnished from time to time; and all curves, tapering pipes, junctions, syphons, and other pieces required shall be properly excavated for and laid as directed. The ends of all junctions laid in for any future house-drain or other connexion shall be closed up with a flag, or slate, circular piece of wood, or other effectual covering to prevent the entrance of any dirt or material. An exact record shall be kept of the point where every such junction is made.

*Defective pipes to be rejected.*—No broken or damaged pipes shall be used in the works. It will be for the contractor to reject all defective pipes that may be delivered on the ground, as he will have to make good or to pay for all breakage which may subsequently occur.

*Mode of joining pipes.*—In joining the lengths the socket or rebate of the pipe shall be neatly filled round with clay well-tempered and worked to the proper consistency, and the end of the next pipe being then carefully placed in, the joint shall be bedded and surrounded externally with a band or layer of clay, extending three inches each way beyond the external line of joint, and tapering off from three inches thick in the middle. Especial care shall be taken that this band is made perfect and tight in the under part of the joint. To ensure this and to allow of the continuous bedding of the pipe, the bottom soil must be dished out at every joint.

*Pipes to be freed from dirt, &c.*—The interior of the pipes shall be carefully freed from all dirt and superfluous clay as the work proceeds, for which purpose a disc plate, mould, or other implement, sufficiently long to pass two joints from the end of the pipe last laid shall be continuously worked through.

*Agricultural drain-pipes to be laid where directed.*—In wet soils, or where the engineer may direct, agricultural drain-pipes shall be laid in the trenches previously to the bedding of the main drainage pipes, the bottom being re-formed and made good over them.

*Pipes to be laid in puddle where directed.*—Whenever directed also, the trench shall be excavated to a depth of six inches below the level at which the drainage pipes are intended to be laid, and nine inches wider than the pipes on each side. The space below the intended level of the pipes shall then be filled in with puddled or well-tempered clay, so as to form an impervious and uniform bed for the pipes. When the pipes shall have been laid they shall be carefully surrounded with the same description of puddled clay, the trench being wholly filled in therewith to a height of nine inches above the top of the pipe.

*Examination of work.*—No line of pipes shall be covered in until they have been examined by the engineer or clerk of the works, and directions given to that effect.

*Filling in.*—The soil on each side and six inches over the pipes shall be carefully laid in, so as not to disturb them, and solidly rammed down. The trench shall then be filled in with layers of earth twelve inches deep at a time, each layer being well rammed over the whole surface. The first layer shall be placed over the pipes with a shovel, and not teamed from barrows. The pipes shall not be walked upon until this is done.

*Reinstatement of paving, &c.*—The contractor shall replace all paving or other surface material which may have been disturbed, to the satisfaction of the engineer and of the persons having control over such several public and private places.

*To make good sewers, fill up cesspools, &c.*—The contractor shall provide for the flow of sewers, drains, or watercourses interrupted during the progress of the works, and shall restore or make good all connexions as may be directed. He shall empty and fill up all cesspools on the line of the excavations, and shall immediately cart away or remove all offensive matter with such precautions as may be directed.

*House-drainage to be connected with consent.*—Any house-drainage or private drainage works shall, with the consent of the engineer or surveyor, be connected with the works in progress, the contractor putting in the first pipe from the junction, for which he will be paid.

*To cart away superfluous earth.*—As the trenches are filled in he shall cart away also all superfluous earth and other materials from the spot, and leave al the roads and places free and clear, and in good order.

*To give up any objects of value.*—Any coins or objects of antiquity or value which may be met with, shall be at once deposited at the office of the Local Board.

*General condition as to execution of works.*—The contractor shall execute with the best materials and workmanship of their several kinds the whole of the works comprised in the drawings and this specification. They are intended to include whatever may be requisite to render the works complete, but should anything be accidentally omitted, which may fairly be implied, as included in the contract, the same shall be executed at the expense of the contractor.

*Alteration of works; extra charges.*—The difference of expense of any addition, diminution, or alteration of the works which may be directed, shall be added to or deducted from the amount of the contract agreeably to the rates specified in the schedule of prices annexed to the contractor's tender. If the items do not appear in the schedule, the charge for the same shall be settled by the engineer, but no extra charges whatever will be allowed, unless with the written orders of the engineer, and a claim is sent in weekly by the contractor for every such charge to which he may consider himself entitled.

*Contractor to pay all fees, and compensate damage.*—The contractor shall pay all fees, and shall compensate for or make good at his own expense whatever damage may occur to any person, or to public or private properties, by reason of the execution of the works, beyond the compensation for way-leave in going through private premises which may be agreed to be paid by the Local Board.

*Contractor to be responsible for entire works.*—The contractor shall have charge of and be responsible for the entire line of works until the completion, and whenever the engineer shall require it, openings shall be made for examination, and if the work should in any respect be found defective, all expenses of such examination and of making good shall be defrayed by the contractor, but if found to be in a satisfactory condition, such expenses will be allowed.

*No allowance for necessary delay of works.*—Should it be deemed necessary on account of the inclemency of the weather, delay in the delivery of the pipes, or any other cause, to suspend the execution of the works, or any portion of them, the engineer shall have power so to direct without any extra allowance to the contractor; but the period of time during which the works may be so suspended shall be allowed to the contractor in computing the time of completion of his contract.

*Notice to contractor for defective work, &c., and proceedings thereon if not remedied.*—If at any time it shall appear that the works, or any part thereof, are not being executed in conformity with the contract, or in a sound and workmanlike manner, and if satisfactory progress shall not be made therein, the engineer shall give written notice to the contractor, and if he shall refuse to amend the defective work, or comply with any order in relation thereto, or if in three days after notice he shall not have adopted ample means for the satisfactory prosecution of the work, the Local Board shall have full power to take the whole of works out of the hands of the contractor, and proceed with the execution thereof, and all extra costs and charges which may arise shall be paid for by the contractor.

*Date of completion of contract, and penalty for delay.*—The time fixed for the completion of the whole of the works of this contract is from the date of the engineer's order to commence them, and the contractor shall pay as liquidated damages *l.* for every day that any part of the said work shall by his default remain unfinished after that time, whether the works shall be in course of completion by the contractor or by the Local Board or others on their behalf.

*Contractor to keep works in good order.*—The contractor shall be held liable for keeping in repair and good order the whole of the works for six months after the date of completion.

*Payments.*—Payments will be made to the contractor in monthly instalments, on the certificate of the engineer of the value of the works executed in the preceding month, subject to a deduction of 25 per cent. upon such value. Full payment of the balance will be made upon the certificate of the engineer that the contract has been fulfilled to his satisfaction, six months after the date of completion, subject to all legal and equitable deductions.

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Additions to Specification for Earthwork, &c. in Contracts which include brick sewers, gullies, and other works appertaining thereto.

All bricks employed in this contract shall be good, sound, well burnt stocks of uniform shape.*

The ground shall be excavated of the proper widths and depths indicated by the drawings, in such manner and of such lengths only at one time as shall be directed by the surveyor.

The invert of the brick sewer, as shown in drawing No. , is to be formed of blocks, each 18 inches long, and of such width as may be directed, to be prepared in proper boxes, and well grouted up with thick cement grout in the boxes, and also after being fixed in the work. These blocks are to be made at least ten days before they are used, and they are not to be used until the cement has become quite hard.

The brickwork shall be formed in the best manner, well bonded. The joints shall be struck flush with the face of the work, and shall not exceed, in any part of the interior of the work, one eighth of an inch in thickness.

All junctions and connexions of drains with the sewer shall be made in the manner shown in drawing No.

All sewers or drains met with, or cut through, shall be connected with the new sewer with approved junctions as indicated, and with such brick-

* Wherever it is possible to procure them, it should be specified that the bricks for sewers should be "radiating."

work in cement as may be directed ; or, if so required, they shall be perfectly restored to the same condition as before the commencement of the works.

The ground shall be carefully filled in, and the work backed up in a proper manner as it proceeds, and the ground shall be properly rammed down, in the whole of the excavation, after the completion of such lengths of the sewer as may be directed.

Gullies shall be constructed, in the position shown on the plan No. , of the materials, forms, and dimensions shown in drawing No.

Side entrances and ventilating shafts shall also be constructed in such positions as may be directed, and of the materials, forms, and dimensions exhibited on the drawing No.

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General Specification of Work to be executed for the Drainage of, and Supply of Water to Houses within the District of the Local Board of Health of

Provide and lay down in the several courses, and at the depths and inclinations indicated on the accompanying plan, No. , stoneware pipe sewers or drains, of the dimensions marked upon each line.*

For the quality of materials, mode of laying, and other stipulations, clauses Nos. of the "Specification for drainage pipes," and clauses Nos. of the "Specification for earthwork and for laying drainage pipes," shall be included in, and form part of this specification.†

Provide and securely fix water-closet pans, kitchen and yard sinks, syphons, bends, and junctions of a description and quality equal to the samples kept at the office of the Local Board, as may be required in each case, and as are marked in the accompanying list or table set forth in each case.‡

Provide and securely fix from the main to the several parts of the premises to be supplied, the requisite length of inch piping, with tops, and all necessary joints, ferules, &c. for the service of water to the water-closets, sinks, and other parts indicated on the plan, No. , and described in the accompanying list or table set forth in each case.

All damage to premises incidental to the works of drainage and water supply, shall be made good in a workmanlike manner, and with sound and suitable materials, and everything restored which may have been interfered with, and left in a complete and satisfactory state, and the whole of the works shall be so carried on as to be of the least inconvenience possible to the inhabitants.

The whole of the work must be done according to the directions and to the satisfaction of the engineer or surveyor, and 24 hours notice in writing shall be given at the office of the Local Board previously to the work being commenced.

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* This specification is made applicable to those cases in which the materials and apparatus will be provided by the contractors employed by owners and occupiers; but it will be desirable that the Local Board should keep a stock of the materials and apparatus required, which would be furnished to contractors for labour, &c. acting under the Local Board.

† The whole of the clauses of these specifications, as far as they will be applicable, should be embodied in this specification.

‡ A form of table should accompany the specification in each case, in which the quantity of materials required should be filled in, of the description most suitable for the property.

CONDITIONS of TENDERS.

Tenders must be made upon the printed form annexed, and must be signed by a principal, or by a declared agent acting in his behalf. Should there be any doubt as to the meaning of any portion of the specification which would affect the amount of any contractor's tender, he should set forth the particulars of such doubt in writing, and submit the same with his tender, in order that it may be removed before acceptance of his tender. Tenders must be sealed and indorsed "Tender for laying drainage pipes," and must be addressed "To the Chairman of the Local Board of Health of ," and be delivered at the office by o'clock, on the day of

No tenders will be entertained sent in after that time, or of which the form and schedule are not completely filled in, and in every respect in conformity with the conditions.

Should the contractor have any doubt as to the meaning of any portion of the specification, he must set forth the particulars of such doubt in writing, and submit the same with his tender, in order that it may be formally settled before his tender is accepted.

The Local Board do not bind themselves to accept the lowest or any tender.

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TENDER for laying DRAINAGE PIPES.

Contract No.

To the Local Board of Health of

Gentlemen,

hereby undertake to excavate the ground and lay the drainage pipes, and to perform all the works, matters, and things in connexion therewith required to be done by the Local Board of Health of , in accordance with the drawings and specification examined by at your office, and with the conditions thereto attached for the sum of .

And further undertake to execute and perform all other additional works which may be required, at the several prices which have set forth, to the several items in the schedule annexed.

And further undertake to execute an agreement (at the expense of the Local Board of Health) for the due performance and fulfilment of the conditions; and do hereby propose of , and of , as responsible sureties, who are willing to be bound with , jointly and severally, in the sum of , for the due and satisfactory performance of the whole of the works comprised in the contract, as well as of such additional works as may be ordered, and for the maintenance thereof in complete repair for the space of six calendar months from the date of the completion thereof.

As witness hand this day of 185

Signature ____________________

Address ____________________

*Local Board of Health of*

Contract No.

SCHEDULE of PRICES referred to in the Specification and Tender for laying Drainage Pipes, applicable to any addition to or diminution of the work comprised in the contract.

The following prices for laying drainage pipes include excavation, shoring the ground and adjacent properties, fencing, lighting, and watching, freeing the trenches from water, laying and jointing the pipes, with the curves, junctions, and other parts, filling in and ramming the earth, restoring and making good the paving, flagging, or other surface material, and clearing away all superfluous earth and rubbish in conformity with the conditions of the specification; the pipes being supplied by the Local Board.

| Diameter of Pipes. | Price per lineal yard, not exceeding in depth | | | | | |
|---|---|---|---|---|---|---|
| | 3 feet. | 6 feet. | 9 feet. | 12 feet. | 15 feet. | 18 feet. |
| | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* |
| 4 inches - - | | | | | | |
| 6 " - - - | | | | | | |
| 9 " - - | | | | | | |
| 12 " - - | | | | | | |
| 15 " - - | | | | | | |
| 18 " - - | | | | | | |

| | |
|---|---|
| Excavating additional depth for and laying agricultural drain-pies, and making good foundation for main pipe, as per specification - - - - - | Per lineal yard. |
| Excavating additional depth for and puddling round 12-inch drainage pipes, at any depth, as per specification - - - - - - - | Per lineal yard. |
| Other sizes in proportion. | |
| Timber shoring, ordered to be left in trenches - | Per cube foot. |
| Brickwork, in blue lias lime mortar, including all implements and labour - - - - - | Per rod. |
| Brickwork, in cement, whole or half brick thick - | Per rod. |
| Concrete - - - - - | Per cube yard laid. |

(No. 11.)

EARTHENWARE PIPE DRAINAGE.—RELATIVE COST of supplying EARTHENWARE DRAIN PIPES and laying the same complete in the under-mentioned Towns, under the superintendence of—

| Diameter of Pipes. | Mr. RANGER. | | | | | | | | | Mr. RAWLINSON. | | | | | | Mr. RAMMELL. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CROYDON. (Pipes laid 9 feet deep.) | | | BARNARD CASTLE. (Pipes laid 9 feet deep.) | | | SOUTHAMPTON. (Pipes laid 9 feet deep.) | | | HITCHIN. (Pipes laid 8 feet deep.) | | | ORMSKIRK. (Pipes laid 8 feet deep.) | | | RUGBY. (Pipes laid 8 feet deep.) | | | SANDGATE. (Pipes laid 6 feet deep.) | | |
| | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. | Total cost of Pipes and laying same complete per yard. |
| inches. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. | s. d. |
| 21 | 16 0 | 3 3 | 19 3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 20 | - - | - - | - - | - - | - - | - - | - - | - - | - - | 8 9 | *5 0 | 13 9 | 7 0 | 1 8 | 8 8 | 8 4½ | 2 9 | 11 1½ | — | — | — |
| 18 | 8 0 | 3 3 | 11 3 | - - | - - | - - | - - | - - | - - | 7 3 | 2 9 | 10 0 | 6 0 | 1 7½ | 7 7½ | 7 1½ | 2 9 | 9 10½ | — | — | — |
| 15 | 6 0 | 3 2 | 9 2 | 4 11½ | 1 10¾ | 6 9¾ | 6 0 | 3 7 | 9 7 | 5 4½ | 2 6 | 7 10½ | 4 3 | 1 7 | 5 10 | 5 4½ | 2 6 | 7 10½ | — | — | — |
| 12 | 3 6 | 3 1 | 6 7 | 3 2 | 1 10¼ | 5 0¼ | 3 6 | 3 5 | 6 11 | 3 3 | 2 4 | 5 7 | 2 6 | 1 6½ | 4 0½ | 3 3 | 2 6 | 5 9 | 3 10½ | 1 9 | 5 7½ |
| 9 | 2 2 | 2 9 | 4 11 | 2 2 | 1 8¼ | 3 10¼ | 2 2½ | 3 0 | 5 2½ | 2 0 | 2 3 | 4 3 | 1 5¼ | 1 6 | 2 11¼ | 2 0 | 2 0 | 4 0 | 2 4½ | 1 9 | 4 1½ |
| 6 | 1 3 | 2 6 | 3 9 | 1 2¾ | 1 7¾ | 2 10½ | 1 3½ | 2 8 | 3 11½ | 1 3 | 2 2 | 3 5 | 0 10½ | 1 5½ | 2 3½ | 1 2¼ | 2 0 | 3 2¼ | 1 4½ | 1 6 | 2 10½ |
| 4 | 0 10 | 2 2 | 3 0 | 0 11 | 1 7¾ | 2 6¾ | - - | - - | - - | 0 11¾ | 2 2 | 3 1¾ | 0 7½ | 1 5½ | 2 0½ | 0 10½ | 1 9 | 2 7½ | 1 0¾ | 1 6 | 2 6¾ |
| 3 | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | 0 9 | 1 9 | 2 6 | 0 10½ | 1 6 | 2 4½ |

* The apparently excessive charge for laying down 20-inch Pipes at Hitchin is to be accounted for by their position under the bed of the river. In some places the pipes are 8 feet below the water line.

*Note.*—At Hitchin and Ormskirk an average increase of 1-8th to the cost per yard on the Pipes may be allowed for junctions, &c., and at Rugby and Sandgate 1-10th.

(No. 11.)—*continued.*

| Diameter of Pipes. | Mr. PILBROW. | | | | Messrs. DYMOND and SONS, EXETER. | | | | Mr. ARTHUR WHITEHEAD, EXETER. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOTTENHAM. | | | | ST. THOMAS. | | | | OTTERY ST. MARY. | | |
| | Cost of Pipes per yard delivered. | Average depth of Pipes laid. | Cost of laying Pipes per yard run. | Total cost of Pipes laid per yard. | Cost of Pipes per yard delivered. | Average depth of Pipes laid. | Cost of laying Pipes per yard. | Total cost of laying Pipes per yard. | Cost of Pipes per yard delivered. | Cost of laying per yard. Average depth 6 feet. | Total cost of Pipes laid. |
| inches. | s. d. | ft. in. | s. d. | s. d. | s. d. | ft. in. | s. d. | s. d. | s. d. | s. d. | s. d. |
| 24 | - - | - - | - - | - - | - - | - - | 3 6 | — | — | — | — |
| 21 | - - | - - | - - | - - | 10 0 | - - | 3 3 | 13 3 | — | — | — |
| 18 | 7 4·20 | 5 0 to 13 0 } 8 5 | 2 4·5 | 9 8·7 | 8 0 | 7 6 | 2 9 | 10 9 | — | — | — |
| 15 | 5 4·8 | 7 0 | 1 7·5 | 7 0·3 | 6 0 | 8 6 | 2 3 | 8 3 | 6 6 | 2 4½ | 8 10¼ |
| 12 | 3 4·5 | 6 5 | 1 4·5 | 4 9 | 3 7½ | 6 0 | 2 0 | 5 7½ | 3 3 | 2 1½ | 5 4½ |
| 9 | 2 0·75 | 6 0 | 1 0·0 | 3 0·75 | 2 3 | 5 0 | 1 3 | 3 6 | 2 0 | 1 3¾ | 3 3¾ |
| 7·5 | 1 7·5 | 5 0 | 0 10·5 | 2 6 | — | — | — | — | — | — | — |
| 6 | 1 2·25 | 4 5 | 0 8·5 | 1 10·75 | 1 3¾ | 4 6 | 1 3 | 2 6¾ | 1 2¼ | 1 2¼ | 2 4½ |
| 4 | - - | - - | - - | - - | 1 0 | 3 0 | 1 0 | 2 0 | 0 10½ | 1 0¾ | 1 11¼ |
| 3 | - | - - | - - | - - | 0 10 | - - | 1 0 | 1 10 | — | — | — |
| 2 | - - | - - | - - | - - | 0 8 | - - | 1 0 | 1 8 | — | — | — |

(No. 12.)

## Results of Inquiries as to the Expenses of the Manufacture of Drain Pipes on a large Scale, and also of Hollow Bricks.

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### *Memorandum as to the Manufacture and Prices of Tubular Drain and Water Pipes.*

Great obstacles to the progress of sanitary works have been presented by the defective manufacture of articles required for new construction, as well as by the excessive charges for them by the makers; the whole art of earthenware tube manufacture being very rude, and generally the intelligence and economic condition of the traders engaged in it very low.

A poor brickmaker or potter, receiving an order for a new sort of pipes, charges the whole expenses of his new kiln, and his new machine, upon the single set of the new articles ordered. Hence the actual charges of production, which are very low, form but a small element in the prices to the public, which are excessively high; which prices are nevertheless maintained even after the plant has been paid for. When the demand has become extended, and new makers have been brought into the field, while their numbers are few, and they are of this class, they rather combine to keep up prices, and divide the business amongst them, than compete, either as to the price or the quality of the articles supplied.

It is true that generally excessive prices really restrict profits as well as limit consumption; but traders of this class prefer the smaller sales at the higher prices, even with less aggregate profit. Where competition does arise upon these high prices, it is competition by trade allowances and "discounts off" to intermediate dealers; and sometimes, a corrupting competition by per-centages and allowances, or, in the proper words, by bribes to engineers, surveyors, architects, and builders.

Upon the investigation of the older works of construction, the obstinate preferences of the local administrators, and of their officers for works, on an extravagant scale, and of evidently doubtful efficiency,—the manifest sympathy of the subordinate officers and clerks with contractors in the case of defects and failures, against the public,—the palpable remissness in the measurements and checks against bad or deficient work, were collectively so strong as to lead to the belief that similar influences acted upon the officers, and even upon the administrative bodies themselves. Amongst these bodies were found relations of contractors, or of professional persons, or tradesmen indirectly connected with them; in fact, such trading influences, often assuming the garb of party politics, had prevailed in the constitution of the administrative bodies having the direction of the works. Majorities were, however, often misled by interested minorities; and indeed, a whole Board of gentlemen, perfectly disinterested, were often misled from not scrutinizing the details of the business themselves.

It is highly probable, that if Mr. Law Hodges, and several other gentlemen of enterprise, had not examined the manufacture of agricultural drain-tiles, analyzed the labour and expenses of constructing kilns and manufacturing tiles themselves, and proved at what cost they might be produced, the prices of the ordinary pipes would,—under the circumstances of there being no inducements to investments of capital on a large scale, or in the improvements of the works in any one locality,—have remained four or five times as much as their present price, the excessive charge continuing a formidable obstruction to land drainage. It appeared to the members of the Sanitary Commission that the most efficient, if not the only means of protecting the public, was to ascertain carefully at what cost the articles requisite for town drainage might be made; and, to promote their manufacture under contracts, on a large scale, at such a moderate rate of profit, as, whilst it ensured the production, would preclude the payments of per-centages or of allowances.

To verify the information obtained, it was proposed to erect kilns as trial works, to give data for the prices of production by contractors on a large scale for the new works; or, in case of the failure of this method, to let out the kilns, and allow them to be worked by contract. The whole of this proceeding was vehemently opposed by the tradesmen; and every indirect, as well as direct, effort made to thwart it. Nevertheless, it appeared, upon inquiry, that the prices at which the chief article used in the old constructions had been supplied, were 50 or 60 per cent. above the prime cost at which they might have been produced; whilst, upon a subterranean survey, it appeared that large extents of brick sewers, even those of comparatively recent construction, were falling to pieces, from the bricks used having been far inferior to the qualities contracted for, and paid for, at those very high rates of profit. At the time of the supersedeas of the district commissions in the metropolis, there were large brick sewers projected, which would have been sewers of deposit, at an expense for one single district of a quarter of a million, of which sum the greater proportion would have been expended in brick, probably at the previous prices, or what were called the market prices, but which was far above the fair cost, including a reasonable profit.

In respect to the earthenware drain-pipes, it appeared that there could be only an inconsiderable extra cost in the manufacture of the glazed stoneware pipes made for house-drains beyond that for the production of the red earthenware pipes used as land-drains, except for the clay. This was brought from Dorsetshire, and ground and otherwise prepared at an expense of 10*s*. per ton, but it is now found that an equally good clay might be wrought at 7*s*. per ton.

The prices charged by the small makers in the country, with all the advantages of fuel as well as of clay upon the spot, appeared to be much higher than the prices of the makers of pipes in town, which both were greatly above the cost of production. For example, it may be mentioned, that whilst a 2-inch socket-pipe could be made at 4-16ths of a penny per foot, the lowest sale price at which they were offered from Staffordshire was 4*d*., and from London at 3½*d*.; that whilst a 4-inch pipe could be manufactured at 5-8ths of a penny per foot, the lowest sale price in Staffordshire was 6*d*. per foot, in London 5*d*.; that pipes 1 foot in diameter might be made at 2¼*d*. per foot, the sale prices in Staffordshire and in London were 1*s*. 8*d*.; and that socket-pipes of 16 inches in diameter made at 3¼*d*. were charged at the rate of 3*s*. 6*d*. per foot.

These results show how the members of a Local Board might be unconsciously led to adopt even the lowest tender of goods, and yet pay some 200 or 300 per cent. beyond the cost prices of production. Where the competitors were few, the tenders themselves appeared to be so arranged as to leave little choice to the authorities in the selection of contracts, and almost to preclude competition in the improvement in the qualities of the goods produced. When such improvements were suggested to the makers of the pipes as the application of a second pressure, by which their exactitude of form, the smoothness of their interior surface, and their strength might be increased, at an additional expense, whether by hand labour or by a machine, of a halfpenny or a penny a yard, they almost invariably protested that their profits were so very low that they really could not afford to make the improvement unless they were paid extra for it.

As an example of the rate of charge to the public, it may be mentioned, that the charge of builders for the first soil-pans of a very rude and inferior description was 7*s.* each. When the makers were remonstrated with on the workmanship, they pleaded that they could not afford to improve it, inasmuch as they were only paid 2*s.* 6*d.* each for them by the builders. Yet it appeared that the prime cost of production to the potter, for the same article, was little more than half that sum.

Since the subject was first investigated, there has been much reduction in the prices of the pipes, but it is chiefly by per-centages to contractors and to tradesmen, amounting, it is understood, to 40 per cent. or more upon the trade or the list prices, in itself a very objectionable mode of proceeding, maintaining the old and corrupt influences at the public expense. There has been very little improvement, however, in the manufacture of pipes or the connected apparatus ; except in syphon water-closets, which have been much improved, but the prices of the best of them appear still to be extravagantly high, as compared with the cost of production and any superadded fair profit for articles produced on a large scale.

The quantity of clay used in the manufacture of hollow bricks of the common sizes is less than in the solid bricks ; in the larger sizes it is very much less ; there is less digging, less working, less wheeling and moving, and less carriage. Nevertheless, common brickmakers have charged more for the hollow bricks than for the common bricks, and full two thirds more than they are actually manufactured for by gentlemen who make them in their own kilns. It is probable, however, that there will be few, if any, of the smaller towns where it would not be found worth while, if from other circumstances it were practicable, for the Local Board to do what individual owners might do, *i.e.* construct kilns for the manufacture of the drain-pipes required. The delay of efficient measures of sanitary improvement is in itself a source of great expense, and sacrifices may be required for speed. It is only for undertakings on a very large scale, and under peculiar circumstances, that it could be recommended as worth while for the Local Board of any town to erect works for the manufacture of pipes, as contemplated for the service of the metropolis. In general, more money would be lost by delay than would be saved upon the prices of the articles, even where the circumstances were more than usually favourable for such a course ; but it will, nevertheless, be of use that members of Local Boards should, to protect the ratepayers and themselves from excessive charges, acquaint themselves with the real expenses of production, and of how much room there is for improvement in the quality of the goods supplied, without trenching upon a fair remuneration for their manufacture.

When the labour and expense of production has been analysed and ascertained beyond a doubt, a liberal profit should be allowed to the manufacturer, with a fair allowance for the irregular nature and risk of the demand.

In respect to the trial works, hereafter described, although as being the first known to have been made, they may be important and useful as far as they go, it is to be observed, that the nature of the clays was so various, and the burnings and manipulations of them so different, that it is recommended, that for any large or special works, new and varied trials will be made. It was intended that the trials should be renewed and varied by different observers.

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*Extracts from a Report of the Works Committee of the First Consolidated Metropolitan Sewers Commission.*

" The manufacture of earthenware drain-pipes is, apparently, in a very primitive state. The machines now in use are only a few years old. It is admitted, that by the use of steam-power and machinery great improvements might be effected in the manufacture; but the demand for such pipes has hitherto been only at distant places, scattered over the country, and not sufficiently large in any one place to make it worth while generally to resort to the use of steam-engines, at least for the manufacture of red earthenware pipes. There are very few manufacturers of those articles, and their average profits are known to be upwards of one hundred per cent., which is not too high, perhaps, to compensate for the uncertainty of the demand in that season in which pipes, as well as bricks, may be made in the common method. Private individuals, owners and occupiers, gentlemen who wish to drain their own lands, find it to their interest, contrary to the practice in other matters, to erect kilns and manufacture pipes for themselves. The Town Council of Liverpool, who contemplate carrying out a tubular system of drainage, have, it is understood, engaged with a potter to construct works on their behalf on a contract. The question which is now pressed for decision is, whether it be expedient that the Commissioners should to any and what extent manufacture pipes, by persons directly under their own control.

" It appears that various new forms of pipes and apparatus will require to be tried, involving expense on the part of the manufacturers.

" Several potters have offered to the Commission their kilns for trial works.

" But the acceptance of any of these offers would apparently be attended with the inconvenience of connecting the Commission with an individual manufacturer or tradesman, who will expect compensation for his trouble, and whose wares may not eventually prove to be suitable; nor could trial works be carried on in such premises with perfect freedom, nor would the arrangement be so satisfactory to competing manufacturers, from several of whom it may be found eligible to take supplies of earthenware pipes.

" On the other hand it is objected, that governments and public bodies never manufacture so well or so cheaply as private individuals.

" In the mode in which governments and public bodies have usually proceeded, of not making it the strong interest of any individual manager of works to manufacture so well or so cheaply as private individuals, this must no doubt continue to be so; but it does not appear to be absolutely impossible or hopeless to give to a manager of works an interest as strong and facilities as great as those of any private individual.

" The question for immediate consideration is, however, not of permanent manufacture, but of trial works, to ascertain what descriptions of articles will best serve, and what prices may be fairly given to private manufacturers, who will not erect the trial works without some assurance of obtaining large orders.

" In consequence of a resolution adopted by the Court, invitations were issued to manufacturers in all parts of the country to send in prices and specimens of their wares. Lists of prices have been received from a considerable number of manufacturers and specimens from . Mr. Donaldson has made up a comparative table of the lists sent in, an abstract of which is hereto appended. (Page .) From this it will be seen that the prices of goods offered, from Staffordshire and Newcastle for instance, are as high as the goods manufactured at Lambeth and Vauxhall, notwithstanding the comparative cheapness of coal, and that clay for pipes is found on the spot at several places from which lists of prices have been sent; it appears, moreover, the quality of specimens, not on the average better, if so good as those already obtained in London. Most of the specimens are exceedingly rude. The pipes delivered from the manufacturers in London, not as specimens, but for actual use, are however frequently inexact in form, rough in the interior, and greatly below the qualities which there is reason to believe may be obtained without any additional expense.

"The drainage of the Dean's Yard was much delayed by the necessity of returning the pipes first sent, which were of a very inferior quality; and at last the surveyors, to avoid further delay, found it expedient to use pipes of four inches in diameter where they would have preferred pipes of three inches diameter had the construction been more exact. It is to be feared that the private house builders, judging from the common construction of house-drains, will no be so particular, and that there will, on this account, be many instances of the failure of tubular house-drainage. Whilst there is a rising demand for such articles, of whatsoever quality can be obtained, great care or expense for the improvement and perfect finish of the manufacture cannot be reasonably expected.

"The inquiries into the means of improving the manufacture, commenced, from convenience, with the kilns. The chief results obtained on this topic are set forth in Mr. Roe's Report. The most decided improvement in these constructions is the Ainslie Tile-kiln, the use of which is strongly advocated by Mr. Smith of Deanston. By this kiln, it is stated, that five parts out of seven of the coal ordinarily consumed may be saved. The royalty asked for the use of the patent, is one fourth of the fuel saved; which does not appear to be an unfair compensation. The Company have, however, at the instance of Mr. Smith, offered the use of the patent for one set of kilns gratis to the Commissioners, being desirous of its trial.

"An analysis of the labour, quantity of clay, and expense of making pipes, has been made out, in part, from the information furnished by the manager of the Ainslie tile-works, and reduced to a tabular form by the Court's assistant-surveyor, Mr. Gotto. The Committee are assured that, if kilns and works be provided under the Commission, the production of goods at the prices therein stated may be obtained by contract for management with a manager, who will, for a rate of per-centage on the quantity manufactured, produce good pipes according to a specimen at the prices therein set forth. Apart from any peculiar advantages derivable from the Ainslie tile-kilns, and supposing that the prices there set forth were varied to the extent of fifty per cent., the results furnished by the system of piece-work or contract work proposed, appears to be such as there is no prospect of obtaining in any other method.

"The analysis of the prices of labour and material in making tubular drain-pipes, shows grounds for the expectation of the production, at immensely reduced prices, of articles of at least equal construction to the pipe-drains at present commonly sold. The stoneware material of the pipes commonly sold in London is of very high quality, vitreous, impermeable, and strong. Its chief use was for the manufacture of bottles for holding spirituous liquors, ginger beer, soda water, &c. The vitreous qualities in the higher degree adapt the stoneware more for water-pipes at high pressure than for drain-pipes, or at least for the larger sizes, which, it appears, may be made as exact in *form*, and smooth in surface, of well-selected red clay as of the stoneware material. The experiments made on the flow of sewer-water through glass pipes tend to show that smoothness of surface is a very inferior quality to rectitude of form. The burning for the glazing of earthenware pipes is very apt to injure their quality. The red earthenware pipes admit of a glaze, but it does not at present appear for the pipes of the larger sizes to be worth the expense.

"The durability of earthenware pipes, especially of those which are alternately wet and dry, and are exposed to frost, is to a great extent as their permeability. If they be lightly baked, and of a sandy clay, they may be expected to chip and fall away, and be as perishable as badly-constructed garden-pots. Red earthenware drain and water pipes have, however, been taken out of the ground several centuries old. The red earthenware Roman tiles, made of the clay in this country, their bricks and flues, are found in good preservation at this time. If red earthenware pipes be made only of the same clay of which the bricks are made which are used in the construction of sewers, from the process used, from the thickness of the clay being less, the earthenware pipes will be better burnt, harder, and more durable than the brickwork. Mr. Roe has expressed a confident opinion that pipes properly made of the London clay will be as good and useful pipes for the construction of drains as those commonly made of stoneware in London.*

"Specimens of red earthenware pipes, of a close impermeable texture and smooth surface, have been presented, which appear to be of a superior quality. Amidst the various qualities of clay, some appear to be peculiarly adapted to the purpose. Clays, it is stated, may be obtained at an expense of 6*s*. per ton. In calculating the prime cost of the manufacture of earthenware pipes, a selected description of clay is estimated for. It is recommended, that specimens should be sought and tried. It will be seen that the estimates will admit of considerable additions, not only for select clays, but for extra care in its preparation, and in the whole process of the manufacture, for omissions, errors, and contingencies, even if the ultimate cost were more than doubled; important reductions may, there is fair reason to expect, be made, as compared with all the lists at present sent in.

"The contrast at present stands thus, in respect to the larger sized pipes, which are of first-rate importance, as superseding, for all perhaps except valley lines, expensive lines of sewer, such as cost from 15*s*. to 25*s*. per foot, or from 3,960*l*. to 6,600*l*. per mile.

| ——— | Present price offered according to tenders sent in from private tradesmen. | Estimated expense of production by contract, by works and machinery found by the Commission. |
|---|---|---|
| | £ s. d. | £ s. d. |
| Per 1,000 feet of 16-inch earthenware pipe, 1 inch thick - - | 125 0 0 | 16 2 6 |
| Per mile - - - - | 660 0 0 | 85 2 9 |

"The expense of stoneware glazed pipes, 16 inches diameter, at the price at which they are at present furnished to the Commission, would be 135*l*. per 1 000 feet, or 712*l*. per mile; so that, as compared even with the price of executing such work, it appears to be practicable to save, by the system proposed, at the rate of 600*l*. per mile,—or allowing for extra expense in the selection of clays, and the manufacture and contingencies, say from 500*l*. or 400*l*. per mile. Any such saving, if realized in any proportion to the extent estimated, would admit of extension of improved sewerage works and means of relief at a rate never hitherto contemplated. Thus an example was given in a report by Mr. Hale of the drainage of upwards of 900 houses of the first class with one 12-inch drain-pipe. A 16-inch pipe would apparently have carried away extraordinary floods of storm-water from such an area. Mr. Gotto was requested to estimate what would be the expense of similarly laying down a mile of 16-inch pipe in an old sewer, with junctions of 4-inch branch pipes to every house-drain made good.

* All this is dependent on making them as impermeable as the stoneware pipes, either by glazing or burning.

"He estimates that the expense would be 254*l.* 14*s.* 5*d.* per mile. (*Vide* Appendix.) In many situations such a line of pipe would keep the sewer entirely clear of deposit, and, so far as the sewer itself was concerned, clear of smell, and greatly diminish, if not prevent, the circulation of foul gases from the house-drains through the sewers. According to the report of Mr. Lovick, the present expense of flushing in some districts is 2*l.* 10*s.* per mile per week, and the average expense throughout the new district is 29*l.* per annum per mile. This rate is, however, deemed to be owing to old accumulations now in course of removal. Even in the Holborn and Finsbury division, where the flushing is regular, the expense of keeping the sewers clean by flushing, averages, even with piece-work, 12*l.* 5*s.* per mile per annum. Now the annual expense of a mile of earthenware tubular sewer, constructed as above, and to keep itself clear, as in the example given by Mr. Hale, but allowing for a 16-inch pipe instead of a 12-inch, at 20 years payment, would not be more than 19*l.* 8*s.* 5½*d.* per mile per annum. Under the flushing system, in the least uncleanly sewers district, the expense of flushing represents, at 8*d.* per load, the present expense of removal of 517 loads of detritus and decomposing refuse, spread in portions over a mile of surface three feet wide on the average, until it is removed at weekly and fortnightly intervals. At an extra expense of 2*l.* 3*s.* in the best-conditioned district, the retention and spreading of the 517 loads may be prevented in streets where there happens to be a sufficient fall.

"Mr. Gotto has been requested to examine what, on the same data, would be the saving practicable in the construction of the connected works of gully-shoots, made with materials obtained on the contract system by the Commissioners, as contrasted with the recent and present expense of such works in the Metropolis. From this table it appears that the price of gully-shoots was :—

| | Price each. £ | s. | d. |
|---|---|---|---|
| As constructed in the city - - - - - - - | 12 | 16 | 10 |
| As constructed in the Westminster district in 1839 - | 7 | 17 | 6 |
| Ditto in 1845 - - - - - - - - - - | 4 | 4 | 11 |
| Of 9-inch stoneware pipe at the present time in the Westminster district - - - - - - - - | 3 | 17 | 0½ |
| Of 6-inch stoneware pipe at the present time in ditto - | 3 | 5 | 4 |
| As they may be constructed of red earthenware pipe, 6 inches in diameter - - - - - - - | 1 | 10 | 3 |
| As they may be constructed of 4-inch earthenware pipe, by contract, under the Commissioners - - - - | 1 | 7 | 5 |

"The proposed reduction of the price of gully-shoots will be of great importance for suburban road drainage and road construction.

"In addition to the earthenware pipes required for house and general drainage, it appears that there will be need for large quantities of bricks for arching over large watercourses, also for side entrances, and for other connected works. The Commission is entitled to an exemption of duty for bricks used for such purposes, and which are marked with the word 'drain.' This economy the previous Commissions do not appear in any one instance, in any one district, to have thought worth the trouble of effecting by getting bricks made expressly for the purpose. There is reason to believe that, apart from the exemption from duty, bricks may be made hollow for the purposes of the Commission with great advantage.* The attention of the General Purposes Committee was some months ago directed to the subject, and Mr. Roe was ordered to get specimens made

* The duty is now repealed.

and tried. He states that the larger brickmakers have expressed their belief that hollow bricks may be made about one third cheaper than the common bricks. He has had samples made of various shapes for arch-work, and some of them are made in preparation for trials. Such trials as have been made show that the hollow brick constructions will be superior to the common brick in strength. If made by contract under the Commissioners on the same principle as the earthenware tubes, the prospect of economy to the ratepayers is very large indeed. Mr. Gotto has been directed to make estimates of the comparative prices, and he gives the following, of a mile of watercourse sewers six feet wide, to be arched over, supposing the bricks to be in both cases free of duty:—

| | | | |
|---|---|---|---|
| One mile of 6-feet arch, of 9-inch stock brick - - | £384 | 10 | 0 |
| The same might be constructed of hollow brick for - | 220 | 10 | 0 |
| Gain per mile by the use of hollow brick - - | £164 | 0 | 0 |

"Mr. R. Rawlinson, one of the Superintending Inspectors of the General Board of Health, has built of hollow bricks one of the largest roofs recently constructed in Europe, 196 feet long by 64 feet wide. He states that by the substitution of hollow bricks he gained in strength, and he saved upwards of 300 tons in weight. Some apprehensions having been expressed as to the strength of these bricks made hollow, of common clay, and of the common size, he tested them with 15 tons of weight.

"He has made a highly important table, given in the Appendix, of the relative cost of the hollow brick and the solid brick construction. From this table it will be seen that in some of the forms, the advantages of the hollow brick construction are very great for walls and partitions.

| | | | |
|---|---|---|---|
| The present expense of constructing side entrances on the plan of those made by Mr. Roe, including iron work, is - - - - - - | £16 | 6 | 0 |
| The same, with hollow brickwork, would be, as estimated by Mr. Gotto - - - - - | 10 | 18 | 0½ |
| Gain by the use of hollow bricks - - - | £5 | 8 | 0 |

"As from the unanimous opinions of the consulting engineer and the surveyors, and from the lists sent in from tradesmen, it appears that there is no reasonable probability of obtaining early in the market the articles in question so cheaply as they appear to be obtainable by contract under the Commission, it is recommended to the Court—

"That a sum of 300*l*. be placed at the disposal of the Works Committee for the construction of one set of the Ainslie kilns, machines, and a drying shed.

"That the Works Committee be authorized to engage a manager of the works, to be paid by a commission not exceeding 5 per cent. on the quantity of good wares he produces, according to a specimen to be agreed upon, at the scale of prices estimated in Mr. Gotto's table.

"That to give the manager a further interest in carrying out further improvements, an arrangement be made with him that his rate of percentage shall increase with any improvements he may make in the qualities of the articles in comparison with the specimens, or with any reduction in their prices."

COST at which TUBULAR DRAIN-PIPES were manufactured in these Experiments.

| Size of pipes, inches in diameter. | Materials. | | Cost of materials, labour, and burning, per 1,000 feet. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Clay. | Coals, 1 cwt. to a ton of clay. | Cost of clay, say at 7*s*. per ton, including royalty, digging, &c. | Labour in pugging, &c., at 2*s*. per ton. | Labour in moulding, carrying to drying shed, and attendance during drying. | Cost of coals, at 20*s*. per ton. | Extra for management, kiln-rent, waste, labour, packing, and drawing kiln. | Total primecost per 1,000 feet in the field. |
| | ton. cwt. lbs. | cwt. | £ *s*. *d*. | *s*. *d*. | £ *s*. *d*. | *s*. *d*. | £ *s*. *d*. | £ *s*. *d*. |
| 5 | 4 0 20 | 4 | 1 8 0 | 8 0 | 1 0 0 | 4 0 | 1 10 0 | 4 10 0 |
| 6 | 5 15 0 | 5¾ | 2 3 0 | 11 6 | 1 8 9 | 5 9 | 2 3 1 | 6 9 4 |
| 7½ | 6 16 70 | 6¾ | 2 9 9 | 13 7 | 1 14 2 | 6 9 | 2 12 0 | 7 16 1 |
| 8½ | 8 18 50 | 9 | 3 2 5 | 17 10 | 2 4 8 | 9 0 | 3 7 0 | 10 0 11 |

TABLE contrasting the PRICES of TUBULAR DRAIN-PIPES. Fifty per cent. is here added to the prices in the foregoing table, for profit, carriage, &c.

| Size of pipes, inches in diameter. | Lengths. | Red earthenware pipes, if made by contract. | Red earthenware pipes, at the present sale prices. | Stoneware glazed, at the present sale prices. | Average gain | |
|---|---|---|---|---|---|---|
| | | | | | On red earthenware pipes, if made by contract, over the present prices. | On red earthenware pipes, if made by contract, over glazed stoneware pipes. |
| | | £ *s*. *d*. | £ *s*. *d*. | £ *s*. *d*. | £ *s*. *d*. | £ *s*. *d*. |
| 5 | Per foot - | 0 0 1½ | 0 0 5 | 0 0 6 | 0 0 3½ | 0 0 4½ |
| | Per 1,000 feet | 6 15 0 | 20 16 8 | 25 0 0 | 14 1 8 | 18 5 0 |
| | Per mile - | 35 12 9 | 110 0 0 | 132 0 0 | 74 7 3 | 96 7 3 |
| 6 | Per foot - | 0 0 2¼ | 0 0 6 | 0 0 7 | 0 0 3¾ | 0 0 4¾ |
| | Per 1,000 feet | 9 14 0 | 25 0 0 | 29 3 4 | 15 6 0 | 19 9 4 |
| | Per mile - | 51 4 4 | 132 0 0 | 154 0 0 | 80 15 8 | 102 15 8 |
| 9 | Per foot - | 0 0 3¾ | 0 0 9 | 0 1 0 | 0 0 5¼ | 0 0 8¼ |
| | Per 1,000 feet | 15 1 6 | 37 10 0 | 50 0 0 | 22 8 6 | 34 18 6 |
| | Per mile - | 79 11 10 | 198 0 0 | 264 0 0 | 118 8 2 | 184 8 2 |

PRICES at which HOLLOW BRICKS could be made under the Commissioners, by the use of improved machinery and kiln.

| Size. | Quantity of material used per 1,000 feet. | | Cost of materials, labour, and burning, per 1,000 feet. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Clay. | Coals at 1 cwt. per ton. | Cost of clay and digging, at 2*s*. per ton. | Labour in working, at 2*s*. 6*d*. per ton. | Labour in making at 1*s*. per ton. | Cost of coals, at 20*s*. per ton. | Double duty. | Extra for management, kiln-rent, waste, labour, packing, and taking out of the kiln, and contingencies. | Total cost per 1,000 feet in the kiln. |
| | tons cwt. lbs. | cwt. lbs. | £ *s*. *d*. | £ *s*. *d*. | *s*. *d*. | *s*. *d*. | *s*. *d*. | *s*. *d*. | £ *s*. *d*. |
| 4 by 4 | 6 13 0 | 6 73 | 0 13 4 | 0 16 7½ | 6 8 | 6 8 | 10 6 | 9 4¾ | 3 3 2½ |
| 5 „ 5 | 7 15 2 | 7 85 | 0 15 6¼ | 0 19 5 | 7 9¼ | 7 9¼ | 10 6 | 10 11 | 3 11 10¾ |
| 6 „ 6 | 8 18 6 | 8 104 | 0 17 10 | 1 2 4 | 8 10½ | 8 10½ | 10 6 | 12 6 | 4 0 11 |
| 8 „ 8 | 12 19 3 | 12 54 | 1 4 11 | 1 11 2 | 12 5¾ | 12 5¾ | 10 6 | 17 4¾ | 5 8 11¼ |

TABLE contrasting the PRICES of SOLID BRICKWORK at the contract price under the Commission, namely, 11*l.* per rod, with Brickwork of Hollow Bricks, if made by contract under the Commission, including the duty in both cases.

| Description of labour, materials, &c. | Quantities. | 9-inch solid brickwork, laid in mortar. | 8-inch hollow brickwork, laid in mortar. | Gain by using 8-inch hollow, instead of 9-inch solid brickwork. |
|---|---|---|---|---|
| | | *s.* *d.* | *s.* *d.* | *s.* *d.* |
| Bricks - - - - | Per sq. yard | 2 10¼ | — | — |
| Labour, carriage, &c. - - - | " | 1 2 | 0 8 | — |
| Mortar - - - - | " | 0 10 | 0 6 | — |
| Cost of hollow bricks, if made by contract under the Commission - - - | " | — | 1 5½ | — |
| Total - | " | 4 10¼ | 2 7½ | 2 2¾ |

TABLE showing the STRENGTH of PIPES made by MACHINE, March 2, 1849.

| Number of Experiments. | Marks. | Bore of pipe, in inches. | Thickness of pipe, in inches. | Length of pipe, in inches. | Weight of pipe, in pounds. | Bursting pressure in lbs. per inch. | Bursting pressure in feet of altitude. | Rolled or not. | Glazed or not. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | H. | 2·812 | ·469 | 20·68 | 8·75 | 420 | 970·2 | Rolled | Unglazed | Smith's fine clay. |
| 2 | H. | 2·87 | ·471 | 22·37 | 9·25 | 380 | 877·8 | " | " | |
| 3 | H. | 2·87 | ·471 | 22·37 | 9·25 | 280 | 646·8 | " | Glazed | |
| 4 | N. | 2·68 | ·472 | 21·0 | 7·75 | 180 | 415·8 | Unrolled | Unglazed | Smith's fine clay. |
| 5 | N. | 2·7 | ·473 | 21·5 | 7·89 | 170 | 392·7 | " | " | |
| 6 | N. | 2·69 | ·471 | 21·3 | 7·9 | 200 | 462·0 | " | " | |
| 7 | A. | 2·75 | ·468 | 21·5 | 8·12 | 140 | 323·4 | Rolled | " | Smith's coarse clay. |
| 8 | A. | 2·75 | ·468 | 22·31 | 8·25 | 270 | 623·7 | " | " | |
| 9 | B. | 2·75 | ·468 | 22·37 | 8·25 | 260 | 600·6 | " | " | |
| 10 | M. | 2·75 | ·5 | 21·37 | 8·25 | 160 | 369·6 | Unrolled | Glazed | Smith's coarse clay. |
| 11 | M. | 2·75 | ·468 | 21·37 | 8·5 | 120 | 277·2 | " | Unglazed | |
| 12 | M. | 2·73 | ·475 | 21·47 | 8·36 | 110 | 254·1 | " | " | |
| 13 | — | 2·375 | ·656 | 23·12 | 12·25 | 660 | 1,524·6 | Rolled | Glazed | Smith's fine clay. |
| 14 | — | 2·375 | ·656 | 22·75 | 12·25 | 360 | 831·6 | " | " | |
| 15 | — | 2·375 | ·630 | 24·12 | 12·75 | 500 | 1,155·0 | " | " | |

Averages of the above.

| | | | | | | | | Difference per cent. | |
|---|---|---|---|---|---|---|---|---|---|
| 1 to 3 | 2·8506 | ·470 | 21·806 | 9·083 | 360 | 831·6 | Rolled | 96·36 | Fine clay. |
| 4 to 6 | 2·69 | ·472 | 21·26 | 7·846 | 183·3 | 423·5 | Unrolled | | |
| 7 to 9 | 2·75 | ·468 | 22·06 | 8·206 | 223·3 | 515·9 | Rolled | 71·79 | Coarse clay. |
| 10 to 12 | 2·743 | ·481 | 21·403 | 8·37 | 130 | 300·3 | Unrolled | | |
| 13 to 15 | 2·375 | ·6473 | 23·33 | 12·416 | 506·6 | 1,170·4 | Rolled | — | Fine clay. |

Analysis of the Cubic Contents, Area, Height, and Cost Price of Hollow Tile and Solid Brick.

| No. | Description of Materials. | Thickness of Tile in section. | Dimensions of Common and Hollow Bricks. Inches. Length. | Breadth. | Thickness. | Relative cost per 1,000. | Number of Bricks in one square yard. | Number of square yards in 1,000. | Thickness of Wall in inches. | Net cost of Bricks in one square yard. | Cost of Labour to set one square yard. | Cost of Mortar to set one square yard. | Cost of one square yard set complete. | Remarks. | Extra cost per yard if set in cement. | Cost of one square yard set complete in cement. | Cube inches of space in one square yard. | Cube inches of solid in one square yard. | Weight in lbs. of one Brick. | Weight of 1,000 solid and hollow bricks. | Weight in lbs. of one square yard. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | In. | | | | £ s. | | | | s. d. | d. | d. | s. d. | | d. | s. d. | | | | T. c. q. lb. | |
| 1 | Common brick | – | 9 | 4½ | 3 | 1 10 | 96 | 10⅖ | 9 | 2 10¼ | 9 | 9 | 4 4¼ | Wall one brick or 9 in. thick. | 9 | 5 1¼ | – | 11,664 | 8½ | 3 15 3 16 | 816 |
| 2 | Common brick for partitions. | – | 9 | 4½ | 3 | 1 10 | 48 | 21 | 4½ | 1 5 | 5 | 5 | 2 3 | Wall one brick or 9 in. thick. | 5 | 2 8 | – | 5,832 | 8½ | 3 15 3 16 | 408 |
| 3 | Hollow brick, square on section. | 1 | 12 | 9 | 9 | 5 15 | 12 | 83⅓ | 9 | 1 4½ | 8 | 6 | 2 6¼ | Wall half-brick, or 4½ in. thick. | 6 | 2 8 | 7,056 | 4,608 | 27½ | 12 3 1 6 | 327 |
| 4 | Hollow ditto - | 1 | 12 | 8 | 8 | 4 15 | 13½ | 74 | 8 | 1 3½ | 8 | 6 | 2 5½ | Wall one hollow brick, or 9 in. thick. | 6 | 2 6½ | 5,832 | 4,536 | 23 | 10 5 1 12 | 310½ |
| 5 | Ditto - - | ¾ | 12 | 6 | 6 | 3 10 | 18 | 55¾ | 6 | 1 3¼ | 8 | 6 | 2 5¼ | Wall one hollow brick, or 8 in. thick. | 7 | 2 1¼ | 4,320 | 3,456 | 14 | 6 5 0 0 | 252 |
| 6 | Ditto - - | ¾ | 12 | 5 | 5 | 3 0 | 21¾ | 47½ | 5 | 1 3 | 8 | 6 | 2 5 | Wall one hollow brick, or 6 in. thick. | 8 | 2 5 | 3,132 | 3,348 | 10¾ | 4 15 3 26 | 233¾ |
| 7 | Ditto - - | ¾ | 12 | 4 | 4 | 2 5 | 27 | 37 | 4 | 1 2½ | 8 | 6 | 2 4½ | Wall one hollow brick, or 5 in. thick. | 9 | 2 10 | 1,944 | 3,240 | 7½ | 3 6 3 24 | 202 |
| 8 | Hollow ditto partition tile set on edge. | ½ | 12 | 6 | 2 | 1 10 | 18 | 55¾ | 2 | 0 6½ | 4 | 2 | 1 0½ | Wall one hollow brick, or 4 in. thick. | 4 | 1 4¼ | 864 | 1,728 | 7 | 3 2 2 0 | 126 |

N.B. One square foot of tile one inch thick is taken at 10 lbs. weight.

TABLE showing the COMPARATIVE STRENGTH of PIPES.

| Bore of Pipe, in inches. | Thickness of Pipe, in inches. | Sectional Area of Pipes. | Bursting pressure in lbs. per inch. | Bursting pressure in feet of altitude. | Rolled or not. | Remarks. |
|---|---|---|---|---|---|---|
| 2·8506 | ·470 | 4·903 | 73·41 | 169·6 | Rolled | Fine clay. |
| 2·69 | ·472 | 4·688 | 39·2 | 90·41 | Unrolled | |
| 2·75 | ·468 | 4·732 | 47·2 | 109·07 | Rolled | Coarse clay. |
| 2·743 | ·481 | 4·872 | 26·7 | 61·61 | Unrolled | |
| 2·375 | ·6473 | 6·146 | 82·5 | 190·6 | Rolled | Fine clay. |

TABLE showing the STRENGTH of RED EARTHENWARE PIPES made by the PIPE MACHINE, July 18, 1849.

| Number of Experiments. | Mark. | Bore of Pipe, in inches. | Thickness of Pipe, in inches. | Length of Pipe, in inches. | Weight of Pipe, in pounds. | Bursting pressure in lbs. per inch. | Bursting pressure in feet of altitude. | Rolled or not. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A. | 2·75 | ·5 | 23·125 | 7·437 | 175 | 404·25 | Rolled | Sound to 120 lbs., then the water came through in several places |
| 2 | „ | 2·75 | ·5 | 22·312 | 6·875 | 135 | 311·85 | „ | |
| 3 | „ | 2·625 | ·5 | 20·375 | 6·25 | 110 | 254·10 | Unrolled | Sound to 100 lbs., and then same as No. 1 |
| 4 | „ | 2·687 | ·5 | 20·5 | 6·25 | Unsound | — | „ | |
| 5 | B. | 2·687 | ·5 | 23·5 | 7·5 | 105 | 242·55 | Rolled | |
| 6 | „ | 2·687 | ·5 | 22·25 | 7·25 | Unsound | — | „ | |
| 7 | „ | 2·625 | ·5 | 21·187 | 6·624 | 95 | 219·45 | Unrolled | |
| 8 | „ | 2·625 | ·5 | 17·562 | 5·5 | 50 | 115·50 | „ | |
| 9 | C. | 2·812 | ·5 | 23·25 | 6·562 | 185 | 427·35 | Rolled | |
| 10 | „ | 2·625 | ·5 | 21·5 | 6·062 | 155 | 358·05 | Unrolled | |
| 11 | D. | 2·75 | ·5 | 23·875 | 7·624 | 125 | 288·75 | Rolled | |
| 12 | „ | 2·687 | ·5 | 23·687 | 7·624 | 120 | 277·20 | „ | |
| 13 | „ | 2·687 | ·5 | 21·625 | 6·875 | 95 | 219·45 | Unrolled | |
| 14 | „ | 2·562 | ·5 | 21·25 | 6·562 | 100 | 231 | „ | |

Averages of the above Pipes, &c.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A. | 2·75 | ·5 | 22·719 | 7·156 | 155 | 358·05 | Rolled | 40·9 difference per cent. |
| „ | 2·656 | ·5 | 20·437 | 6·25 | 110 | 254·10 | Unrolled | |
| B. | 2·687 | ·5 | 22·87 | 7·375 | 105 | 242·55 | Rolled | 38·9 „ |
| „ | 2·625 | ·5 | 19·37 | 6·062 | 77·5 | 167·47 | Unrolled | |
| C. | 2·812 | ·5 | 23·25 | 6·562 | 185 | 427·35 | Rolled | 19·3 „ |
| „ | 2·625 | ·5 | 21·5 | 6·062 | 155 | 358·05 | Unrolled | |
| D. | 2·718 | ·5 | 23·78 | 7·624 | 122·5 | 282·97 | Rolled | 25·6 „ |
| „ | 2·624 | ·5 | 21·5 | 6·718 | 97·5 | 225·22 | Unrolled | |

TABLE showing the COMPARATIVE STRENGTH of PIPES, July 18, 1849.

| Bore of Pipe, in inches. | Thickness of Pipe, in inches. | Sectional Area of Pipes. | Bursting pressure | | Rolled or not. |
|---|---|---|---|---|---|
| | | | in lbs. per inch. | in feet of altitude. | |
| 2·75 | ·5 | 5·105 | 30·3 | 70·1 | Rolled. |
| 2·656 | ·5 | 5· | 22· | 50·82 | Unrolled. |
| 2·687 | ·5 | 5·007 | 20·9 | 48·4 | Rolled. |
| 2·625 | ·5 | 4·9 | 15·8 | 34·2 | Unrolled. |
| 2·812 | ·5 | 5·203 | 35·5 | 82·1 | Rolled. |
| 2·625 | ·5 | 4·9 | 31·6 | 73· | Unrolled. |
| 2·718 | ·5 | 5·1 | 24· | 55·4 | Rolled. |
| 2·624 | ·5 | 4·8 | 20·3 | 46·9 | Unrolled. |

TABLE showing the Delivery of Water through Red unglazed Pipes, compared with glazed Stoneware.

| Description of Pipe. | Inclination. | Time to discharge 25 Cubic Feet. | Height of Water above Top of Pipe. | Diameter of Pipe. | Cubic Feet per hour. | Velocity per second. | Stoneware compared with the Red Pipe. |
|---|---|---|---|---|---|---|---|
| | | m. s. | Inches. | Ft. In. | | Feet. | |
| Glazed stoneware | 1 in 60 | 2 0 | 3 | 0·24 | 750· | 4·9 | – |
| Red-ware rolled, B. | " | 2 18 | 3 | 0·23 | 652·17 | 3·72 | 5 to 4·34 |
| Red-ware, B. - | " | 2 48 | 3 | 0·23 | 535·71 | 3·06 | 5 to 3·57 |
| Red-ware rolled, D. | " | 2 28 | 3 | 0·23 | 608·1 | 3·47 | 5 to 4· |
| Red-ware, D. - | " | 2 46 | 3 | 0·23 | 542·1 | – | 5 to 3·61 |

The Pipe in the above experiment was fully charged.

EXPERIMENTS with the same Pipe running half full.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Glazed pipe - | 1 in 60 | 4 16 | Water level with head of pipe | – | 351 | | |
| Red-ware rolled, B. | " | 5 58 | " | – | 251 | – | 5 to 3·52 |
| Red-ware, B. - | " | 6 34 | " | – | 228 | – | 5 to 3·24 |
| Red-ware rolled, D. | " | 6 15 | " | – | 238 | – | 5 to 3·39 |
| Red-ware, D. - | " | 7 15 | " | – | 206 | – | 5 to 2·93 |

TABLE showing the STRENGTH of PIPES gained by a Second Pressure with Machine, when partially dried.

| Number of Experiments. | Mark. | Bore of Pipe, in inches. | Thickness of Pipe, in inches. | Length of Pipe, in inches. | Weight of Pipe, in pounds. | Bursting pressure in lbs. per inch. | Bursting pressure in feet of altitude. | Rolled or not. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | S | 2·718 | ·5 | 21·56 | 7· | 37·5 | 86·62 | Unrolled | Smith's Red Clay. |
| 2 | S | 2·687 | ·463 | 21·68 | 7·09 | 40· | 92·40 | " | |
| 3 | S | 2·765 | ·49 | 21·5 | 7· | 35· | 80·85 | " | |
| 4 | C | 2·75 | ·5 | 21·55 | 7·33 | 45· | 103·95 | Rolled | Smith's Red Clay. |
| 5 | C | 2·609 | ·487 | 21·36 | 7·26 | 90· | 207·90 | " | |
| 6 | C | 2·718 | ·496 | 21·68 | 7·31 | 75· | 173·25 | " | |
| 7 | D | 2·812 | ·531 | 21·5 | 7·75 | 30· | 69·30 | Unrolled | Reading Red Clay. |
| 8 | D | 2·95 | ·531 | 21·68 | 7·8 | Unsound | — | " | |
| 9 | D | 2·875 | ·535 | 21·7 | 7·79 | Unsound | — | " | |
| 10 | D | 2·875 | ·531 | 21·7 | 7·76 | 40· | 92·40 | " | |
| 11 | D 1 | 2·87 | ·521 | 21·75 | 7·89 | 45· | 103·95 | Rolled | Reading Red Clay. |
| 12 | D 3 | 2·86 | ·523 | 21·73 | 7·9 | 80· | 184·80 | " | |
| 13 | D 4 | 2·89 | ·53 | 21·75 | 7·85 | 65· | 150·15 | " | |

Averages of the above Pipes, &c.

| | | | | | | | | Difference per cent. | |
|---|---|---|---|---|---|---|---|---|---|
| 1 to 3 | 2·723 | ·486 | 21·58 | 7·03 | 37·5 | 86·62 | Unrolled | 86·6 | Smith's Red Clay. |
| 4 to 6 | 2·692 | ·494 | 21·53 | 7·30 | 70· | 161·70 | Rolled | | |
| 7 and 10 | 2·843 | ·531 | 21·6 | 7·75 | 85· | 80·85 | Unrolled | 80·9 | Reading Red Clay. |
| 11 to 13 | 2·873 | ·524 | 21·74 | 7·88 | 63·3 | 146·30 | Rolled | | |

TABLE showing the COMPARATIVE STRENGTH of PIPES.

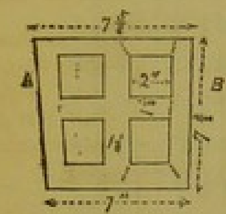
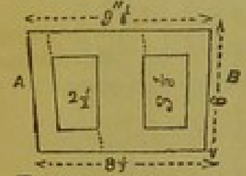
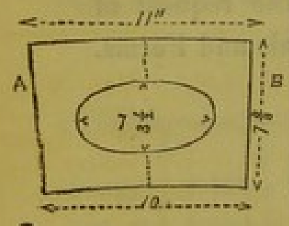
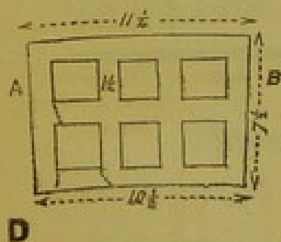
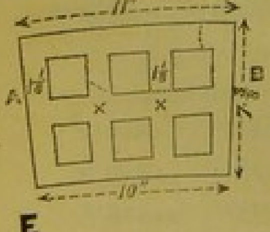
| Bore of Pipes, in inches. | Thickness of Pipes, in inches. | Sectional Area of Pipes. | Bursting pressure in lbs. per inch. | Bursting pressure in feet of altitude. | Rolled or not. | Remarks. |
|---|---|---|---|---|---|---|
| 2·723 | ·486 | 4·900 | 7·65 | 17·7 | Unrolled | Smith's Red Clay. |
| 2·692 | ·494 | 4·944 | 14·2 | 32·73 | Rolled | |
| 2·843 | ·531 | 5·628 | 6·23 | 14·39 | Unrolled | Reading Red Clay. |
| 2·873 | ·524 | 5·592 | 11·3 | 26·2 | Rolled | |

(No. 13.)

RESULTS of EXPERIMENTS made by Messrs. Burton, at the request of Mr. Roe, to try the Strength of Blocks of various Materials and Forms.

(No. 13.)

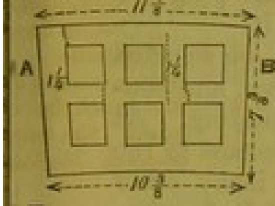
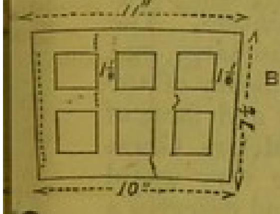
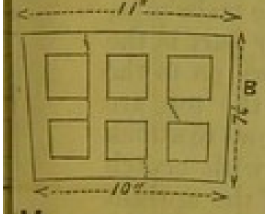
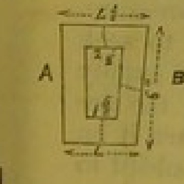
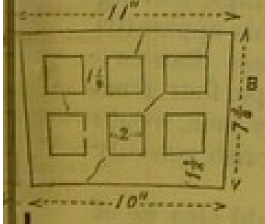
RESULTS of EXPERIMENTS made by Messrs. Burton, at the request of

| SIZE AND FORM OF BLOCK. | Number of Experiments. | Length of Block, in inches. | Weight of Block, in pounds. | Total Area. | Area through A B. | First Crack, in tons. | Total Weight to crush. Tons. | Weight per inch for total area, in pounds. | Weight per inch at AB, in pounds. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
|  A | No. 1. | 13¼ | 33½ | 105·5 | 44·7 | 5·6 | 9·7 | 214 | 486 | Staffordshir Clay, or Terr Metallic. Direct weight o this Block for 4 hours. Not quit crushed. *See Not* |
|  B | No. 1. | 14 | 40 | 127·7 | 53·3 | 6·15 | 183·6 | 3,220 | 7,716 | Staffordshir Clay, or Terr Metallic. |
|  C | No. 1. | 15 | 58 | 165 | 52·5 | 2·0 | 4·4 | 59 | 187 | Concrete. Stones in ditt large. |
| | No. 2. | 15 | 56½ | 165 | 52·5 | 1·74 | 3·76 | 51 | 160 | |
|  D | No. 1. | 15⅛ | 68 | 170·1 | 75·6 | 3·7 | 9·85 | 129 | 291 | Concrete. Stones in ditt large. |
|  E | No. 1. | 14⅞ | 54½ | 163·6 | 66·9 | 6·1 | 85·9 | 1,176 | 2,876 | Where marked thu (×) cracked at starting. Light-coloured Fire Brick |

*Note.*—From the very great difference in the weight required to crush the two Blocks, **A** and **B**, i is to be inferred that the Block **A** was imperfect, although no defect was observable.

(No. 13.)

Mr. Roe, to try the Strength of Blocks of various Materials and Forms.

| SIZE AND FORM OF BLOCK. | Number of Experiments. | Length of Block, in inches. | Weight of Block, in pounds. | Total Area. | Area through A B. | First Crack, in tons. | Total Weight to crush. Tons. | Weight per inch for total area, in pounds. | Weight per inch at AB, in pounds. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
|  F | No. 1. | 13¼ | 58 | 147·4 | 66·2 | 73·4 | 150·3 | 2,284 | 5,085 | Flew to pieces. Light coloured Fire Brick, but not the same make as E. |
|  G | No. 1. | 17½ | 65 | 192·5 | 78·7 | 24·2 | 159·3 | 1,853 | 4,534 | Flew to pieces. Hard Stoneware. |
|  H | No. 1. | 17½ | 69 | 192·5 | 78·7 | 18·6 | 104·1 | 1,211 | 2,962 | Hard Stoneware, of a lighter colour than the last. |
|  I | No. 1. | 9 | 15 | 37·1 | 19·1 | 5·7 | 42·6 | 2,569 | 4,496 | Staffordshire Clay, or Terro Metallic. |
|  J | No. 1. | 9 | 36½ | 99 | 40·5 | 11·3 | 45·7 | 1,034 | 2,527 | Stoneware. Very open. |

The small dotted lines on the Sketches in the margin are to show where the Blocks first cracked.
The letters in the margin refer to the pieces of material accompanying this report.

(No. 14.)

TRIAL WORKS in respect to STREET CLEANSING by the use of the FLEXIBLE HOSE and the WATER JET.

*Extract from a Communication by Mr. Lee, Superintendent Inspector, describing Trial Works for Improved Street Cleansing, conducted by him at Sheffield:—*

"Messrs. Guest and Chrimes, of Rotherham, are patentees of a tap for the discharge of water at high pressures. They called upon me in February last, with an adaptation of their invention to the purpose of a fire-plug and stand-pipe, and expressed a wish to make an experiment with it.

"As their object was to show its powers to extinguish fires, we selected Church-street, one of the most public thoroughfares in the town, and containing the hall of the Corporation of Cutlers, a rather lofty building. At my request, the apparatus was applied with the most perfect success to the cleansing of the street; the Mayor, the Town Regent, and many other influential persons were present. The hose was of leather, 3 inches diameter, and about 60 yards long, with a discharge-pipe $1\frac{1}{4}$ inch diameter. The carriageway is from 20 to 24 feet wide, and about 150 yards long. It was washed almost as clean as a house-floor in five minutes. The surface of the reservoir is 350 feet higher than the point of discharge, and 2,557 yards distant from it. The time occupied, and the efficacy of the cleansing experiment, depended, of course, upon the quantity and force of the water, and not, to any material extent, upon the use of Messrs. Guest and Chrimes's stand-pipe. The apparatus will, however, be very useful where a constant supply of water at high pressure is given, and deserves a brief description.

"It consists of two parts; one of which, containing a female screw and closed valve, is to replace the common fire-plug, to be fast to the main pipe, and to be covered, when not in use, by a metal cap. The other part is the stand-pipe—a copper cylinder about 2 feet long, which screws on to the fire-plug. On the sides of the cylinder, about 6 inches from the top, are two arms at *right angles*, and each about 4 inches long, with screws to attach the hose. A screw piston about half an inch in diameter, with crutch handle, working in a stuffing-box, passes through the centre of the upright cylinder, and opens or shuts the valve of the fire-plug. Its advantages are, that it can be applied to the mains, and used with great readiness, without the assistance of the turncock, at any amount of vertical pressure. With the ordinary plug it is necessary, on the discovery of a fire, to seek the turncock, who is obliged, if the mains are full and a constant supply given, to seek the nearest main-tap, and turn of the water until the fire plug is opened and the hose attached, and then to go back and turn it on again. In the midst of the confusion much valuable time is thus added to that already lost in procuring the engines, and the jet is at last directed, as a matter of prudence, to the preservation of adjoining buildings, leaving that in which the fire originated to certain destruction. If this apparatus were at hand, two men could have it in full operation in less than two minutes. By a slight increase in the diameter of the stand-pipe, four arms might be connected with it, and four jets, managed by as many men, would throw into any building torrents of water sufficient to extinguish speedily any fire that had not been long raging.

"It will be obvious that this saving of time and labour would also be of great importance as affecting the cost of any system of public cleansing by the agency of water. In consequence of the gradual opening and closing of the valve there is much less danger of bursting the hose by a sudden rush of water, or of damage to the pipes by its recoil, than with any other apparatus I have seen. The wear and tear of hose under great pressure must be a considerable item in *any* system of public cleansing. In extinguishing fires the hose is frequently burst, and before other hose can be attached, irreparable mischief is done by the raging element.

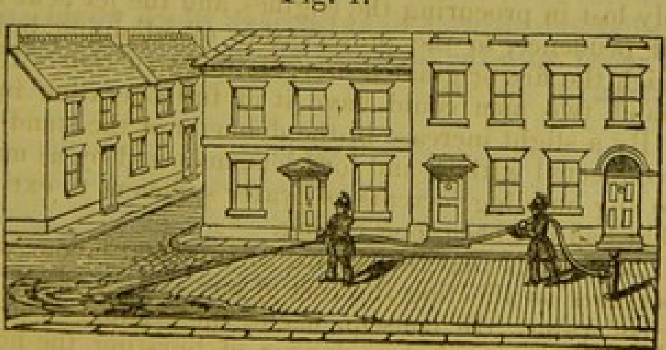
"This, therefore, is a great advantage possessed by the apparatus in question.

"A serious defect in Messrs. Guest and Chrimes's invention is, that the water has to pass one right angle at the fire plug, and another at the insertion of the arm in the stand-pipe. The time necessary for the discharge of a given quantity of water through a straight pipe being 1, the time for an equal quantity through a pipe of the same length and diameter, having a curve of 90°, would be 1·11, and with a right angle, 1·57. Two right angles would therefore increase the time to 2·464. As the *quantities* of water discharged in equal times by the same orifice, with the same length and form of pipes, under different pressures, are nearly as the square roots of the corresponding pressures; so, the *times* during which equal quantities of water are discharged, under the same circumstances, are nearly in the inverse ratio of the square roots of the corresponding pressures. Consequently, with the same discharge, from the same orifice *under the same vertical head*, and with a pipe of equal length and form, *a given increase of time* will indicate the amount of retardation due to any flexures, curves, or angles of the pipe. And, the retardation caused by any such flexures, curves, or angles in the pipe, *will be equivalent to a certain diminution of the vertical pressure*, easily ascertained. In the experiment in question, the jet from a $1\frac{1}{4}$ inch discharge-pipe with 350 feet pressure rose only to about 60 feet vertical height, in consequence of the two right angles in the apparatus.

"The time for a straight pipe being, as already stated, 1, two curved junctions would have only increased it to 1·23, while the right angle prolonged it to 2·464. The form of the pipe therefore becomes most important in any system of street-cleansing, not only as to the direct economy of time and labour, but also in reference to the power of the water in effectually removing the refuse.

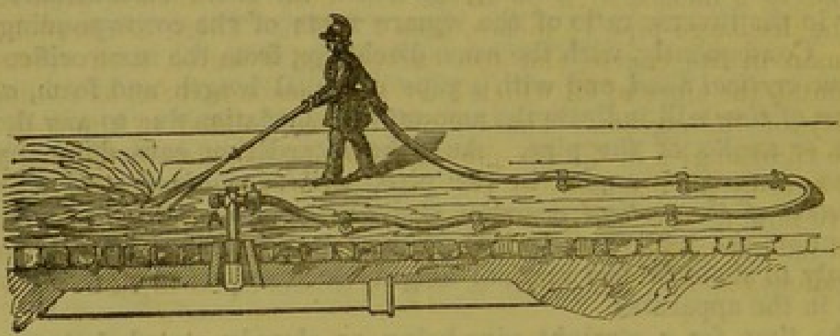
"The form of the pipe is no less important when applied to the extinguishing of fires, because with curved junctions, not only will the jet rise to nearly twice the height, under the same pressure, but the hose and stand-pipe will be available without fire-engines, under about half the vertical pressure necessary with right angles; and, not the least consideration is, that with an equal pressure, nearly double the quantity of water would be impelled to the same height in a given time. I suggested to Messrs. Guest and Chrimes the substitution of curved junctions, and pointed out these advantages, and am glad to hear they are about to adopt my recommendation.

Fig. 1.



"Sketch No. 1 shows the manner in which the experiment was performed, which was clumsy enough, but the best that could be adopted under the circumstances. The hose was stretched from the stand-pipe up the street, and the foreman having placed the end of the hose upon his shoulder with the discharge-pipe pointing to the pavement, at a distance of abont nine feet before him, the plug was opened, and he commenced walking down the street, moving the jet slightly from side to side. The weight and rush of the water through the hose was, however, too much for one man, and he was therefore assisted by a second, taking up the hose in a similar manner, and walking at a distance of two or three yards behind him. The work was laborious, but I have no doubt that with the substitution of curved junctions to the stand-pipe, giving a greater force to the water, and the adoption of some contrivance similar to what I have figured in the sketch No. 2, the work would be done as effectually, even in less time, and with perhaps half the expenditure of physical strength.

Fig. 2.

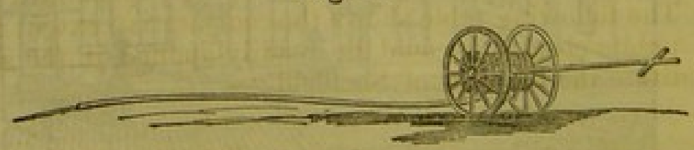


"The sketch shows a series of saddles, to be attached to the hose at regular distances, and moving on small wheels, so as to take off a great portion of the friction which has to be overcome in dragging the full hose along the pavement. The sketch will, I think, explain itself without further remarks, and if it is not the best thing that can be, may lead to something better from a wiser head. This sketch also shows the curved junctions for the fire-plug and stand-pipe.

Plan and sections of saddles.


"The third sketch shows a light carriage which would enable a man to run at great speed with the hose and all the necessary apparatus for extinguishing fires.

Fig. 3.



" It is little more than a wooden drum from 18 to 24 inches in diameter, which can be made either to revolve with the wheels or to remain stationary; it would be further useful in unfolding and folding the hose without loss of time.

" There would be a peg or button upon the drum, to which a loop at the end of the hose nearest the stand-pipe would be attached, and the movement of the carriage, however rapid, along the line of the hose, would wind it upon the drum. The drum would now be thrown out of gear with the wheels, and the carriage and apparatus removed to another place. On reaching its destination, it will be evident that if the drum be again put into gear with the wheels, and the carriage drawn in a contrary direction to the former, the hose will be unwound and ready to be attached to the stand-pipe without delay.

" We now come to consider the quantity of water necessary for public cleansing with the hose and jet. The line of pipes leading to Church-street, used for the experiment, is 12 inches in diameter, with an area of 113·097 square inches when it leaves the reservoir. It is afterwards reduced to 9 inches, area 63·617. The hose is 3 inches, area 12·566; and the discharge-pipe 1¼ inches, area 1·2271. There are branches from the main in its course, and also curves and flexures, both vertical and horizontal, the sines of all which have to be accounted for, as reducing the velocity of the stream. These circumstances added to the loss caused by the right angles in the fire-plug and stand-pipe, already alluded to, very much impede the discharge. The quantity of water actually used during the five minutes was 27·19 cubic feet, or about 170 gallons. I am disposed to add half as much more for waste in emptying the hose, &c., making 255 gallons for the 150 yards of street, this is equal to 2,992 gallons per mile.

" I have stated that the jet was in operation for five minutes in cleansing this street. In order to make a safe estimate I allow five minutes more for unfolding and *fixing* the apparatus; five minutes for *unfixing*, &c., and five minutes for removing to the next plug, or point of operation, making altogether 20 minutes for 150 yards in length: equal to rather more than 2½ miles in length per day of 10 working hours. With improvement in the hose and means of transit, such as I have suggested, two men would by sufficient for one set of stand-pipe, hose, and jet, and would probable execute a greater length of work.

" I will now endeavour to apply the data obtained to the cleansing of a town like Sheffield. No one will doubt if two men can with ease cleanse 2½ miles of road per day, *including the carrying away of the refuse*, that this is the most *economical* mode of street cleansing that can be adopted, even if we leave out of consideration, entirely, the fact that the work is done more perfectly by the agency of water than by any other means. All public highways, therefore, in all large towns, ought to be cleansed with the hose and jet as a matter of economy, exclusive of sanitary considerations. Unfortunately it will be long before this is practicable in Sheffield. The roads outside the dense population are numerous, and without either pipes to convey the water, or sewers to remove the refuse. I have been compelled, therefore, to consider the question as a sanitary regulation only, and to confine my estimate to the densely populated part of the borough. The following table shows the comparative extent to which this method of public cleansing could be readily applied in the six townships which constitute the borough of Sheffield:—

| Township. | Total length of Public Carriage-ways. | Length to be cleansed with water three times per week. | Length to be cleansed with water twice per week. | Length to be cleansed with water once per week. | Total length of Public Highways to be cleansed with water. |
|---|---|---|---|---|---|
| | Miles. | Miles. | Miles. | Miles. | Miles. |
| Sheffield - - - | 31½ | 6 | 10 | 9 | 25 |
| Ecclesall Bierlow - | 26¾ | 2 | 6 | 4 | 12 |
| Brightside Bierlow - | 20 | 1 | 1½ | 1½ | 4 |
| Nether Hallam - - | Suppose 10 | 1 | 1 | 1 | 3 |
| Attercliff-cum-Darnall - | " 3½ | - - | 2½ | ½ | 3 |
| Upper Hallam - - | " 12 | — | — | — | — |
| Total in the Borough | 103¾ | 10 | 21 | 16 | 47 |

"Thus, it appears that 47 miles, or nearly half of the public highways in the whole borough might, without difficulty, be effectually cleansed in this manner. Ten miles three times a week, equal 30 miles; 21 miles twice per week, equal 42 miles; and 16 miles once per week; making a total of 88 miles per week, or 4,576 miles per annum. This at 3,000 gallons of water per mile would require 13,728,000 gallons of water per annum. At *one penny* per thousand gallons, the price at which I have shown in the Report on the sanitary condition of Sheffield, an abundant supply of water could be obtained, the quantity necessary for the purpose would cost 57*l.* 4*s.* per annum.

"At 6½*d.* per thousand gallons, the price obtained by the Waterworks Company, the same quantity would amount to 371*l.* 16*s.* per annum.

"I now proceed to the cost of labour:—4,576 miles per annum is equal to 14⅝ miles for each working day, or to six sets of two men cleansing 2½ miles per day each set. To these must be added three horses and carts, and three carters, for the removal of such debris as cannot be washed away, and for such parts of the town as cannot be cleansed by this system, making a total of 15 men. Their wages I would fix at 50*l.* per annum each. Taking into account, in addition, the cost and repair of hose, horses and carts, &c., the estimate given at page 110 of the report already alluded to is correct. It is as follows:—

| | £ | s. | d. |
|---|---|---|---|
| Annual interest upon the first cost of hose and pipes, three horses and carts, &c. - - - - - | 30 | 0 | 0 |
| Fifteen men's wages - - - - - | 750 | 0 | 0 |
| Three horses' provender - - - - | 150 | 0 | 0 |
| Wear, tear, and depreciation of hose, &c. - - - | 250 | 0 | 0 |
| Management and incidentals, say - - - | 120 | 0 | 0 |
| | £1,300 | 0 | 0 |

"It is there stated that the estimate is made on the supposition that the water supply was at the public cost. I have no doubt that with the use of canvas hose, the amount allowed in the estimate for wear and tear would more than cover the 57*l.* 4*s.* required for water;—but even with this sum added, the statement in the report would not be affected, namely, that *this would be about an average of one shilling per annum for each house in the borough.*

"The principal thoroughfares could be thus made perfectly clean, three times every week, before business hours, and the minor streets and lanes twice, or once per week, at later hours in the day; by the agency of an abundant supply of water, *at less than half the sum necessary for the cartage alone of an equal quantity of refuse in a solid or semi-fluid condition.*"

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*Extract from an Examination of Mr. Lovick, Surveyor to the Metropolitan Commission of Sewers.*—(Report on the Supply of Water to the Metropolis, 1850.)

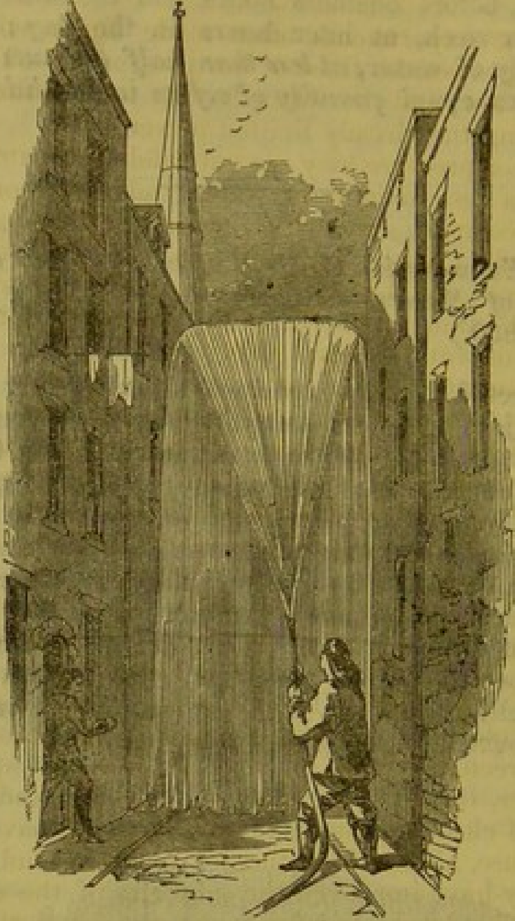
"You were directed to make experiments in cleansing by water by means of the hose and jet; will you state at what place you first carried them on?—Yes; the experiments were first carried on in Charles-street, Old and New Compton-streets, Church-passage, Dean-street, and Greek-street, Soho; subsequently in Church-lane, and four courts in Saint Giles's.

"Were you not able not only to cleanse the pavements by this means, but also to cleanse the walls from urine stains and other filth?—Yes.

"You were directed to prepare a sketch to show how the same plan can be carried out in courts and alleys. Give it in?—The sketches which I now hand in show the jet in operation. No. 1 is an illustration of the mode of surface-cleansing; No. 2, of the method of using the jet as a shower in close courts and alleys.

No. 1.

No. 2.



" State the quantity of water used each time, and the expense ?—The quantity of water used was nearly one gallon per square yard ; the cost was at the rate of 9*d.* per 1,000 yards, taking the cost of water on Mr. Wicksteed's estimate.

" Then it is clear from your reports that, in respect to the economy of time and of money, it is superior and is more efficacious in removing surface-evaporating matter or filth than any other method ?—In a report to the Commissioners of Sewers I have estimated that the cost of the ordinary scavengering would be nearly double the cost of cleansing by the jet, and the jet has been shown to be far more efficacious in removing evaporating matter and filth.

" You were directed to prepare an estimate of street-cleansing by these modes, as applicable to two large thoroughfares ?—Yes ; I prepared estimates of the cost of cleansing by the jet in the Strand and High-street, Borough.

" Within what time and at what expense did you estimate this could be performed, apart from the cost of the water used ?—The estimates were framed on the supposition that the work should be performed in one hour. In the Strand the daily cleansing of the carriageway would have cost 3*d.* per house per week ; in the Borough, 2¾*d.* per house per week. But this rate is for wide streets with a large amount of traffic, on data from experiments with very low pressures, and is greatly in excess of the ordinary description of works, and would by no means, therefore, be a criterion of the average expense.

" What is the quantity of water required per square yard of pavement ? —The quantity of water required I have found to be rather less than one gallon per square yard of carriageway ; but this was with extremely low pressures.

"Were not the experiments often made under what were considered other disadvantages besides those of low pressures ?—They were ; the pressures being very low, and the water having to pass through a great length of hose, decreasing the already limited power.

"With a higher pressure may we not safely estimate that they might be performed with a less amount of water and in a shorter time ?—Yes ; I had occasion to compare some experiments in cleansing by the jet made by Mr. Lee, of Sheffield, with very high pressures, with my own experiments with low pressures, and I found that he could perform the work in less than one third the time, at one third the cost, and with less than one third the expenditure of water. From this it would appear that the economy of high pressures must be very great.

"What is the quantity that would have been used for the Strand for each complete cleansing ?—By the latest experiments 18¼ thousand gallons.

"In a day of partial rain, when the streets are sloppy and muddy, would not the cleansing by jet be the most eligible mode of cleansing?—The cleansing by jet on those days I consider would be by far the most eligible mode.

"What was the effect in hot weather and at other periods of this new mode of cleansing as compared with the mode of cleansing by scavengering? What was your general conclusion from these experiments as to the effect of this mode of cleansing?—The cleansing by water produced a most perfect state of cleanliness by the removal of *all* decomposing refuse, and the jet, when directed upward in the form of spray, appeared to have the effect of a shower, the air being made much cooler and fresher by it. The ordinary mode of cleansing by scavengering would have failed in removing much of the refuse, all of which the jet removed, and of course could not in any other way have improved the salubrity of the atmosphere. In hot weather these effects were more marked, the jet performing, but in a far more efficient manner, the office of the watering-cart. The ordinary mode of scavengering, without possessing any of the advantages of the jet, performed the work in a most imperfect manner. The system of cleansing by water eminently combined completeness with efficiency of action.

"Even where it might be desirable to use a street-cleansing machine to prevent accumulations of solid dung and the like, would it not be of importance to use the jet also?—In a report upon this subject I have stated the general conditions wherein the combination of the two would be of advantage for this purpose, but that the machine should be auxiliary to the jet, than conversely, as implied in the following passage : 'The frequency of application of this system (cleansing by jet) to the cleansing of the streets would be determined by their specific requirements, some, as the main thoroughfares, requiring daily cleansing, others cleansing at longer intervals. Thoroughfares having a large amount of traffic would require cleansing at an early period of the day ; from this period to the cleansing on the following day the accumulations will have been going on, and the exhalations from them discharging into the atmosphere. It may be necessary to employ measures for the prevention of this condition in conjunction with the systematic operations of cleansing by water. To effect this there are two methods, by sweeping with hand labour, and cartage of the refuse; by the cleansing machine; hand labour, when compared with the cleansing machine, would appear to be the least economical in the proportion, as stated in Mr. Whitworth's evidence, of about three to one. The machine therefore, would appear to be the best adapted for this purpose, and with the least interference with the traffic of the street.'

"What is the total quantity of water, according to your estimate, that would be required for the purpose of street washing by means of the jet? —Assuming that there are 300,000 houses in the metropolis, with an average to each house of paved carriageway 28 square yards, of paved footway 16 square yards (on data afforded by an average district, in the absence of other certain data), the area of carriageway would be, in round numbers, 8½ millions, of footway 4⅘ million square yards. With one gallon of water for each square yard of carriageway (a proportion somewhat greater than I have found in practice with low pressures, and far greater than I believe would be the case with high pressures), and half a gallon for each square yard of footway, the quantity of water required for the *daily* cleansing of these areas would be nearly 11 million gallons, or 65½ million gallons per week, or a rate per house of 218 gallons weekly, or 36½ gallons daily. With a population of 7 to each house the rate would be nearly 5¼ gallons per diem for each inhabitant. Taking the cleansing of the streets in a ratio approximating to their specific requirements, about *one third* daily, *one half* twice, and the remainder *three* times per week, the quantity of water *per diem* would be 6·2 million gallons, or 20 gallons per house, or nearly 3 gallons per diem for each inhabitant. The following tables show the particulars more in detail:—

No. 1.—Of the Carriageway.

| Period of Cleansing per Week. | Quantities to be cleansed at each Period. | Total Quantities cleansed per Week. | Water required, in Gallons. | | | |
|---|---|---|---|---|---|---|
| | | | Per Week. | | Per Diem. | |
| | | | For Quantities cleansed. | Per House. | Per House. | Per Individual. |
| No. | Square yards. | Square yards. | | | | |
| 6 | 2,750,000 | 16,500,000 | 16,500,000 | | | |
| 3 | 1,000,000 | 3,000,000 | 3,000,000 | | | |
| 2 | 4,750,000 | 9,500,000 | 9,500,000 | | | |
| | 8,500,000 | 29,000,000 | 29,000,000 | 96·7 | 16·1 | 2·3 |

No. 2.—Of the Footway.

| Period of Cleansing per Week. | Quantities to be cleansed at each Period. | Total Quantities cleansed per Week. | Water required, in Gallons. | | | |
|---|---|---|---|---|---|---|
| | | | Per Week. | | Per Diem. | |
| | | | For Quantities cleansed. | Per House. | Per House. | Per Individual. |
| No. | Square yards. | Square yards. | | | | |
| 6 | 1,536,000 | 9,216,000 | 4,608,000 | | | |
| 3 | 576,000 | 1,728,000 | 864,000 | | | |
| 2 | 2,688,000 | 5,376,000 | 2,688,000 | | | |
| | 4,800,000 | 16,320,000 | 8,160,000 | 27·2 | 4·53 | 0·65 (nearly.) |

No. 3.—Of the Carriage and Foot Ways.

| Period of Cleansing per Week. | Quantities to be cleansed at each Period. | Total Quantities cleansed per Week. | Water required, in Gallons. | | | |
|---|---|---|---|---|---|---|
| | | | Per Week. | | Per Diem. | |
| | | | For Quantities cleansed. | Per House. | Per House. | Per Individual. |
| No. | Square yards. | Square yards. | | | | |
| 6 | 4,286,000 | 25,716,300 | 21,108,000 | | | |
| 3 | 1,576,000 | 4,728,000 | 3,864,000 | | | |
| 2 | 7,438,000 | 14,876,000 | 12,188,000 | | | |
| | 13,300,000 | 45,320,000 | 37,160,000 | 123·9 | 20·63 | 2·95 (nearly.) |

"It is stated that the quantity of water pumped into the metropolis is 50 million gallons per diem, or at the rate of 200 gallons per house?—It has been so stated."

# GENERAL BOARD OF HEALTH.

MINUTES

OF

INFORMATION

COLLECTED ON THE

PRACTICAL APPLICATION

OF

SEWER WATER AND TOWN MANURES

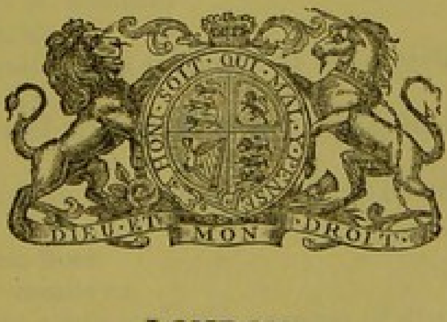
TO

AGRICULTURAL PRODUCTION.

Ordered to be printed for the use of Local Boards of Health and their Surveyors, engaged in the Administration of the Public Health Act.

DECEMBER 1851.

Presented to both Houses of Parliament by Command of Her Majesty.

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FOR HER MAJESTY'S STATIONERY OFFICE.

1852.

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# GENERAL BOARD OF HEALTH.

MINUTES OF INFORMATION on the APPLICATION of SEWER WATER and other Town Manures to AGRICULTURAL PRODUCTION.

THE General Board of Health deem it important to bring under the consideration of Local Boards the chief results of experience collected as to those methods of applying sewer water for agricultural production which appear to be the most profitable,—the least offensive,—and the least objectionable in a sanitary point of view. With this object, and to aid the preparation of practical measures for the distribution of sewage manure in the several towns under the Public Health Act, where plans of combined works for water supply and house and street drainage and for cleansing have been adopted, the Board have collected information, and directed their Inspectors to examine the latest experience of the application of such manure, and of liquid manure generally, to agricultural production. The results of these inquiries will be herein-after set forth for the information of Local Boards on this most essential work, by which eventual reduction of local charges may be effected, to the common benefit of towns and their contiguous agricultural districts.

The general aspect and important sanitary relation of the subject are thus described in the Sanitary Report of 1842:—

"Within many of the towns we find the houses and streets filthy, the air fœtid; disease, typhus, and other epidemics rife amongst the population, bringing in their train destitution, and the need of pecuniary as well as medical relief, all mainly arising from the presence of the richest materials of production, the complete absence of which would, in a great measure, restore health, avert the recurrence of disease, and, if properly applied, would promote abundance, cheapen food, and increase the demand for beneficial labour. Outside the afflicted districts, and at a short distance from them, as in the adjacent rural districts, we find the aspect of the country poor and thinly clad with vegetation, (except rushes and plants favoured by a superabundance of moisture,) the crops meagre, the labouring agricultural population afflicted with rheumatism and other maladies, arising from damp and an excess of water, which if removed would relieve them from a cause of disease, and the land from an impediment to production, and if conveyed for the use of the town population would give that population the element of which they stand in peculiar need as a means to relieve them from that which is their own cause of depression, and return it for use on other land as a means of the highest fertility.—The fact of the existence of those evils, and that they are removable, is not more certain than that their removal would be attended by reductions of existing burdens, and might be rendered productive of general advantage, if due means, guided by science, and applied by properly-qualified officers, be resorted to."

Later investigations of the subject have established two general conclusions applicable to the subject,—that,

> In towns all offensive smells from the decomposition of animal and vegetable matter indicate the generation and presence of the causes of insalubrity and of preventible disease, at the same time that they prove defective local administration:

And correlatively that,

> In rural districts all continuous offensive smells from animal and vegetable decomposition indicate preventible loss of fertilising matter, loss of money, and bad husbandry.

Of the first of these two conclusions any one may convince himself who will visit the spots most frequently afflicted with typhus and other epidemic, endemic, or contagious diseases, where he will find that his own sensations, without any other direction, will commonly indicate the chief seats of insalubrity. Such indications are given by the "sickening," depressing, and deadening sensations produced by breathing air rendered impure by the admixture of organic vapours arising from "decay," as well as by pungent and offensive stinks; for though such stinks always indicate danger, it does not follow that there is no danger when there are no such warnings; the danger is often greater from foul air which less strongly affects the olfactory organs. The main objects of the present paper are, however, to point out the evidence which establishes the latter of the above conclusions, and to state the improvements which have been made in the mechanical means for distributing manures.

In the absence of proper hydraulic works for the drainage of houses and towns, various palliatives of the evils connected with the retention of the refuse beneath or near habitations have been tried, but all those examined are unsatisfactory. The discharge of animal or vegetable excreta from houses through drains into sewers has been objected to abroad on the ground that the discharge of the contents of the sewers into the watercourses or the rivers would, as a necessary consequence, occasion the entire loss of the manure; the manure is therefore accumulated beneath or about habitations. But as conclusive against this practice, it has been established by the sanitary investigations conducted in this country, that if the loss of the manure were total, the pecuniary loss would be trivial compared with the pecuniary loss arising from the excessive sickness and mortality occasioned by the retention of filth amidst habitations. The excessive mortality, with a superior natural climate, which prevails in Paris, Brussels, and other continental cities, is chiefly attributable to their inhabitants living and sleeping in confined habitations, more polluted by the emanations from a greater quantity of cesspool matter retained beneath or amidst them, than in the better portions of London or of English towns in general where the watercloset system has been introduced.

The mechanical and economical disadvantages of the cesspool system are displayed in the Report of Mr. Rammell on an Examination of the Cesspool System of Paris, printed as an appendix to the Board's Report on the Supply of Water to the Metropolis.

As one palliative of the excessive annoyance of emptying cesspools amidst habitations, and of the evils of the retention of the foul matter, the use of moveable and closed receptacles has been tried in several foreign towns; but such receptacles are often ineffectually closed; decomposition of the matter contained in them goes on, and the noxious gases escape. The moveable receptacles mitigate the annoyance from emptying and cleansing the fixed cesspools, but they are causes of numerous inconveniences; and the cost of their construction and action is greater than the expenses of a proper system of tubular drainage. Various palliatives for the evils arising from retention of manures have been tried; chemical agents have been used to disinfect or deodorize them, to fix the ammonia and to arrest decomposition; the value of these deodorizers as disinfectants has been examined, and it has been shown in the Second Report of the Metropolitan Sanitary Commissioners, that even if the constant and proper application of these substances by the public could have been ensured, their complete sanitary efficacy was doubtful, their addition to the manure was often useless or detrimental, (*Vide* Evidence of Dr. Lyon Playfair, 2d report, p. 71 *et seq.*), and, where earths or absorbents were used, the bulk was augmented, the expense of removal increased, and the range for the application of the manure was thereby diminished. In some instances expedients have been tried, by means of air shafts and steam jets, to carry off the products of decomposition, and ventilate the cesspool matter deposited in sewers and covered receptacles; but it has been found that these expedients increase the amount of evaporation, and while they diminish the intensity of the effluvia on the spot, they spread the gaseous impurity more widely amongst habitations, and waste the manure itself.

Whilst none of these expedients have succeeded in the complete removal of the sanitary evils, it appeared from various trial works, that, altogether, they would have cost as much, supposing them to have been practicable on a large scale, as would have sufficed for the execution of a new and complete system of house and town drainage and cleansing, by which the whole of such expedients would have been rendered unnecessary.

The investigations as to the means of overcoming the obstacles to the improvement of the sanitary condition of the population, created by the expense and inconvenience of cleansing by hand labour, have established the conclusion that the refuse of towns is the best received, most completely preserved, least offensively and most quickly and economically removed, by water, in impermeable pipes leading into covered receptacles.

The watercloset with its connected apparatus, even as now commonly constructed, is a cheaper apparatus for cleansing, or rather for keeping clean, houses in towns, than the cesspool with all its attendant expenses.* It has appeared as

* The average quantity of cesspool matter or manure is about two loads per annum per house. The noxious matter must be emptied by hand labour, and is usually carted several miles. The contract price for the cleansing and removal of such matter from cesspools or of deposit from sewers is in the metropolis 10*s*. per ton. The expense of cleansing properly the poorer tenements in London (*Vide* Contractors evidence, Sanitary Report,) averages about 1*l*. per tenement. In some places where the manure is of value the cost of removal falls upon the farmer. In Paris the contract price is from 8 to 10 francs per ton. In general the removal may be effected constantly in the water-closet system, at between 3*s*. and 4*s*. per annum. The results of the investigation made at Paris as to the inherent expenses of the cesspool system are fully corroborated by a Report made to the "Conseil de la salubrité publique de la province de Liège, sur des moyens

a result of the local investigations under the Public Health Act, now comprehending nearly 200 towns, that the principle of the removal of the refuse in suspension in water may be applied universally at a far lower rate of charge than the expense of cleaning cesspools; that until the principle is applied,—until the obstacles created by the expense of hand-labour and cartage in the removal of refuse are overcome,—until cesspools are abolished and all refuse, liable to run into putrefactive fermentation, is constantly removed from amidst habitations,—until the surface-cleansing of the courts, closes, and alleys of the streets and markets in densely-populated districts is effected more quickly,—a marked improvement in the public health of the districts occupied by the majority of the population cannot be expected.

But if cesspools be superseded, and the watercloset system generally introduced, as it has been in large numbers of houses in the metropolis, and in the newly-built portion of Hamburgh since the destructive fire, then as the old practice of engineering converts the rivers into great sewers, the rivers would become more polluted even than those which at present pass through the larger towns.

On the other hand, avoiding the pollution of rivers by the extension of the old practice of cleansing by hand-labour and cartage, and the removal of manures in the solid form to "laystalls," is to surround all large towns with mounds of ordure proportioned to the number of their population, or with establishments like that of the manufacturers of *poudrette* at Paris, which would be a greater evil than the pollution of rivers; while the continuance of that practice implies the continuance, in or near towns, of those numerous smaller collections of putrefying filth from which many of the present evils to the public health arise.

At this stage of the investigation, which brings us to the dilemma either of polluting the waters of the natural streams, by the discharge of the refuse into the nearest watercourses, or of polluting the air by the retention and accumulation of the refuse near to our habitations, we are driven, in the search for the means of relief, to inquire into the necessities of agriculture, and to consider the various

de recueiller et d'utiliser les engrais, qui se perdent dans les grands centres de population, au detriment de la salubrité publique et de l'agriculture. Par J. P. Schmit, architecte, professeur agrégé à l'Université de Liège; Membre du Conseil de salubrité publique de la province, &c. Rapport, fait à la suite d'une circulaire adressée à M. les Gouverneurs des Provinces, sous date du 8 Avril, 1846." Par M. Ch. Regier, Ministre de l'Interieur, 1850. Vide also, Mr. Rammell's Report on the Parisian system; and the Minutes of Information on House and Town Drainage.

means of applying the refuse of towns, suspended or dissolved in water, that is to say, sewer water, as a fertiliser.

The examination of various important examples hereinafter cited establishes the fact, that by the application of manures in the liquid form a degree of continuous and increasing fertility is obtained, such as has been produced by no other method. In 1841, the late Mr. Smith of Deanston was consulted upon the subject, in connexion with the first sanitary inquiry. His recommendation at that time was simply the extension of the Edinburgh method of applying the sewer water of towns by means of water meadows. He proposed to carry the sewage to an outfall, and (where there was not sufficient elevation for its distribution by gravitation) to elevate it by large scoop wheels worked by steam power, and thence to distribute it over the adjacent land, which was to be laid out in tables for its reception, and periodically flooded by the method of water meadows. An account of the Edinburgh practice, and of the extraordinary produce obtained by this method, (indicated by an average rent of twenty pounds per acre,) is given in the recent account furnished to the Board by the Hon. Dudley F. Fortescue, Appendix II. Further experience of the fertilising powers of sewer manure on an extensive scale, —an experience now spread over more than half a century, —is set forth in the account of the irrigation with the sewage of the city of Milan, Appendix V. Other similar examples of the application of sewage manure by the method of water meadows are given in Mr. Lee's Report, Appendix VI.

The examination of the practice of irrigation with sewer water at Edinburgh has brought to notice objections on sanitary grounds to the practice as there pursued, on account of the offensive and no doubt injurious emanations which the sewer water gives off when spread over *and allowed to stand upon* the meadows. The probable evils arising from the emanations from sewer water distributed eight times a year for about twenty-four hours each time, in the vicinity of a town are, however, certainly much less than the constant decomposition and discharge of the emanations *within* a town from badly constructed sewers, and within and beneath habitations, from cesspools, ill-constructed house drains, or from surface accumulations. The emanations from irrigation with sewer water appeared also to be actually much less than from ordinary top-dressings with solid manure, and such as would have escaped notice, as copious emanations do when they are constant instead of intermittent. Moreover, the offensive emanations indicate a proportionate waste of the manure itself, which, when known, will probably be avoided. Much of the offensiveness of which the Town Council of Edinburgh made complaint appeared, however, to arise, less from the irrigation itself than from the open sewers in which the sewer water was conveyed, and the open tanks in which it was improperly retained in a stagnant condition near habitations.

Though injurious effects were very likely to arise from these known causes near Edinburgh, none happened to be proved to have occurred there at the time of the inquiry; whilst it has been proved, in various parts of the country, that fevers have been produced in certain states of the atmosphere amongst the inhabitants of villages and towns by top-dressings in adjacent lands, with decomposing refuse and animalized manures.

Sanitary objections are, however, established to the common irrigations even with plain water, as they are usually conducted, when water is allowed to stand upon the land for any length of time. Mr. Lee, one of the Board's inspectors, in reporting on irrigation by water meadows in Wiltshire, thus states his information in relation to them: "It not only shows, as an agricultural fact, the enormous quantity of water requisite to produce a high state of fertility on the open gutter and bed system of irrigation, but also, that for about half the whole year these meadows are under water. The first 'turn' is during winter, seven days on and seven days off. The second 'turn' in spring, four days on and four days off. The third in summer, three days on and three days off, then three days on and six days off. In every 'turn,' except the last, the periods of irrigation are equal to those during which the water is shut off, but during frost the water is kept on, if possible, altogether. These 'turns' include night and day. The whole of these meadows, therefore, during about half the year, form one large evaporating surface, as much as would be the case if the whole area constituted an immense lake. Even when the water is off, the ground is so saturated that the evaporation must still be going on. No fen or morass in any low-lying, ill-drained district of the country would, I apprehend, impart, area for area, an equal amount of moisture to the atmosphere. The consequence is such as might be expected:—ague is extensively prevalent in this valley, and is in some spots so general that scarcely any of the inhabitants, rich or poor, young or old, escape it.

"The soil of the high lands is chalk, and the winds that sweep over Salisbury Plain are peculiarly dry, and have a large capacity for moisture. Were it otherwise, the disease would be more general through the valley than it now is, while some localities would be uninhabitable. Where the free motion of the air is prevented by trees or other obstacles, there ague is present every year, and its effects may be seen in the dejected, haggard appearance of the inhabitants, and in the contrast between the amounts dispensed as poor-rates in such places and in neighbouring parishes of equal population, but not subject to the influence of malaria.

"I beg leave to recall the attention of your Honourable Board to the striking proof of this, adduced before me in the course of my investigation into the sanitary condition of the parish of Longbridge Deverill, near the town of Warminster, and stated in my Report. In one portion of the parish, the large village of Crockerton, scarcely any of the inhabitants have escaped ague, and on comparing the poor-rates for seven years back with those of the parishes of Corsley and Horningsham, of about equal size, and in the same Union, it is found that the charges for sickness in Longbridge Deverill are nearly double. I quote two brief reports from the medical officer to the Board of Guardians; it will be seen that two years intervened between the former and the latter.

"GENTLEMEN, *Warminster*, 12*th July* 1849.

"In my report to you on Monday last I omitted to state, that I considered the practice of irrigating the meadows at Crockerton below the pond, with the almost stagnant water from the pond, is amongst the causes producing ague in that locality; and I strongly recommend that the meadows be made dry.

"I am, Gentlemen,
"Your obedient Servant,
GEORGE VICARY."

"*To the Board of Guardians*
"*of the Warminster Union.*"

"The other is as follows:—

"GENTLEMEN, *Warminster*, 30*th July* 1851.

"I am sorry to report that Crockerton still continues in a very unsatisfactory state, and I trust that every effort will be made to restore it to a state of health by sanitary measures.

"I am, Gentlemen,
"Your obedient Servant,
GEORGE VICARY."

"*To the Board of Guardians*
"*of the Warminster Union.*"

The injurious effects upon health of the prolonged retention of excessive moisture on a surface of vegetable mould is established by the production of rot amongst sheep—an effect which sheep-feeders have produced by stocking closes just after they had been flooded and whilst they were saturated with moisture.* The Duke of Portland, who had paid attention to the point, says, in some remarks quoted by Mr. Evelyn Denison, in his account of the irrigations near Mansfield, "None of the irrigated meadows can be said to be quite safe for sheep in autumn, not even those which are on the land naturally most dry." He thinks it probable that more complete drainage of the land would decrease the liability to this disease, and, says Mr. Lee, "I believe that such has been found to be the case; but when the ground is so completely saturated as it must be with the open gutter system, I do not think that any arrangements for drainage can obviate all risk."

In respect to Mr. Pusey's irrigations by catchwater-meadows, Mr. Lee says, "Some sheep fed upon this land have become lame. Mr. Pusey says, that opinions are divided as to whether this lameness is attributable to the irrigation or not. I believe, however, that none have rotted. The practice of cutting the second crop, after feeding the first, before turning in sheep again, is a precaution taken to prevent that disease from appearing."

The like facts to those above recited as to the prevalence of ague or other disease common to exposure to marsh miasma, are strongly reported of the neighbourhood of irrigation works in other counties which the Board have had no opportunities of examining. But the general conclusion as to the insalubrity of the common irrigations, and their unfitness for the proximity to towns, is corroborated by the fact that in the Lombardo-Venetian provinces, where there is some of the oldest, most extensive and skilfully conducted irrigation in Europe, the Government has long found it necessary to interfere for the protection of the health of towns. By law, as stated in some information on the subject received from the Government of Milan, "permanent" irrigations are prohibited within five miles distance of towns.†

To obviate the inconveniences and evils established by the investigations as objections against the several common processes, as well against the distribution of manures by the water meadows as against the common dry dressings being conducted near towns and villages, if they could be avoided,—

* *Vide* Dr. R. Harrison's pamphlet, cited Sanitary Report, p. 84.

† The permanent irrigations are there mostly applied to the cultivation of rice. Cases are reported from the irrigated districts of the appearance and disappearance of fevers coincident with the operations of flooding and drying particular tracts of land. It appears, indeed, from extensive experience, that wheresoever water is laid on the land in greater quantities than it can immediately or very soon absorb, or wheresoever there is alternate wetting (in such excess) and drying afterwards, malaria is apt to arise.

Mr. Chadwick suggested the trials of methods of distribution by subterranean irrigation, of which some examples had been collected by him, giving promise for certain descriptions of soils.* Although favourable opinions have been given of the plan, no sufficient trials of it have been made; and it appears to require too large a change of culture to render it expedient to press that method for consideration at the present time; whilst long practical and successful trials have been made of another method of surface distribution of liquid manure, under varied circumstances, on farms of high cultivation in different parts of the country; and it is proved to be as free as garden or horticultural cultivation (to which the method in principle belongs) from the evils and inconveniences apprehended.

The facts derived during the late agricultural and especially horticultural experience, establish that a degree of dilution of town manures such as almost extinguishes smell is the best state for their application to plants; that the delivery of the manure in a high state of concentration, or its prolonged exposure, in a state of fermentation manifest to the senses, is wasteful of the manure; whilst not only is the produce improved, but offensive emanations are prevented, by greater dilution with water and more frequent applications of the manure and the water, to the plants. These conclusions were early cor-

* Count Manetti, the Superintendent of the Royal Gardens at Monza near Milan, in a letter to Mr. Chadwick, in 1842, describes the method of subterranean irrigation, as the method of irrigation by regurgitation :—" There are three ways of irrigating land; viz., by submersion, by filtration, and by regurgitation. The irrigation by submersion is in Lombardy limited to rice fields. Elsewhere, as, for instance, in Tuscany, it is employed to improve the soil by the deposit of earthy matter from the water, whilst in France and Germany it is employed both to arable lands and meadows, leaving them under water till a scum appears, which indicates that the crust of the soil begins to decay. The irrigation adopted in Lombardy for arable and pasture lands, as well as for meadows, is by filtration, for one could scarcely call submersion that very thin veil of moving water so skilfully spread over the water by our irrigators, who in this point are the best agriculturists in the world. The irrigation by regurgitation (more properly subterranean irrigation) is not in use in Lombardy; but in Switzerland, in the neighbourhood of Berne, and especially at Hofwyl, a considerable extent of land is irrigated in this manner with great success. The famous Fellenberg reclaimed the bogs of his Hofwyl estate by the application of subterraneous drains, so contrived that by stopping their mouths when the surface of the soil is too dry, he compels the water to swell back to the roots of the grass. This mode of irrigation is not only adapted to grassy lands after they have been drained, but to every other description of light soils, especially in hot climates. It was common in Persia long ago." Although the Count considered the last method applicable only to irrigation with simple water, examples were adduced to show that manures in a complete state of solution had been similarly distributed.

roborated by an able agriculturalist, the late Mr. Oliver, of Lochend, who held a portion of the irrigated meadows near Edinburgh, and who complained that the sewer water as there obtained was far too highly charged with manure for its best application, and that such tenants as himself were prevented from improving the system by the want of water for proper dilution, and of means necessary for more frequent applications of the manure. The more improved applications of liquid manure, by steam power, through pipes and hose with jets, hereafter described, have not, in several important instances, had their full effect, from the want of sufficient supplies of water for dilution; and in several instances farmers have from experience been so convinced of the necessity of greater dilution, that they have pumped water by steam for the purpose. This objection will not exist, to the same degree at least, and possibly not at all, with respect to the sewage from towns copiously supplied with water.

By the more rapid discharge of sewage from a town through closed tubular sewers, instead of open ditches, and by covering over the reservoirs for the storage of the sewer water, or rather by such extended arrangements for an increased frequency of the applications of the sewer water to the land as would prevent the necessity of any extensive storage of such matter, the objections on sanitary grounds to the existing practice at Edinburgh would be greatly diminished but not entirely removed; although the existing evils there would be considered trivial, if they were properly compared with the evils arising from defective drainage of the houses, and the consequent retention of decomposing refuse amidst them.

The consideration of the method of applying town manures by the Edinburgh water meadows did, however, present several economical objections diminishing its comparative eligibility as a means of fertilising land; first, because manures might be applied yet more productively, for the application of manure by the submersion of the land is extremely wasteful, a large proportion of its most valuable part being carried away in solution when the water is let off; next, because works equally efficient for this purpose might be constructed less expensively, which would give, moreover, the power of applying manure to arable land; while the method of applying town manures by means of water meadows confines its use to the raising of fodder.

In the course of inquiries as to the means of street cleansing by jets of water it had been ascertained that where pipes are laid down and water maintained in them at a pressure of about 150 feet, plugs being fixed at proper intervals, two men may water, by means of a flexible tube and jet, an extent of surface at the rate of twenty acres per diem. It suggested itself as a result of this investigation, that flexible hose might be employed in the distribution of manures in the liquid form. In the summer of 1842, Mr. Chadwick suggested to Mr. Henry Thomson of Clitheroe the application of large quantities of manure by means of a jet through a flexible hose, the liquid being pumped into an elevated tank by steam power; the only methods of applying liquid manure previously in use being by water meadows, or by the water-cart, or by hand. Mr. Thomson pumped up the sewage water from a well or shaft into a tank made at the top of a field about eighty feet above the lower part of the farm, and found that, by means of the hose, two men, one to remove the hose and another to direct the nozzle, could distribute about 2,000 gallons of liquid manure in an hour, which he deemed to be a sufficient dressing of concentrated liquid manure for an acre of grass land. The distribution was effected by means of a hose two inches and a half diameter and a maximum length of 800 yards. Of course the rate of delivery varied with the length of hose and difference of level. One important result obtained was, that the delivery of 2,000 gallons or 9 tons was accomplished by the labour of two men, and, allowing for the labour 2½*d.* an hour, at a cost of 5*d.* The water-cart was tried on land immediately adjacent, and by it the expense of delivery of the same quantity was about 5*s.*; the expense of leading and spreading an equivalent quantity of stable dung was about 11*s.* (*Vide* Appendix IX. for the account of this experiment as given by Mr. Thomson.)

The attention of Mr. P. H. Holland, surgeon of Manchester, who has so efficiently promoted the cause of sanitary improvement in that district, was subsequently directed to this first practical example of the use of the hose and jet in the distribution of liquid manure. Being well aware of the value of improvements in the mechanical processes of removing and rapidly applying town manures as means for preventing disease, he pursued the experiments with great labour and very successful results, and invented machinery for applying the manure by steam pumps from a barge on a river or canal. Nightsoil or other town manure was diluted in a separate boat or tender, and by means of a hose with several jets, worked by a steam engine of eight-horse power, three hundred tons were distributed per diem. He found it practicable to use the hose in lengths of one thousand yards on land with elevations of thirty or forty feet. Worse land,—heavy undrained clay, surcharged with water in a moist climate, with nearly forty inches annual fall of rain,—could scarcely be chosen for the application of manure in the liquid form, yet its fertilising power was everywhere found superior to the ordinary top-dressings with manure in the solid form. This process, for more economically distributing town manures, would in many districts render navigable rivers and canals the means of giving increased fertility to the land upon their banks, and thus to some extent counterbalance the diminution of their value as channels of inter-communication.

A very important sanitary result obtained from these experiments, and corroborated by subsequent experience in other places, was, that after three tons of nightsoil and urine diluted with about twenty tons of water had been applied to an acre of land, in little more than an hour no *offensive* smell was perceptible. Most persons may be aware of what would be the nuisance created for days, and sometimes even weeks, by the spreading of such a quantity of that manure undiluted upon the surface as a top dressing, which quantity would, however, be insufficient to produce the effect desired, because, instead of its being absorbed by the soil and plants, much of it would be wasted in the air if the weather were hot, or washed into the ditches if it were wet.

The following questions put to the late Mr. James Dean, an agricultural engineer, who had much practice in the formation of water meadows, may assist the exposition of the rationale of the application of manures in the liquid form :—

" You are aware that in the neighbourhood of towns, fields and gardens are occasionally top-dressed with town or stable manure. For example, Hyde Park has been top-dressed with stable dung or street refuse consisting chiefly of dung, which for a time emitted offensive smells, and the amount of offensive smell, as indicating the extent of decomposition (as is stated in evidence), indicates the extent of escapes of gases injurious to whoever is exposed to it. Now, if the same quantity of dung, instead of being so applied in the solid form for top-dressing, had been put on in solution or suspension in water, and applied in the liquid form to the surface of the park by means of water-carts or by irrigation (supposing that practicable) or by any other mode, what would have been the comparative escape of miasma, so far as you can judge ?—By the application of the refuse in the liquid form, the emanations would be inconsiderable as compared with the emanations from the top-dressing.

"In the liquid form, how long a time would the emanations generally continue in the ordinary state of intensity?—When applied in the liquid form on a drained and permeable soil, and at a temperature of about 60, the emanations would not last above a day. I presume in all cases that the land is properly drained. Even if the refuse were applied by water-carts, which would be in a state of concentration, not to make the expense of cartage too heavy, the absorption would remove the emanations in the course of the day.

"Under favourable circumstances as to weather, in how short a time might the emanations from the top-dressing of stable dung on the park have ceased?—In about six days, if the temperature were below 60; if the temperature were above that, the decomposition would be more active, and would go on for a longer time, until the substance itself had disappeared.

"That is to say, by the application of manure as top-dressing and in the solid form, much more is and would have been given off as emanations injurious to the public health, and less left to be absorbed productively by the land as manure?—Yes; the process would go on until the substance was almost worthless as manure.

"Then the process of receiving and applying the refuse in water, of diffusing and separating the particles in water, so as to render them more immediately and directly applicable for absorption by the plant, is the best process for reducing the amount of escapes of emanations injurious to the public health, and of avoiding the dispersion and loss of valuable material of production?—Yes, certainly it is so.

"Is this applicable as a principle to the whole of the decomposing animal and vegetable refuse, nightsoil, or other matter, as well as stable dung, that may be conveyed away in suspension or solution in water through the channels, or the house drainage, and street drainage, and cleansing of towns?—Yes, certainly.

"To what casualties are the applications of manures as top-dressing exposed from the weather?—To almost entire loss of that which constitutes the food of plants. If there be a heavy and continuous fall of rain, the most productive portions of the manure would be washed away from the surface of the land into the adjoining ditches or watercourses. A long-continued frost in a great measure destroys the value of the manure. It locks up the ground, and the ammonia is dissipated. A long-continued drought and hot weather, as in the present year, dissipates the ammonia by a more active decomposition.

"By receiving and keeping such refuse in water, the amount of loss from emanations is then not only diminished, but the disintegration necessary to the productive application of the refuse is rendered more complete, and the time of the application greatly shortened, and the chances of loss from adverse weather diminished?—That is true, and is certainly an important principle to be constantly borne in mind."

Extensive distributions of sewer water as manure, and of other manures in the liquid form, have perfectly justified these reasonings, and they prove that parks and grounds in the vicinity of towns may by this method receive dressings of manure early in the morning before they are visited, and that all the offensiveness of the common applications of manures on lands adjacent to towns may be entirely avoided. Even when the liquid manures were applied in too high a state of concentration, the offensiveness was confined to the actual time of delivery; and within an hour, or a very short time after the application, there was no offensive smell, and rarely any perceptible smell, even on the very spot.

These results have been subsequently fully corroborated, in respect to clay lands, by the scientific experiments into their absorbent power which have been successfully prosecuted by Professor Way, chemist of the Royal Agricultural Society. They are stated in an important paper "On the power of soils to absorb manure."* One fact established by these experiments is, that the action of clays upon urine and other manures is not merely mechanical, but chemical, and that upon the application of the liquid manure to the earths an immediate and beneficial combination was effected. The attention of His Royal Highness Prince Albert was bestowed upon the same subject, and by some experiments which he independently and concurrently directed similar results were elicited. His Royal Highness moreover suggested a convenient and ingenious apparatus described in a paper (Appendix I.) transmitted to the Royal Agricultural Society, for applying the discovery practically.

The greater proportion of what is lost from decomposition and evaporation, by the retention of manure in the dry state, or in its application as top-dressings, is saved by its being

* *Vide* Journal of the Royal Agricultural Society, xxv. 1850; also a Paper in the same Journal, by Mr. H. S. Thompson, of Moat Hall, who appears first to have experimented on the same subject.

diluted and carried in water beneath the surface of the soil amongst the roots. The more minute subdivision of manures in the liquid form facilitates their rapid decomposition and complete absorption, and there are various examples to show that one load of solid manure, properly liquified with sufficient water, will have four or five times the fertilising power that it would have if applied in the solid form.

Mr. Barber, of Muirdrockwood in Kirkcudbrightshire, has twenty-seven acres of land before his house, naturally of so poor a quality that it originally served for the feeding of two cows only, and that poorly. He put the dung of forty cows with that of four horses which he kept in a stable close to his house, into a tank, through which he passed a rill of water, and irrigated with the solution twenty-two acres of the poor land below. With the miscellaneous refuse of his house and scullery five acres were irrigated. The produce from the same twenty-seven acres of land, fertilised by the liquid manure, now enables him to fodder forty cows and four horses. An important experiment was also tried showing the comparative results of the effects of liquid and solid manure on similar land. There were some knolls of land close by, which being elevated, not having the use of the hose, he could not irrigate; upon this land he could only apply manure in the solid form as top dressing, and whilst he has obtained four or five fold crops by the application of liquid manure, with all the top-dressings he has been able to use he has never succeeded in getting more than one and a half fold of produce by the dung unliquified.

On Mr. P. W. Kennedy's farm at Myer Mill in Ayrshire the general result of the application of the farm-yard manure in the liquid form, and its distribution in four times its weight in water, by means of steam power through fixed and flexible pipes, was, that five times as many cattle were fed on the same ground as had been fed previously, and this without any addition to the manure bought for the farm, and with an increase instead of a diminution of the fertility of the soil.

The recent and important experience of Mr. Pusey presents analogies to the instance above cited.

Being, as he states in a letter to Mr. Chadwick, like most arable farmers, in difficulty as to the live stock for converting profitably his straw into dung, he made arrangements for decomposing it in water, liquifying it, and throwing it in the liquid state upon the land, availing himself of a very small rivulet, which he made to run through his farm-yards, and catch the juices of the dung after rain, and liquify the solid manure there. At such times he takes care "that the water shall be so applied as to run *into* the land, and not escape beyond it into the outfall. This is easily contrived by the waterman." With this stream, (which is "muddy during and after rain from the washing of the manure of farm-yards, the organic refuse from the houses in Pusey, and from the roads,") when he considers it in its best state, he fertilizes a considerable area of land, previously not worth more than about 5*s*. per acre, and from that same land, and by these means, he obtains four and five fold crops, an extent of fertility far beyond anything obtained or practicable by top-dressings, with the available manure in the solid form.

Mr. Lee, the inspector, in whose Report Mr. Pusey's work is described in detail, thus states the effect of the irrigation with the liquified manures:—

"The whole of the annual produce from any of this land has not been either measured or weighed; but Mr. Pusey said, while we were examining the part first irrigated, that the first crop cut was estimated at a ton and a half to the acre. Sheep were then turned on repeatedly, and the whole annual produce was estimated to equal the keep of 36 sheep per acre during five months.

"I have already spoken of the former sterile condition of the part brought under irrigation only two years since. Within that time twenty-eight acres of it have been sown with Italian rye grass. My informant said, that this year there had been five crops of grass, each as high as the sheep-pens. A sixth crop is nearly ready for the scythe. He added:—'If the old men who died twenty years since were to come to life again, they would never believe that this was Cherbury.'

"Excuse me for re-adverting to a few of the points in this, as it appears to me, beautiful process. Here is an arable farm with much surplus straw, some poor grass land, and a small rivulet of water. All the arrangements being made, the stock, while feeding, convert the straw into solid manure,—the stream liquifies it,—gravitation conveys the nutrition and stimulant to the roots of the grass; while the after or clear stream washes it in, and prevents any injury from being done to the herbage by the acridity of the first runnings. The only attention required throughout the whole operation is the opening and shutting of the sluices."

Mr. Pusey himself observes upon this process,—

"One advantage of the catch-meadow system besides its cheapness is, that as the fall is slight, a very much less quantity of water, say one sixth, is sufficient. It appears to me, therefore, particularly adapted for your purpose, in which the object is not to irrigate, but to manure. Irrigation requires the liquid to be carried pretty briskly off; but your object would be to arrest it. In reasonably favourable circumstances with intelligent landowners, I should think you might dispose of the refuse of towns in a profitable method, at an insignificant outlay."

It appears to be important to bear in mind the fact already referred to, in the experience of horticulturists, that an extent of dilution such as extinguishes smell is about the best for absorption and assimilation by the plant; that all the progress of horticultural improvement is made by diluting more and more, and applying the diluted manure more and more frequently. A very experienced horticulturist, Mr. Pince of Exeter, states that he has arrived at this point, that he applies the liquid manure twice a week, and with one of plain water in the interval between each watering with the liquid manure. He gets rid of fibrous matter, and, to use his own expression "I give this water with the manure in it so clear, that if you were not to know what it was, you would not object to drink it.' The conclusions are all in favour of frequent applications of manure in solution, of getting rid as much as possible of fibrous matter, and of much greater dilution than has been hitherto customary, or indeed generally practicable while the liquid manure has to be carried by human or animal power.

One practical reason for this course on the part of horticulturists is, the perception by them, that not only does the fibrous matter tend to clog the pores of the soil, or in some such way impede the process of vegetation, but that every portion of fibrous matter is apt to become a *nidus* for animalcules. It commonly escapes the farmer's attention, that each mass of exposed dung becomes a source of devastating insects, which he unwittingly in that form spreads over his fields, frequently with the seeds of unsuspected and injurious weeds.

A further reason, however, for the superior success which has attended all careful applications of manure in the liquid form appears in the fact that all solid matter, the separate particles of which are visible to the eye, must be decomposed before it can be absorbed by a plant. The most powerful microscopes fail to detect the apertures to the spongioles in plants; if, therefore, there be any fibrous matter or particles of manure visible to the eye, the fact is conclusive that that manure is not in a fit condition for assimilation by the plant. All attempts, says Bousingault, "to make plants absorb solid bodies in a state of minute division, and held in suspension in water, have been ineffectual. In these attempts the spongioles have acted precisely like perfect filters, with which those that we employ in our laboratories cannot be compared. Further, the weakest solutions are not entirely absorbed by certain roots; a kind of separation takes place: a portion of the dissolved salt appears to abandon the water at the moment of its penetrating the spongiole." When the roots of plants are placed in solutions of gum, sugar, or starch, they thrive, if the solutions are thin; but if thick solutions of these substances be prepared, the plants die in them. Sir Humphrey Davy attributed the non-absorption of the thick solution and the death of the plant to the thick matter blocking up the pores of the vegetable tissue.

All the plans for the precipitation of sewer water, which have been examined, precipitate some portions only of the manure, leaving to be wasted those most valuable portions which remain in solution. The portion of the manure precipitated, and at much expense reduced to the solid state, with the addition also of a chemical agent which is often useless and sometimes detrimental, must be again resolved into the liquid state before it can be absorbed by the plant. The usual processes of precipitation are processes of expensive and partial decomposition, involving recomposition.

It is acknowledged by eminent agriculturists, that experience derived from horticultural or garden cultivation often forms the best basis for culture on a large scale, inasmuch as horticultural results are derived from the observation of individual plants, under more varied circumstances than usually occur within the same period in respect to whole fields. Such experience is the safest to follow in agriculture, with the substitution of mechanical and cheaper means of culture than the hand cultivation of horticulturists; and, in horticulture, many of the greatest advances in production, and many of the prizes for the most eminent success, have been obtained by the skilful application of liquid and liquified manure.

Sir Joseph Paxton collects at Chatsworth the manure water from water-closets, horse-dung linings, and various other sources, into large covered tanks; the waste also from a small bath is emptied into one of these, by which means the solution becomes very thin. The liquid so collected passes almost immediately into a state of incipient or partial decomposition, and thus becomes fit for the food of vegetation; when drawn off for use, it is always greatly diluted with water, and never supplied except when the plants are in a state of activity and growth; otherwise he considers the effects would in many cases be prejudicial, rather than otherwise. It is used by him liberally to vine-borders, peach-trees, melons, cucumbers, pines, and other fruits, with the most powerful and satisfactory results; in fact, the use of plant food in a liquid state, if properly prepared and administered, supersedes in a great degree the necessity for manure in a solid form; and the produce in favour of the liquid greatly preponderates, being both larger in quantity and weight, richer in colour, and superior in flavour.

These advantages, however, could not be secured with certainty, unless the solution were so prepared as to suit the habits and requirements of the various plants to which it is supplied. This preparation is of two kinds:—*first*, by diluting the liquid sufficiently with water to prevent the spongioles of roots becoming glutted with too great a supply of food; and, *secondly*, rendering it of a proper temperature by the addition of hot water. Pines require the liquid at about a heat of 80 degrees Fahr., and other plants in proportion; fruit trees, and other open air products, however, do not necessarily require the addition of hot water to the same extent as indoor produce, but are, notwithstanding, much benefited by receiving it in a moderately warm state. Wherever a steam engine is employed, Sir Joseph Paxton's practice of artificially warming the liquid manure might be easily adopted, by allowing some of the waste steam to blow through the tank or pipe*. Experience has, however, amply shown that for ordinary crops, sewage in its usual state is the most valuable manure that has yet been introduced.

By attention chiefly to the proper administration of liquid food, and other suitable appliances, the pine-apple, a plant formerly considered of so slow a growth as to require three years before it could produce full sized fruit, has by Sir Joseph been so hastened in its growth, as to yield, within an average of fifteen months, a far greater supply of finer fruit than was formerly produced by three years expense and labour. From every day's experience, an instance or two out of a multitude might be cited by way of illustrating that even a much shorter period than fifteen months is not unfrequently sufficient to accomplish all that could be desired.

* *Vide* Mr. Lee's Report, Appendix No. VI.

An ordinary sucker of a Providence pine was detached from the old stock during the month of March, and was planted out in a prepared bed of soil in a pit, and in the following August it produced a ripe well-grown fruit weighing 8 lbs. Two suckers also of a Cayenne pine were separated and planted out in April, and in the following September one of these produced a fruit weighing 7¼ lbs. and the other one 8 lbs. A large pit of Cayenne suckers of various sizes were planted out in a pit last spring, and in the autumn the fruit when ripened gave an average of one pound in weight for every month the plants had grown. These were not isolated or extraordinary instances of early production, but the common and natural result of this system of culture, which stimulates to extraordinary growth, and the most perfect development. The effects of liquid manure, when applied to the roots of vines in pots, and on rafters, and to cucumbers and melons, are equally apparent; the leaves assume a rich deep colour, become large and spreading, the growth is rapid and healthy, and the produce is invariably fine, plump, and becomes quickly matured.

On the question being asked, in what method the most can be made of a given quantity of manure, Sir Joseph Paxton answered, "From my own experience, I am satisfied that a given quantity of manure in a liquid state, collected in covered tanks, affords far more immediate support to vegetation than the same quantity of plant food administered in a solid form can possibly do. In the first, the thin liquid is appropriated to use at once, and little or no loss is sustained, whilst in the latter mode the solid matter, whether spread on the surface or dug into the ground, is dependent on a variety of subsequent circumstances, before plants can derive much of the benefits of its application; many of its valuable properties are, during these processes of preparation, dissipated and lost."

In respect to a direct application of liquified and liquid town manure,—night-soil, and urine,—from a hose on the method introduced by Mr. P. H. Holland, Mr. John Mitchell, Lord Ellesmere's head gardener, states, "that he has never seen any manure produce so good a crop of strawberries as the liquid" (i.e. town or sewer manure) "has this year done at the Worsley Hall gardens. Manure," he says, "often causes a crop of strawberries to be lost, by forcing the growth of leaves. Liquid may be applied just when the plants are forming their flower buds, and the strength of the manure is spent in producing fruit, not leaves. When the plants were bearing, it could be seen to a plant how far the irrigation had extended."

Of course liquid manure may be misapplied in wet weather, and is subject to the casualties of storms, but less so than top-dressings of solid manure; it is not, as the farmers term it, so "risky." And the risks of single dressings of liquid manure are diminished in proportion to the frequency of the applications. By this mode, it may be taken as an axiom, that time is saved and risk is diminished.

But whilst the effects of liquid manure are immediate on the vegetation, they have been practically found not to be so transient in the soil as at the commencement of these experiments it was reasonably supposed they would be.

Inquiries were early made of Professor Liebig as to the application of the sewage of towns as manure, but his mind appeared to be pre-occupied by another system of fertilizing land, namely, that by application of manures in a solid form. In 1845 he thus expressed his views:

"The reason why in certain years the influence of the best and most plentiful manuring is scarcely perceptible is, that during the moist and rainy springs and summers the phosphates and other salts with alkaline bases, as also the soluble ammoniacal salts, are entirely or partly removed. A great amount of rain and moisture removes, in the greatest quantity, the very substances which are most indispensable to the plants at the time that they begin to form and mature seeds. The system of draining, which of late has been so extensively followed in England, brings the land into the state of a great filter, through which the soluble alkalies are drawn off, in consequence of the percolation of rain, and it must therefore become more deficient in its soluble efficacious elements.

"Attentive farmers must have observed that after a certain time the quality of the grain on land laid dry according to this principle deteriorates; that the produce of grain bears no due proportion to the produce of straw.

"What is more evident, after these remarks, than that intelligent farmers must strive to give to the soil the manuring substances in such a state as to render possible their acting favourably on the plants during tho whole time of their growth. Art must find out the means of reducing the solubility of the manuring substances to a certain limit; in a word, of bringing them into the same state in which they exist in a most fertile virgin soil, and in which they can be best assimilated by the virgin plants.

"The attention which I have paid to this subject has been crowned with success. I have succeeded in combining the efficacious elements of manure in such a manner as that they will not be washed away, and thus their efficacy will be doubled. Owing to this, the injurious consequences of the present system of draining are removed, agriculture is placed upon as certain principles as well-arranged manufactories, and instead of the uncertainty of mere empiricism, the operations of agriculture may be carried on with security, and in place of waiting the results of our labours with anxiety and doubt, our minds will be filled with patience and confidence."

A composition such as Professor Liebig described is much to be desired, and its success would be hailed as a great boon; but from all accounts of his patent solid manure it appears to have been a signal failure.* And experience has proved that plants are best supplied with food by watering them at short intervals "during the whole time of their growth" with weak solutions of the elements which compose their structure. Moreover, the results of actual experience obtained since the eminent chemist wrote the passage above cited have shown that the hypotheses contained in it are not well founded.

In the first place, it is established by wide general experience that drained land does not deteriorate, but increases in fertility, and maintains its increased fertility from year to year, though washed through and through by all heavy falls of rain carried away by the drains. The rationale of this fact was subsequently displayed in the experiments prosecuted by Professor Way, already referred to, which show that upon the application of manures in the liquid form the fertilizing elements do not escape through the soil, but are retained by it chemically.

On the other hand, where manures are applied as top dressings in the solid form, it is proved by experience that after heavy showers of rain the solid manure is washed away, bodily as it were, into the ditches and watercourses; so that whilst the outfalls from land top-dressed and undrained are turbid with the matter carried away, and complained of as a nuisance, the outfalls from drained land, richly manured with the liquid, discharge pellucid streams. Where there are two outfalls from contiguous portions of the same soil, the one outfall from land that is under or thorough drained, the other from land undrained or only surface drained, the visible contrast is most remarkable. Simple and decisive proofs of the power of soils for chemical combination were given experimentally by Professor Way, before the Royal Agricultural Society, by passing large doses of urine and

* *Vide* Mr. Pusey's paper, Royal Agricultural Journal, XXVI., p. 382.

sewer water in a turbid and offensive condition through clay soils, and producing a liquid free from smell and pellucid.

Where more manure is applied at any one time than the earths can absorb, the excess is, as might be expected, discharged through the drains. This is displayed in the excessive quantities of sewer manure delivered on the sandy lands near Edinburgh. The discharges after dressings with liquid manure have hitherto been unexamined, and the results only of irrigation displayed in the extraordinary crops. But if there be waste, the remedy is, not returning to the use of solid manure, with which there must be still greater waste, but in extending the application of the liquid, so that there may be land enough to employ it all.

It is also now established that land manured by liquid or liquified manure retains its fertility in a remarkable manner, and that the effects, instead of being transient, have a far greater permanency than was anticipated. It is a subject of common observation, that where there has been transudation through the hose canvass pipe the mark of the line traversed by the pipe is visible in the better growth and higher colour of the grass in the second year; and the extra quantities of manure on particular spots from irregular sheddings were not washed away by the next shower, as the hypothesis would imply, but were all displayed with the like permanency. The heavy and ill-drained lands near the Worsley Canal, dressed with one dressing only of liquid manure during the season, but which had no dressing during the second season, bore superior crops the second as well as the first season.

The Reverend A. Huxtable has recently reported an experiment tried to test the durability of manure applied in the liquid form. He found that wheat manured at the time of sowing with 10 hogsheads per acre ($=2\frac{1}{2}$ tons) of cows' urine produced as good a crop as that manured at the time of sowing with guano in the proportion of 2 cwt. per acre. The result of this experiment shows, that liquid manure lasts not only during the winter, but even until the harvest time of wheat, the latest of our cereals, and is exactly correspondent with Mr. Huxtable's former experiments, which proved the power possessed by soil of absorbing, and retaining for the sustenance of vegetation, manure contained in any liquid which filters through it, for it is evident that the liquid itself could not be retained for months in the soil.

The experiments made by the Rev. A. Huxtable and by

Mr. Way*, and the scientific results already referred to as thence deduced, are in complete accordance with the results of practice, and leave no doubt that liquid manure may be applied to the land when it is fallow, with the certainty of the best incorporation, and that the deposit there will be safe and available for the subsequent crop. These experiments, corroborated by the results of practice of repeated applications during the growth of the vegetation, prove that the application of liquid manure to land may, under proper management, with the interruptions of hard frost only, be as continuous as its production. They dissipate the exaggerated estimates as to the extent of storage, and the great expense and inconvenience of the reservoirs required for such manure.

We may advance a step further, and state, what appears to be fully borne out by experience, that the fertility producible by liquid manure irrigation is a cumulative and continually increasing fertility, the limit of which is not yet ascertained. Evidence recently obtained from cultivators of the soil on which liquid manuring has been scientifically practised, in different and widely-separated parts of the country, bear out former conclusions, and prove that the productive powers of the land are increasing every year.†

The produce which has been obtained by the application of liquified manure at Milan, Edinburgh, and other places, has exceeded that obtained from grass land by any other yet known means in agriculture ; this superabundance of produce has gone on from year to year for the last half century, without any exhaustion of the soil or deterioration of the herbage, which instead of being inferior is superior in quality. The average yield at Edinburgh has been four thick crops a year of grass eighteen inches long, and the collective weight of grass cut was stated to be on some parts at the rate of eighty tons per acre.

With cabbages, with root crops of every description,—turnips, mangel wurzel, carrots, and potatoes,—with garden produce,—beans, onions, rhubarb,—and with fruits of all kinds,—heavier and quicker crops have been obtained by applications of manure in the liquid form than by any other method of which the results have been noted.

In some instances where liquid manure, consisting of cows' urine, was applied to wheat, the weight of the ear was increased beyond the strength of the straw, and the

* *Vide* Lectures of Professor Way, and papers printed in the Journal of the Royal Agricultural Society.

† *Vide* statements quoted by Mr. Lee in his report, Appendix VI.

crops were lodged; this would, however, it is suggested, be prevented by thin sowing, and is less to be apprehended if miscellaneous manure be used, which contains the food of all parts of the plant, siliceous matter for the stalk and phosphates for the seed as well as nitrogeous matter for the herbage.* If any material should be deficient either in the soil or in the sewage, as, for instance, silica, to give strength to the stalks, it may be easily and economically added in the tank by macerating in it straw, or adding a soluble silicate directly. In several applications of sewer manure near the metropolis to oats, as well as to wheat, generally with moderate dressing, the results were satisfactory, and in analogy with the applications to other descriptions of produce.

In the Journal of the Royal Agricultural Society, Mr. Cuthbert Johnson adverts to the experiments of Professors Hembstadt and Schubler, which he thus states:—

"The question of the comparative agricultural value of nightsoil having been submitted a few years since to the consideration of the late Professor Hembstadt of Berlin, by the Saxon and Prussian authorities, who were desirous to apply the contents of the city drains and cesspools to the recovery of barren and sandy lands in the environs of Berlin and Dresden. That eminent agriculturist undertook, in conjunction with other learned men, and with practical farmers, a series of experiments, which were carried on for a great length of time, and were varied in every possible way in order to avoid all sources of fallacy. The results of those experiments Hembstadt afterwards published, and they led to extensive agricultural operations, all of which proved successful. Professor Schubler, the writer of the most esteemed and certainly the most able treatise on Agronomia, or the best mode of farming and treating every species of land, repeated, and added to the experiments of Hembstadt, from which he obtained similar results. These he published in a tabular form, which has since passed into the hands of all the large practical farmers in Germany, and has formed the basis of instruction on manuring, in the hands of the professors of agriculture, whom many of the continental governments have, with infinite advantage, established in institutions purposely formed to disseminate useful and practical truths in the art of farming. From that table the following facts may be collected. If a given quantity of the land sown without manure yield three times the seed employed, then the same quantity of land will produce —

* For more full explanation, see Appendix XV.

" 5 times the quantity sown, when manured with old herbage, putrid grass or leaves, garden stuff, &c.,
" 7 times with cow dung,
" 9 times with pigeon's dung,
" 10 times with horse dung,
" 12 times with human urine,
" 12 times with goat's dung,
" 12 times with sheep's dung, and
" 14 times with human manure or bullock's blood."

But if the land be of such quality as to produce without manure five times the quantity sown, then the horse dung manure will yield fourteen, and human manure nineteen, two thirds the quantity sown. In addition to this information, it was ascertained that the most important crops, those I mean which yield most profit, such as flax, for example, so extensively cultivated in both Flanders, can only be obtained in abundance, and of the finest quality, by employing human manure.

" But by far the most important point of practical knowledge in this matter, put forward by the same great authorities, and the truth of which was afterwards confirmed to me by more than one great farmer in East Flanders, is, that while the manuring with human soil has produced fourteen times the quantity sown, where horse dung has only yielded ten, the proportion of the human or Flemish manure employed was, to that of the horse dung, as one to five only; so that with one ton of the Flemish, a larger produce is obtained than with five tons of stable manure.* In Flemish husbandry the land is ploughed and harrowed several times till it is thought sufficiently fine. Liquid manure is now put on; this consists chiefly of the emptyings of privies and the urine of cows, and also of rape-cake dissolved in urine."

Accepting these conclusions as the result of actual experiment, they place an equal quantity of fertilising matter in the form of town sewage above all other manures, considered with reference to its producing capability alone, irrespective of the greater pecuniary economy of its application.

It has been found that the miscellaneous nature of the town manures, instead of being unfavourable, is favourable to vegetable production. In the instances of irrigation with compounded or miscellaneous manure, as compared with the applications of simple or comparatively simple manures, the

* "Manures" by C. W. Johnson, Esq., F.R.S., p. 121.

grass which had received the miscellaneous manure was by far the richest, and the cattle went first to the portion of the field so irrigated. These results are in accordance with the principles of vegetable physiology, for it is the faculty of the roots of plants, not only to seek their food, but when they have arrived at it to *select* that which is the most suitable to them, as Sir Humphrey Davy long ago ascertained; they do not take up everything that is presented to them. This, which may be designated as the selective power of the roots of plants, appears to be a most important property for practical application to the absorption of town manures, which, consisting of the remains of everything taken into the town, are in the highest degree miscellaneous.

The quantity of the refuse and the colouring matters from dye-works discharged into the rivers passing through some manufacturing towns often excites doubts as to the applicability of such waters for irrigation. But the dark colouring matter which excites attention is chiefly logwood, indigo, and woad*, and the banks of such streams often exhibit the most luxuriant vegetation; for but little injurious mineral matter and much valuable manure is discharged from such works, and the important experiments of De Saussure on the absorption of poisons by plants, prove that plants do not suffer much by exposure to *weak* poisonous solutions. This fact is also corroborative of the view taken as to the importance of the extensive diffusion of manures in water, and frequent applications of weak solutions, rather than single or unfrequent applications of concentrated solutions, with much solid matter in suspension.

The fertilizing power of sewage and other liquified manure appears to be similar, whatsoever is the nature of the soil, but is the most striking on sandy soils, from the contrast

* *Vide* Appendix XV. for Analysis by Dr. Angus Smith of the River Medlock, a stream which receives large quantities of dye-house refuse. Nothing could be more satisfactory as a practical demonstration on this point than the following statements on the Clipstone Water Meadows by Mr. Lee: "The carriageway passes along the bank of the flood-dike for about two miles; and I could not but observe that the combination of sewage and *dye-water*, without any flowing current, had a very forbidding unpleasant appearance. The fluid was so nearly opaque that objects became invisible at a depth of about three inches." This is the state of the water before irrigation. The following is the description of the same water after it has been applied to the land: "I was delighted to find the water as clear as crystal, with great numbers of fine trout and grayling, and producing large beds of watercresses, which are cut daily by the poor people for the Mansfield markets. I think there could be no stronger proof of the facility and rapidity with which plants will take food, when it is offered to them in a state of solution, than the contrast of these two streams."

with their previous sterility; some of the most productive portions of the Edinburgh meadows are the sandy lands, the productiveness of which was rapidly increased, and seems to be still increasing. Additional applications of liquid manure upon the sterile sands not long recovered from the sea at Ayr, produced proportionately heavier crops than those derived from somewhat less frequent applications on the good loamy clay land belonging to Mr. Kennedy at Myer Mill.

Trials which have been made prove that by the like means a high value may be given to many soils now left waste, and they appear to realize the results anticipated by Bousingault from the simple irrigation of poor sandy soil.

" A light sandy soil," says he, " which in the south of France would be of small value only, presents real advantages in the moist climate of England. Irrigation supplies the place of rain; and in those countries or situations where recourse can be had to it the question in regard to the constitution of soils loses most of its importance. Land that can be irrigated has only to be loose and permeable in order to have the whole of the fertility developed which climate and manure can confer. Upon the sandy downs of the coasts of the Southern Ocean a brilliant vegetation is seen along the course of the few rivers which traverse them; all beyond is dust and sterility. I have seen rich crops of maize gathered upon the plateau of the Andes of Quito in a sand that was nearly moving, but which was abundantly and dexterously irrigated."

The injurious consequences of extreme variations of seasons are prevented or mitigated when land is perfectly drained, and cultivated with town sewage or liquid manure; for the risk of injury in a wet season is greatly diminished when the excess of water can at once run off, and drought need be little feared when an artificial shower of any amount is always at command. Drainage, and the free supply of manure which sewage will afford, would, moreover, to a considerable extent, compensate for the deficiency of solar heat in a cold summer: drainage, by removing excess of water, and therefore saving the heat otherwise required for its evaporation*; and a free supply of liquified manure by stimu-

* *Vide* Minutes of Information on Suburban Land Drainage. Every one must have remarked, on passing from a district with a retentive soil to one of an open, porous nature,—which are respectively characterised as cold or warm soils,—that whilst the air on the retentive soil is cold and raw, that on the drier soil is comparatively warm and genial. As to the effect upon temperature produced by the formation of extensive stagnant surfaces of

lating as well as nourishing the vegetation. It would appear that two of the chief causes of extreme fluctuations of crops, and of a farmer's anxiety as to the season, excess and deficiency of moisture, may thus be brought nearly under control; that the third, deficiency of heat, may be to a great extent compensated by the mode of cultivation described, which in some instances has already given to fen lands the advantage in certainty and regularity of culture over undrained and unirrigated uplands, naturally far more productive.

The vegetation on the lands irrigated with simple water is chiefly distinguished by tissues of softer and more spongy texture,—by more tender stems,—by thicker and more porous leaves; and this increase of the green parts often takes place at the expense of the more solid and farinaceous deposit; but the increased produce obtained by the irrigation with sewer water and liquid manure is less exclusively that of the herbage merely; it is preferred by the cattle, which greedily devour the crops raised on those portions of the meadows so treated; and the cattle feeders at Edinburgh have for many years been steady in their demand for that kind of produce.

Besides the enormous increase of produce on the sands at Ayr, its quality was so much improved that Mr. Telfer was obtaining twopence per pound above the current price in the district for his butter; this difference amounting to a sum more than equal to the whole previous rent of the farm.

water meadows, or by the removal of surplus moisture by drainage, the statements of the facts, as given by scientific observers, will appear extraordinary to those who have not paid attention to the subject, *e. g.*, that more heat is requisite to vaporize one foot of water than would raise the temperature of three million cubic feet of air one degree; from which it follows, that for every inch in depth of water carried off by drains, which water must otherwise evaporate, as much heat is saved per acre as would elevate about eleven thousand million cubic feet of air one degree in temperature. It is easy then to understand how local climate is so much affected by surplus moisture, and so remarkably improved by drainage. A farmer, being asked as to what effect had been produced on the temperature by some new drainage work, said, that all he knew was, that before the particular fields were drained he could never go out after night-fall without a top-coat, and now he could, and that he considered that it made the difference of a top-coat to him. The sanitary importance of such works is proportioned to the proximity, to the number, and the susceptibility of the population affected by variations of climate. Mr. Lee, in his Report on the application on the Public Health Act to Worksop, shows from meteorological observations of Mr. William Tillery, the head gardener of the Duke of Portland, that in consequence of the land drainage upon part only of the district the climate was improving, and that there had been a rise of one degree in the mean temperature of the whole district within the last ten years as compared with the preceding ten years, as well as a corresponding diminution of the dampness of the air; and dampness affects comfort more even than temperature.

The example of cultivation with liquified manure and of the increased production obtained by improved management, without any addition to the manures of the farm, commonly present to the eye, and in striking and encouraging contrast to the vegetation of the surrounding country, palpable demonstrations of the condition to which the whole surface of the land might be brought by the exercise of the like skill, without even the enterprise of the first trial, which has been accomplished. The following statement of a visible impression in relation to a recent example of improved culture by means of liquid manure distributed by pipes, introduced by Mr. Edward Romilly on a farm in Wales, may be cited as equally applicable to the cases where the improvements in question have been longer in operation.

"In the month of December," says Mr. Lee, the inspector, "and with a hazy atmosphere, the journey from Cardiff to Porth Kerry is dreary to any one travelling alone. The roads narrow and heavy, the woods leafless and gloomy, and the general aspect of vegetation in the fields brown and inactive. After a drive of nearly two hours I saw, at a distance of nearly a mile, a large grass field of a most beautiful green colour. The contrast to every thing upon which the eye had rested for many miles conveyed more pleasure than I had previously conceived possible from so simple a fact. I knew at once that, at this season of the year, nothing but irrigation with liquid manure could clothe the surface with such verdure, and needed nothing else to direct me to Mr. Romilly's farm. I afterwards walked over that field, and saw the fertilizer—the jet—in operation. Observing that the blades of grass had been cropped off, I asked if sheep had been turned on, and was surprised to learn that it was only sown with Italian rye-grass in September last. Game is preserved in the neighbourhood, and this field is a centre of attraction now for the hares, who come from considerable distances all round to feed upon its delicate and nutritious herbage. They had done ample justice to the productive powers of liquid manure."

In the report on Mr. Pusey's application of liquified manures by means of the catch-water meadows, Mr. Lee observes, "The Winchester meadow in this part has one corner too high for the fluid, and I was much struck with the contrast between the irrigated and non-irrigated land. The line of demarcation was as strongly marked as if two pieces of cloth, one bright green and flossy, and the other brown and thread-bare, were seamed together."

In speaking of the irrigation with liquefied manure on the Exmoor hills, referred to by Mr. Pusey, Mr. Lee thus describes the visible contrast presented with land top-dressed with solid manure:

"On the higher parts of the farm the land is top-dressed with solid stable manure. Some of the land thus manured is above the reach of irrigating gutters, and the highest gutters of course contain the smallest quantities of water. In one sloping field the gutter runs obliquely across, one side being above the irrigation, and the other below. The land on both sides of the gutter had been equally dressed with solid manure. The water had been shed over the lower part immediately, and the manure washed in, leaving only a few straws on the surface. On the upper side the exposed herbage was brown and coarse; on the lower, a more beautiful green colour could not be imagined." *Vide* Mr. Lee's Report, Appendix VI.

The question will naturally suggest itself in relation to the older examples of the applications of town manures or of manures in the liquid form, from year to year, with increasing productiveness, why such eminent success was not immediately and extensively imitated in the surrounding districts.

But the like question may be put in respect to almost any agricultural improvement, e. g. to land drainage. All over the country fields may now be seen water-logged and covered with rushes, close to clean fields of the same soil bearing heavy crops, which have notoriously repaid within three years the expense of the permanent work of drainage, but nevertheless a small percentage only of the land in the country is yet properly drained. The answers to such questions might comprehend the questions between landlord and tenant as to the outlay of capital, and would further extend to disquisitions as to the condition of agriculture as an art and as a science, in which success notoriously demonstrated by no means ensures spontaneous adoption; instances would, indeed, be exhibited of the state of local administration, as shown in the fact that the highly beneficial and profitable applications of the manure of part of a town, displayed before them year after year, do not, under existing arrangements, lead the administrators to bethink themselves whether the like beneficial results might not be obtained by the like applications of the whole of such manures, or apparently to pay the slightest attention to the subject.

One example, however, elicited in the course of the recent examination of this subject, it may be useful to advert to, as displaying the beneficial influences of legal process or of an impulse *ab extra* in the promotion of improvement.

About 1809 Mr. William Harley, observing the inferior quality of the supplies of milk in Glasgow, from cows kept in the town in close, filthy, and unventilated sheds, constructed a cowhouse in which sanitary principles were applied in the keeping of the cows, and consequently improved the quality and increased the quantity of the milk, and was able to reduce its price. Instead of allowing the urine to stagnate in or near the cowsheds, he applied it with most eminent success as a manure. These successful improvements were made known from time to time as they were effected. They were the subject of extensive notoriety, and in 1829 they were published under the name of the Harleian Dairy System (8vo. London, Ridgway). The cowshed attracted so many visitors that at length they became inconvenient, and a shilling each was charged for the exhibition, which raised nearly 200*l*. per annum. But this example of the successful application of the liquid manure gained no general imitation—indeed no known imitation whatever—amongst the farmers, or cattle owners, in the neighbourhood, who thenceforward, as indeed generally at the present time, allowed the urine to run to waste. Such was the case in particular with one large cowshed attached to a distillery, where several hundred cows were kept. At length, about ten years afterwards, the urine from that cowhouse, allowed to flow into a stream or canal, was so copious as to kill the fishes, and became so serious a nuisance that the occupier of the farm was threatened with a prosecution if he continued to pollute the stream by the discharge. He was then urged by Mr. Smith of Deanston to use the urine as a manure, which he did by the method of the water-cart, when its fertilising power became manifest. The expense of carting this valuable manure to distant parts of the farm and to great heights was, however, found to be very serious, and the success of the application of liquid manure by means of pipes having then been proved, he was led to adopt that method. The result, as displayed in a recent examination, has been, that by means of the liquid manure (and by that alone), which he previously allowed to run to waste, he has obtained, and that too by a very imperfect application, a four-fold production on a stiff clay land, much of it ill-drained and overgrown with rushes, and that he now sells all the dung or solid manure, on which he previously depended, to other farmers, many of whom continue to depend on that description of manure alone, whilst they yet allow the liquid manure on their own farms to run into the ditches and the natural watercourses.*

The dung sold is 2,000 tons per annum, at 6*s*. per ton; this manure raised almost entirely from the farm itself. The produce of the manure, which represents the manure previously wasted in that farm, and now generally wasted in others, is 30*s*. per annum per acre, a large instalment of the rent.

* Examples of profitable changes induced by impulses *ab extra* are not confined to agriculture. Great opposition was made by manufacturers in Parliament to a general measure for compulsory proceedings for the suppression of the smoke nuisance, on the ground that it would put them to increased expense. The powers obtained under a local act having, however, been enforced at Manchester, it is stated that the parties who, under the legal compulsion, were driven to adopt measures for the consumption of the smoke, now admit the fact of making large savings from the better combustion effected. Many of the trading gas-work companies were prosecuted for the nuisance they created by discharging ammoniacal and other products as refuse into the streams; from the attention brought about by prosecutions they have improved their processes, and now derive considerable emolument from the products previously wasted. In consequence of the prosecution of the proprietors of some chemical works for the nuisance created by the fumes, they were compelled to construct a flue for carrying those away to a considerable distance. In the flue a deposit is found, which is now a source of large profit. There can be no doubt that nearly all nuisances are occasioned by defective processes, and bad chemistry, involving waste; and that a due application by summary power of the common law against them would ensure most important manufacturing improvements, such as the profitable economy of fuel. It has been shown that at Cornwall, where attention to the economy of fuel has been compelled by its dearness, as much power is obtained by one third the quantity of the fuel as is consumed in Lancashire, where the towns are enveloped in smoke; that by the proper enforcement of the law against the smoke nuisance and the use of proper boiler surface the smoke may be reduced to one sixth; and where the price of coal is only 5*s*. per ton, a saving effected of 1*l*. 16*s*. per diem in working an engine of 100 horse power. (*Vide* evidence of Mr. Samuel Hocking in the Board's Report on the Water Supply of the Metropolis, p. 25. Appendix 2.) So in respect to the ordinary brick and tile kilns, the erection of which in towns is a nuisance; by improved construction the nuisance is obviated, and a saving of more than half the fuel effected by a better combustion. The same principle holds good in other instances. Appeals were made during the cholera against the Board's order for the daily cleansing of dung from all stables in towns, and a weekly cleansing and removal was prayed for as sufficient; but the Local Boards were advised that enforcement of the law by penalties might be proceeded with, as a question of economy merely; for where the condition of horses was attended to for the sake of power, as by the best trainers of racing and hunting horses, the complete cleansing of the stables is effected, not once a day merely, but three times a day, and good care is taken that the dung shall be removed to such a distance that no fumes and no smell from it shall reach the stable. The Board has therefore advised that due enforcement of the law by the prosecution of the occupiers of filthy slaughter-houses and cow-houses in towns, for the nuisance they create, may be proceeded with even simply on grounds of economy and saving to the ignorant or indolent horse-keepers themselves.

It has been proved that by mismanagement of solid manures, whether from farms or from towns, by their retention on the surface, by the evaporation of their most fertilizing portions, and by mismanagement of them in the ground, as much as two thirds, and often more, of their fertilizing powers are commonly lost, and that the loss of the liquid manures is generally total. In all such cases, in all the instances where the dung of the stable and of the cattle sheds is seen in heaps exposed to the weather, and where the washings from it by the rain, together with the urine of the farm, are allowed to run off into the ditches, it may be safely averred that the loss of production from mismanagement, or the sacrifice of the gain derivable from an improved application of the manures, is at least equal to the average rental ot heland.

As a general observation, it may be stated that the English farmer has hitherto considered that only as manure which he could raise with the fork: sooner or later, however, he will consider that only as regular manure which he might apply with the scoop. Deep colour, and strong consistency and smell, are the first qualities he now seeks in liquid manures as conditions for their application. The further advance, according to horticultural experience, will probably be in liquid applications of perfect transparency and void of smell. At Milan and Edinburgh, the fibrous or solid matter, which farmers now most regard, is found to be of comparatively little value, and apparently the difficulty will hereafter be, how to dispose of the fibrous residue of town manures, and turn it to account, and prevent its being injurious.

Experience in England with respect to the application of liquid manures is corroborated by that of horticulturists and agriculturists abroad; especially by the practical experience of the celebrated De Candolle, whose statement on the subject is given in the Appendix. He emphatically states, "It is to be desired that the practical use of liquid manure, which serves at one and the same time as manure and for watering, should become more universal and more popular in a great part of Europe."

The eminent German agriculturist Schwerze (Principes d'Agriculture, 8vo., Paris, 1839) gives the following as the advantages which he had experienced himself, and observed generally in practice, from the application of manure in the liquid form. His summary might be adopted as a statement of the results of the recent examination herein-before referred to.

1st. The advantage of manure applied in the liquid instead of the solid form consists first and above all in the promptitude of its action. For a great number of plants, such as cabbages, turnips, rape, hemp, flax, for fodder plants, for all those of which the growth is rapid, which require prompt nourishment, and which cannot wait the slow decomposition of solid manure for the food which is suitable to them, liquid manure is most important.

2d. In the saving of loss from less emanation by the immediate passage of the manure into the soil.

3d. In hastening production. Whilst solid manure requires a year or more, or often two or three years, to bring the whole of its force into action, manure applied in the liquid form, to trefoil or lucerne, for example, comes into full action in two or three months. THUS THE RETURNS OF CAPITAL FOR MANURE IN THE LIQUID FORM WILL BE MADE IN ONE THIRD OR ONE HALF THE TIME.

4th. Liquid manure is immediately available to repair the failure of other manures, and acts immediately for the relief of plants. In a burning spring it will change leaves which are yellow into green of a deep colour; a metamorphosis which it is impossible at that time to effect with ordinary manure.

5th. For grasses and clovers liquid manure, well treated, is the only manure which does not occasion any exhaustion of the soil; for besides the addition of the water, which is in itself a good thing for fodder plants, it serves to dissolve and spread, and, without loss of time, convey the nutritive matter to the vegetation. Those agriculturists who have for a long time manured fields with the ordinary manure know how little result attends the labour and the expenditure of solid manure in dry weather; for when in that form the manure is nearly all lost.

6th. In charging water instead of straw with the manure, litter is saved, which is of great advantage when straw is scarce.

In short, he says, "it appears sufficiently clear to me, that liquid manure gains in quantity and quality, and in other conditions; that there results from that method of preparing manure a greater quantity than with the ordinary method; that the cultivator may with it always assist a failing vegetation; that it may be given abundantly of a sufficient quality; that liquid manure is the only manure suitable for fodder plants, or that is applicable to them without exhausting the soil; that those who keep animals ought to husband it with the greatest care, and that those who have light sandy soils ought to resort to liquid manure as the basis of their cultivation."

Having recited the above evidence as to the fertilizing powers of sewage and liquid and liquified manure, we now come to that in relation to the description and expense of the several mechanical means of distribution.

Schwerze recites as practical disadvantages of liquid manure, the expense of the re-arrangement of stables and cattle sheds, and the construction of new tanks and reservoirs; the bulk and expense of the carriage of the liquid manure, which he estimates as a triple carriage often to very distant fields, and over bad roads; that many young plants do not bear the application of liquid manure, except in moist weather, when the ground will not bear the passage of laden carts. As to the carriage of the manure, he observes, that the time of frost is the best for the purpose, but at that time a great portion of the manure is wasted, unless the ground be covered with snow. A further inconvenience he notices, as belonging to the use of liquid manure, is that the solid residue of the tanks does not mount in pumps of small diameter, unless the material is kept stirred up during the time of the action of the pumps; and that there is sometimes an inconvenience in distributing the solid deposit on young plants. To obviate this he recommends that the deposit should be cleansed out two or three times a year, and treated as compost, using lime to effect a more prompt decomposition of the fibrous matters.

In Belgium, Switzerland, and many parts of Germany some of the inconveniences of the delivery of liquid manure from the water-cart are obviated by conveying it into the fields in casks carried by labourers on their backs, from whence they distribute it by hand. This distribution, either by water-cart or by hand-carriage, is however attended by the inconvenience of delivery in too high a state of concentration, in order to avoid the increased bulk and weight of carriage by a proper dilution, which would often be with six or more parts of water.

But by the method of distribution through pipes, with the hose and jet, (by steam-power, where there is no sufficient fall,) the objections recited by Schwerze are obviated, and considerable advantages gained, as will be perceived by further reference to the practical examples furnished.

In Mr. Holland's experiments, three tons of nightsoil diluted with seventeen of water produced a more fertilizing effect than a top-dressing of fourteen loads of stable manure. The weight of grass on the irrigated land was 50 per cent. greater.

The expense of applying fifteen loads of stable manure is estimated in Lancashire, where the first trials were obtained, as follows:—

| | | | |
|---|---|---|---|
| The labour of three men half a day, at 2*s.* 6*d.* | £0 | 3 | 9 |
| Cart and two horses half a day, at 20*s.* - | 0 | 10 | 0 |
| Spreading, one man, one day - - - | 0 | 2 | 6 |
| Bush harrowing, man and horse, half a day - | 0 | 5 | 0 |
| Boy half a day - - - - - | 0 | 1 | 0 |
| Total - - - | £1 | 2 | 3 |

| | | | |
|---|---|---|---|
| The removal of the effect of the poaching of the land, the labour of one man, two days | £0 | 5 | 0 |

By skilful arrangements, this expense of labour may no doubt be reduced, but it is seldom found to be less than one shilling per load. The application of fifteen loads of liquid manure by the water-cart is estimated at the labour of two horses, at 10*s.*, and three men, half a day, at 3*s.* 9*d.*, or 13*s.* 9*d.*, or, including the labour of making good the poaching of the land, 18*s.* 9*d.*

The expense of the distribution of equivalent quantities of manure would then be—

| | | | |
|---|---|---|---|
| 15 loads of the solid manure by cart - | £1 | 7 | 0 |
| 15 loads of liquid manure by the water-cart; say - - - - | 0 | 18 | 9 |
| 15 loads of liquid manure by 800 yards of hose, and the jet at 100 feet of pressure, as by Mr. H. Thomson's experiments - | 0 | 1 | 9 |
| 15 loads of liquid manure distributed by a short hose from a stand-pipe by fixed steam engine, on the same principle and at the same expense as street-watering - | 0 | 0 | 6 |

Exclusive of interest on the outlay for works, which is amply repaid by the value of the manure saved, now worse than wasted.

It may illustrate this question as to the expense of distribution, to observe that, by a pump and hose, a man with the same labour required to lift a given quantity of manure into a water-cart, say a seven-feet lift, might convey the same liquid as far as the hose need extend on the same level.

Mr. Neilson, of Halewood, having some time ago had his attention called to the facilities of this method of distribution by hand-pump and hose, as against the water-cart, used a hose of 400 feet long, and found that he could, within the range of the hose, by *hand-labour*, distribute manure at about one third the expense of distribution by the water-cart. By repeated applications of manure by this method, he accomplished the feat of raising, in a well-drained favourable plot of ground, previously in excellent condition and very fertile, about 100 tons of green crop of Italian rye grass and clover from one acre of land within the year. He has since adopted the steam engine, iron pipe and hose distribution. An account of his operations will be found in Mr. Lee's Report. (Appendix No. VI.)

For the distribution of plain water as well as manure, taking into account the expense of the original formation of water meadows as well as other expenses, it now appears to be decided that this method of distribution by hose will be found to be cheaper, particularly when carried out on a large scale, and when the collateral economies are considered, than by the cheapest instances of the water-meadow system.

The Reverend A. Huxtable having had his attention directed to the subject, adopted the system of the distribution of liquid manure by pipes, as extensively as a limited supply of water in a chalk district would permit. For his account of the use of wooden pipes, and also of earthenware pipes as distributary apparatus, *vide* Appendix No. III.

Mr. Holland's steam engine of eight-horse power, by the labour of one engineman and four distributors with hose and jets, distributed three hundred loads of liquid manure in ten hours, about half the time being occupied in shifting the hose.

On Mr. Kennedy's farm, at Myer Mill, the quantity delivered by a jet worked by a twelve-horse steam engine, at an extreme length of three quarters of a mile, or over 400 acres, was above 40,000 gallons, or 180 tons per diem, at the expense for labour of less than one halfpenny per ton. But a double set of men would reduce the expense. Two men there distribute a very heavy dressing of the liquid manure on ten acres per diem.

From some trial-works made of the distribution of liquid manure, by a steam engine on a barge belonging to the Metropolitan Commissioners of Sewers, in a canal in London, it appeared that within a quarter of a mile from the banks 100 tons were distributed at a rate of expense of 1*s.* 8*d.* One hundred tons would cover an acre to about an inch in depth; a good shower would cover it to about the depth of an eighth of an inch.

The removal of manure liquified is a removal in a form in which it may be applied immediately; whereas the removal by hand-labour and cartage of the solid or semi-fluid manure from the town to the suburb is a removal in a form requiring on the farm a troublesome and offensive manipulation. Mr. Cuthbert Johnson, in his valuable work on manures, mentions the offensiveness and difficulty of manipulation as the reason why nightsoil is not more preferred. Indeed, the greater convenience in application of guano has since its introduction caused it to be preferred, and has in several town districts greatly diminished the demand for nightsoil, and lowered its price. In the diluted state, and with pipe distribution, town manure in the form of sewage would have the superiority in convenience.

The cheapness of lifting and removal, on a large scale, by steam power, renders the question of levels far less important than it has hitherto been considered. The expense of raising 43,000 gallons a hundred feet high by a Cornish engine of twenty-five horses power is only a shilling; and with an engine of 180 horses power 80,000 gallons is lifted for that sum, coal being 12*s*. per ton.* Whatever be the manure, it must be carried to the height of the land, and wheresoever solid manure is carried, if it be a tract of any such extent as would come under consideration for the application of town manure, liquid manure would be raised at a cheaper rate.

There appears to be some misconception in relation to the power of pumping, and apprehensions are sometimes expressed that mixtures of common dung would clog the pipes, and could not be pumped.

In the first experiments of the distribution of manure by the hose, in several instances, what was called liquid manure was in fact only semi-fluid manure, but even this was delivered of the consistency of tolerably thick mud, with much fibrous matter, through a hose 800 yards long. In the potteries what is called "slip," that is to say, clay mixed with powdered flint and granite with about one ton and a half of water to one ton of solid matter, is pumped and distributed; and there is no doubt that where water is available, and where the operation required is on a sufficiently large scale, lands might be "clayed" and earths distributed much more effectually and cheaply by this than

* *Vide* evidence given to the Board; Report on Water Supply, Appendix 2, p. 25. The expenses referred to will not be understood as including interest on capital, but the mere working expenses. For the full charges as applicable to the objects in question, *vide* the details of actual outlays given by Mr. Lee. The duty of common agricultural steam engines is of little more than one fourth that of Cornish engines.

by any other method.* To reduce the expense and the time of emptying cesspools in the metropolis a pump with flexible tube and hose is used, and is perfectly successful in the removal of very thick cesspool matter through the hose into a distant opening into a sewer. Much distribution has been effected with one part of solid manure in six or seven of water. With proper adaptations, and with

* From the greater weight of the "slip," the labour of pumping is increased about one third above the labour of pumping water. The power of water in carrying matters in suspension is much neglected in agricultural as well as in engineering operations. Earths may, when properly diluted, be distributed, by the pump worked by steam power, through a hose, with open apertures, not only at a cheaper rate than by any other method, but in a far superior mode, being finely comminuted and evenly spread. In Germany, where water can be obtained at a high level, and gravitation can be used, improvements are effected by the distribution of earths on an extensive scale (vide Von Thæer, p. 210), the principle of the mechanical distribution, by hydraulic power, being the same as warping. In Tuscany the large work of the "*bonificamento*" of the *Maremma* is a work by means of water power so applied by which upwards of two feet in thickness of solid earth has been spread over forty square miles of country, a mass of earth-work equal to nearly eighty-two and a half million cubic yards, regularly deposited as if rammed,—equal in bulk probably to the mass of earth-work required to form several large railways. On an estimate for some work on a large scale in this country it appeared that the working expense of spreading clay by means of a hose would be little more than 2*s*. 6*d*. per inch of depth per acre, equal to 134 cubic yards, the expense of carrying and spreading, which by man and horse power would have been very considerable. The following example of the comparative expense of removal of earth by cartage and in suspension in water is given in the sanitary report:—"A contract was about to be entered into by the West Middlesex Water Company for hauling out from their reservoir at Kensington the deposit of eight or ten years silt, which had accumulated to the depth of three or four feet. The contractor offered to remove this quantity, which covered nearly an acre of surface, for the sum of 400*l*., in three or four weeks. The reservoir was emptied, in order to be inspected by the engineer and directors before the contract was accepted. It occurred to one of the officers that the cleansing might be accomplished more readily by merely stirring up the silt to mix it with water; and then, if a cut or outlet were made in the main-pipe used for conveying the water to London, that it might be washed out. He accordingly got thirty or forty men to work in stirring up the deposit, and accomplished the work at the cost of 40*l*. or 50*l*., and three or four days labour, instead of so many weeks. When the directors went to see the basin, to decide upon the contract, the reservoir was as free from any deposit as a house floor." Under the old practice, sewers were cleansed from deposit by buckets, and the deposit removed by cartage, at an expense of 10*s*. per load, by contract. By means of flushing or by water the cleansing and removal was effected at from 8*d*. to 3*d*. per load. In some pumping operations, on a large scale, and by a pump of a construction in use at Paris (*vide* Mr. Rammell's Report on the Cesspool System, p. 10), dead cats have been lifted and carried away in water. Where there is a sufficient flow, granite grit has been removed in water; and, when freed from the long straw, stable dung and town garbage may be very conveniently and cheaply removed by pumping.

pumps worked by steam power, there is no mechanical difficulty in the distribution of semi-fluid manure; the usual objection is chemical or agricultural, as before recited, to the distribution of the manure in a highly concentrated state. An instance is stated of the distribution of the thick manure of an old town ditch upon grass without precaution as to its intensity, and the consequence was, that the vegetation was entirely destroyed, and that the meadow was for a long time after as bare as a road wherever the manure had fallen, as if oil of vitriol had been distributed upon it. Frequently, however, when destruction of the growing vegetation has been the first result of an overdose of such manure, this has been followed by extraordinary fertility; the herbage may be destroyed without killing the roots.

To facilitate the distribution of manures in dry weather, and to avoid the inconveniences of spreading solid refuse over the leaves of plants, Mr. Chadwick suggested the expedient of distributing sewer water by lengths of flexible hose with lateral openings like the eylet holes of stays. These lengths are laid on the ground in convenient positions for shedding, and the distribution takes place in a manner similar to the overflow distribution by shedding from the carriers of water-meadows. Mr. Donaldson, the surveyor who superintended the preparation and adjustment of the sizes of the lateral openings, reports that the expedient will work as expected, that is to say, that there will be a more rapid discharge, requiring less power probably by one third than the method of discharge by the jet.* By this method of distribution the expense will be reduced; and it was reported that the crops in the fields where it was used were more equal than by the distribution by jet.

The hose (which may now be had of a superior quality of prepared canvass, at about 1*s.* per yard, and will last with ordinary wear and tear and occasional patching about six years,) might be worked by the ordinary farm engine, in considerable lengths, upwards of a thousand yards, and would, in the first instance, pay its expense as trial works merely for the determination of arrangements for fixed systems of pipes and distributary apparatus.

* Gutta percha pipe was found highly convenient for the adjustment of the lateral apertures to the varying extent of pressure under which this method was tried. The sum of the sectional areas of the apertures was adjusted at about three-fourths of the sectional area of the pipe, and this adjustment was proved to answer well in practice. Apertures of about a quarter of an inch in diameter, one foot apart, in a pipe of two inches in internal capacity, and fifty feet long, was found to be a good arrangement.

The methods of irrigation by water-meadows are conveniently described in Mr. Pusey's letter:—

"In shaping the ground for the water to run over, two methods have been pursued. In Wiltshire and the neighbouring counties it is thrown up into beds, the water running along the crown of each bed, and discharging on each side. As the whole surface is remodelled, the operation is expensive, costing from 15*l.* to 40*l.* per acre; the average being full 20*l.*

"The other method is the catch-meadow, used chiefly, until lately, in Devonshire. The gutters being drawn along natural slopes, the water falls from the upper one to that immediately below it, which spreads it anew equally over the surface lower down. Hence the name, catch-meadow.

"This system, originating in an almost mountainous country, has been of late years transferred to land quite as level as any on which the ridge water-meadows were made in Wiltshire."

The Duke of Portland's meadows cost on the average 120*l.* per acre, and in working expenses, including interest, 9*l.* 10*s.* per annum; the Duke of Bedford's, 13*l.* 2*s.* 10*d.* per acre, first cost, or, per annum, with expenses, 1*l.* 14*s.* 8*d.* The average cost of some of the Wiltshire meadows appear to be about 20*l.* per acre, and the annual expenses, including interest, 1*l.* 17*s.* per acre. The more recent expenses of the formation of new irrigation meadows near Edinburgh was above 18*l.* per English acre, and the annual expenses, 1*l.* 18*s.* Where steam power is used for raising the sewage over the panes, the expenses are augmented to 4*l.* 4*s.* 11*d.* per annum per acre. The cheapest meadows of all, for the distribution of liquid manure, met with in the course of the recent investigations, were those formed by Mr. Pusey. But at Edinburgh inconveniences were alleged as attendant upon the catch-water meadows, which there led to the preference of the Wiltshire method of distribution, at an increased annual expense. Nevertheless, for open gutter distribution, it appears that the catch-meadow would generally be the most eligible. The details of the works at Pusey are set forth in Mr. Lee's Report; but the annual expenses of these, the cheapest of the irrigation meadows, appear to be per acre as follows:

| | *s.* | *d.* |
|---|---|---|
| Interest upon 4*l.* 9*s.* at 7½ per cent. - | 6 | 8 |
| Cleaning gutters - - - - | 5 | 0 |
| Labourer - - - - | 2 | 7 |
| | 14 | 3 |

A paper contained in Part I. Vol. XII. Art. 7., of the Royal Agricultural Society's Journal, is referred to by

Mr. Pusey for examples of the formation of catch-water meadows at a lower rate of expense than was incurred by the formation of his own; but these were of "hill-side" catch-water meadows, such hill sides as those of Exmoor, where, to use the words of the author, "the hill side being "already formed by nature to our hands, the spirit level "beautifully traces the varied slopes, and marks the onward "course for the gutterer or waterman." It moreover appears, upon the examination of Mr. Lee, that although the cost of cutting the gutters is in that particular instance less, yet that the cost of the whole of the contemplated arrangements would be greater than the pipe system; so that Mr. Pusey's own case may be fairly taken as one of the best average cases of catch-water construction, and indeed as an *à fortiori* case for a comparison with the expenses of the distribution of liquified manure by underground pipes, with flexible hose and jets.

This comparison between the cases is instituted for the purposes of the Public Health Act, where either pipework or catchwork are required for the distribution of manures already collected at a given point. The system of catch-work is employed by agriculturists in this country *primarily* for a different purpose, the distribution of streams over the surface of meadows in winter, which would have to be considered on different grounds, but into which it is unnecessary here to enter. It is proper to observe, however, that this *primary* object of the agricultural irrigator is now more commonly combined with the application of liquid and liquified manures conveyed in the open water-gutters, and in many cases the whole of the fluid conveyed in such gutters is liquid manures. In scarcely any instance of new works is the opportunity now lost of combining with the irrigating stream all the organic refuse, or manure, within reach. Where the inclination of the ground will admit, much advantage will result in all these cases from arrangements such as are indicated in the Minute on Hill-side Irrigation, Appendix, No. VIII.

At Glasgow the stated outlay for pipe distribution comprehended some erroneous constructions. Including these, such as a set of pipes which had to be replaced, the original outlay was about 5*l.* per acre; but the present work did not exceed 3*l.* per English acre, and the working expenses are 13*s.* 9*d.* per annum. But the more complete example, comprehending arrangements for the pipe distribution in every field, is at the Myer Mill Farm, where a plug was opened in every field, at a cost of 3*l.* 3*s.* per acre. These pipes may be considered as more than equivalent in distributing power to the water carriers. The annual working expenses, including interest on capital, is 11*s.* 1*d.* per acre. *Vide* Mr. Lee's Report for the details. (Appendix, No. VI.) The working expenses of each separate distribution in the latter instance was about 8*d.*, inclusive of all expenses, for the distribution of 4,800 gallons or 21½ tons per acre.

Whilst the weltings by pipe distribution (which appear to have sufficed, and to have produced at the least equivalent effects to the submersions of the lands laid out in beds) have been only 20 tons per acre, or less than a quarter of an inch in depth, in the practice of submersion, about an inch in depth, or 100 tons per acre, is considered a very moderate working quantity. In the practice of the systematic irrigations of Lombardy and Provence, a decimetre, nearly 3·7 inches of depth, or 370 tons per acre, is set down as the proper allowance. On the Edinburgh irrigations as much as 1,000 tons per acre have been applied. *Vide* Mr. Lee's Report, p. 76.

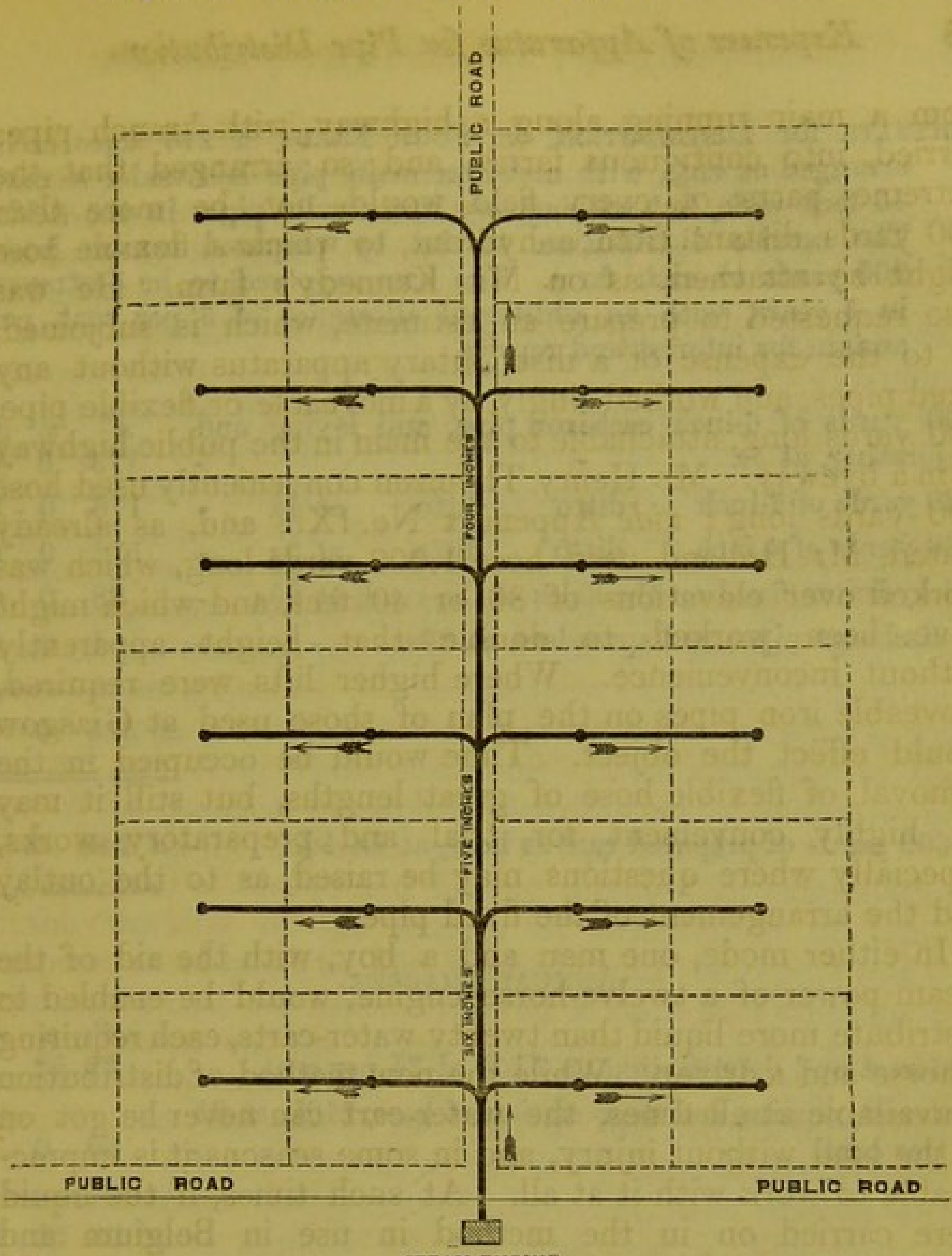
At Mr. Telfer's farm, where iron pipes and steam power are used, the first outlay was 4*l.* 4*s.* per acre, and the working expenses and interest, 10*s.* 8*d.* per acre per annum. Where gravitation or earthenware distributary apparatus was used, the expenses were fully one third less, or not more than the working expenses of catch-water meadows, apart from any interest on the outlay of capital. For exemplifications of the practical applications of the system of gravitation, *vide* Appendix, No. VIII.

The operation of the removal of liquid or liquified manure from the town, and its distribution by pipes and steam power upon the land, is only a reflex operation to the distribution of water into the houses of towns, the principle being the same. In Paris, where water is distributed by cartage and hand labour, the expense of the irregular distribution is two sous per pailful. In many of the towns under the Public Health Act water will be collected from springs, in some instances more than twelve miles distance, conveyed to the town, be raised up to the tops of the highest houses, and there be delivered instantly, or constantly where wanted, at a rate of from one to two hundred pailsfull and upwards for a penny. (*Vide* Report on the Water Supply of the Metropolis, pp. 158—162.) In the practical instance cited, of the delivery of liquid and liquified manure on Mr. Kennedy's farm by steam power, and pipes, two hundred pailsfull were distributed at a working expense of one penny.

Mr. Lee was requested to prepare a plan and estimate, which is subjoined, for the distribution of sewerage manure, from a main running along a highway, with branch pipes carried into contiguous farms, and so arranged that the extreme parts of every field would not be more than 300 yards distant from a hydrant, to which a flexible hose might be attached, as on Mr. Kennedy's farm. He was also requested to prepare an estimate, which is subjoined, as to the expense of a distributary apparatus without any fixed pipes, and worked singly by a moveable or flexible pipe, 900 yards long, attachable to the main in the public highway or in a byeway. Mr. Henry Thomson conveniently used hose 800 yards long; *vide* Appendix No. IX.; and, as already stated, Mr. Holland used hose 1,000 yards long, which was worked over elevations of 30 or 40 feet, and which might have been worked to double that height apparently without inconvenience. Where higher lifts were required, moveable iron pipes on the plan of those used at Glasgow would effect the object. Time would be occupied in the removal of flexible hose of great lengths, but still it may be highly convenient for trial and preparatory works, especially where questions may be raised, as to the outlay and the arrangement of the fixed pipes.

In either mode, one man and a boy, with the aid of the steam power of a twelve-horse engine, would be enabled to distribute more liquid than twenty water-carts, each requiring a horse and a driver. While the new method of distribution is available at all times, the water-cart can never be got on to the land without injury, and in some seasons it is impracticable to work with it at all. At such times, if the liquid were carried on in the method in use in Belgium and Germany the labour of between 100 and 200 men would be required to effect the distribution, which, by the improved method, is effected by one man and a boy.

As illustrative of one element of the superior economy of the method of pipe distribution over that by irrigation, it may be mentioned that, as is shown in the subjoined plan, there will be required less than 12 yards of fixed pipe per acre, whereas in the common plan of water meadows more than twenty times that length of open gutter-work would be required to be formed and kept clear; the open gutter-work in the Edinburgh water meadows being at the rate of 240 yards per acre. On another plan by Mr. Rammell, of a closer arrangement of earthenware as well as of iron pipes, which under many circumstances would be the most eligible, and on which no part of a field would be less than 154 yards from a hydrant, there would be 22 yards of fixed iron pipe per acre. *Vide* Appendix VII.; also various plans of distributary apparatus by Mr. Lee.




The projections on the lines mark the positions of the hydrants.

ESTIMATE for CAST IRON PIPEAGE for FOUR FARMS of 240 acres each.

A main pipe to be laid under a road 45 feet wide. The most remote parts of the farms to be reached by 300 yards of hose.

| | £ | s. | d. |
|---|---|---|---|
| 700 yards of 6-inch cast-iron pipe, and laying and jointing, at 5*s.* - - - - | 175 | 0 | 0 |
| 880 yards of 5-inch ditto ditto at 4*s.* - | 176 | 0 | 0 |
| 880 yards of 4-inch ditto ditto at 3*s.* - | 132 | 0 | 0 |
| 8,200 yards of 3-inch ditto ditto at 2*s.* 4*d.* | 956 | 13 | 4 |
| 24 hydrants, at 20*s.* - - - - - | 24 | 0 | 0 |
| 300 yards of hose to each farm = 1,200 yards, at 1*s.* 4*d.* | 80 | 0 | 0 |
| 4 discharge pipes and spreaders, at 20*s.* - - | 4 | 0 | 0 |
| | £1,547 | 13 | 4 |

Total cost of apparatus complete, 1*l.* 12*s.* 3*d.* per acre.

Annual charge on the land, at 7½ per cent., 2*s.* 5*d.* per acre.

Quantity of iron pipage per acre, 11$\frac{1}{10}$ yards.

With earthenware pipes the expense would be one half or one third those of iron.

Estimate for Distribution on Four Farms of 240 acres each, arranged as *ante*, with cast-iron main pipe laid under a road 45 feet wide, but without any iron service pipes in the fields. The service distribution to be by prepared canvas hose, 900 yards to each farm. The hose supposed to be destroyed in 5 years, with an additional allowance of 5 per cent. per annum for interest and repairs.

| | £ | s. | d. |
|---|---|---|---|
| 700 yards of 6-inch cast-iron pipe, and laying and jointing, at 5*s.* - - - | 175 | 0 | 0 |
| 880 yards of 5-inch ditto ditto at 4*s.* - | 176 | 0 | 0 |
| 880 yards of 4-inch ditto ditto at 3*s.* - | 132 | 0 | 0 |
| 28 hydrants fixed on the sides of the road, at 20*s.* - | 28 | 0 | 0 |
| 4 discharge pipes and spreaders, at 20*s.* - - | 4 | 0 | 0 |
| | £ 515 | 0 | 0 |

| | £ | s. | d. |
|---|---|---|---|
| 3,600 yards of prepared canvas hose, at 1*s.* 4*d.* - | £ 240 | 0 | 0 |

Annual Charges.

| | £ | s. | d. |
|---|---|---|---|
| Interest and depreciation on 515*l.* at $7\frac{1}{2}$ per cent. - | 38 | 12 | 6 |
| Interest, repairs, and depreciation of hose, 240*l.*, at 25 per cent. - - - - - - - | 60 | 0 | 0 |
| | £ 98 | 12 | 6 |

98*l.* 12*s.* 6*d.* divided equally among 960 acres, is equal to an annual charge of 2*s.* $0\frac{3}{4}$*d.* per acre

Mr. Huxtable, having succeeded * in getting good earthenware pipes made, reduced the expense of his distributary apparatus to 1*l.* per acre.

* The Romans used earthenware pipes for the distribution of water, at 100 feet of pressure, and some laid down by them in the first century are still in use; in France such pipes are in use at 120 feet of pressure; at Weymouth they have been in use for upwards of twenty years, at an intermittent pressure of sixty feet; but neither engineers nor pipe manufacturers appear yet generally to have cared to master so economical an apparatus: not having fallen within their own practice, they seem to have considered these pipes not "practical."

The following is a table which Mr. Lee was requested to prepare, to contrast the outlay and working expenses of the old and the new methods of removing and applying manures in the chief instances referred to. [*See Table on following page.*]

From this table it will be perceived that the cost of works and apparatus, on the average of all the examples examined of distribution by bed works and gutters, including the instance of the catch-water meadows, has been 31*l.* 14*s.* 7*d* per acre, and that the total annual charges and working expenses are 3*l.* 7*s.* 1*d.*: that the cost of works and apparatus, on the average of all the examples of distribution by underground pipes, has been 3*l.* 5*s.* 1*d.* per acre, and the total annual charges per acre 8*s.* 11½*d.* per annum: that the total annual expenses of the cheapest example of distribution by open gutters, the Pusey catch-water meadows, was 14*s.* 3*d.* per acre, whilst the total annual expenses in the case of the cheapest example of distribution by underground pipes, and by jet and hose, was 7*s.* 1½*d.* per acre.

The Duke of Sutherland having directed an examination of the working of the system of distribution of liquid manures, as adopted by Mr. Kennedy, and the report was so satisfactory that his Grace ordered a farm at Trentham to be laid down on the same principle; though not yet brought into operation, it is included in the above table for the example of the cost of the distributary apparatus. So, also, in respect to the dairy farm of Mr. Harold, Littledale, which had previously, however, been worked with liquid manure, applied by the water-cart. The farm of Mr. Robert Neilson, at Halewood near Liverpool, which he holds under the Earl of Derby, had, as stated, been previously worked extensively by liquid manure, distributed by moveable hoses worked by hand only.

If it be assumed that the delivery of manure is in both cases proportionate in frequency or in quantity, which appears to be by no means the fact, as a much smaller quantity delivered by the hose and jet is required, still it appears to be demonstrated that the distribution by underground pipes with the flexible hose and jet is cheaper than the cheapest of the water-meadows of which any authentic account has yet been obtained, besides other advantages, such as economy of manure, &c.

But whilst this is demonstrated to have the advantage over other methods in respect to the first outlay required, and in working expenses, it is free from the sanitary objections to the water-meadows, founded on the injury to health arising

TABLE showing COST, &c. of the Application of SEWERAGE WATERS and LIQUID MANURES.

| Name of Place. | No. of English acres. | Mode of Application. | Total cost of works and apparatus per acre. | Annual interest, &c. at 7½ per cent. per acre. | Annual working expenses per acre. | Total annual charges per English acre. | Observations. |
|---|---|---|---|---|---|---|---|
| | | | £ s. d. | £ s. d. | £ s. d. | £ s. d. | |
| NOTTINGHAMSHIRE: Duke of Portland's Clipstone Meadows | 300 | Catch-meadow, gravitation, and open gutters | 120 0 0 | 9 0 0 | 0 10 0 | 9 10 0 | Previously worth from 3s. to 5s. per acre per annum, produce now upwards of 12l. |
| EDINBURGH: Craigentinny Meadows:— High Level | 63 | Steam engine, pumps, and open gutters and panes | 31 14 11 | 2 7 7 | 1 17 4 | 4 4 11 | Average rental, upwards of 16l. per English acre. |
| Sea Meadows | 38 | Gravitation, open gutters, and panes | 18 8 5 | 1 7 7½ | 0 10 5½ | 1 18 1 | Worthless 25 years ago, now worth 520l. per English acre. |
| Old Meadows | 228 | Gravitation, open gutters, and panes | 11 16 10 | 0 17 9 | 0 10 5 | 1 8 2½ | Maximum rental, 25l. per English acre. |
| WILTSHIRE: Wiley Meadows | 150 | Bed-work of ridge and furrow, gravitation and open gutters | 20 0 0 | 1 10 0 | 0 7 0 | 1 17 0 | Four heavy crops of grass per annum. |
| DEVONSHIRE: Duke of Bedford's Tavistock Meadows | 90 | Bed work and catch-meadow, gravitation and open gutters | 13 2 10 | 0 19 8½ | 0 15 0 | 1 14 8½ | Land more than quadrupled in value after only five years irrigation. |
| BERKSHIRE: Pusey Meadows | 100 | Catch-meadow, gravitation and open gutters | 4 9 0 | 0 6 8 | 0 7 7 | 0 14 3 | Land not previously worth more than 5s. per acre is now yielding six heavy crops of grass per annum. |
| STAFFORDSHIRE: Duke of Sutherland's farm near Trentham | 83 | Steam engine, pumps, underground iron pipes, gutta percha hose, and jet pipe | 6 5 5 | 0 9 5 | 0 4 4¾ | 0 13 9¾ | Tanks constructed sufficient for 300 acres. |
| GLASGOW: Mr. Harvey's farm | 508 | Steam engine, pumps, under ground iron main pipes, and iron distributing pipes | 2 17 1 | 0 4 3½ | 0 9 5½ | 0 13 9 | 10 feet thick of grass cut from an acre in six months. |
| GLAMORGANSHIRE. Porth Kerry Farm | 50 | Gravitation, iron pipes and gutta percha hose | 6 0 0 | 0 9 0 | 0 4 0 | 0 13 0 | Tanks constructed sufficient for 300 acres. Upwards of 9 feet of grass grown. |
| AYRSHIRE: Mr. Kennedy's Myer Mill farm | 508 | Steam engine, pumps, underground iron mains, gutta percha hose, and jet pipe | 3 2 6 | 0 4 8¼ | 0 6 4¾ | 0 11 1 | 70 tons of grass cut from an acre in six months. |
| Mr. Telfer's Canning Park farm | 50 | Ditto | 4 4 0 | 0 6 3½ | 0 4 4¾ | 0 10 8¼ | 14½ feet thick of grass cut in seven months. |
| LANCASHIRE: Mr. R. Neilson's Halewood farm | 120 | Ditto | 4 6 11 | 0 6 6¼ | 0 3 3½ | 0 9 9¾ | One dressing of liquid found equal to 25 to 30 tons of solid farm-yard manure per acre. |
| CHESHIRE: Mr. Harrold Littledale's Liscard farm | 150 | Ditto | 4 9 7 | 0 6 8½ | 0 2 4½ | 0 9 1½ | A fourth crop of grass, equal to 10 tons per acre. |
| Marquis of Ailsa, Leg or Dunduff farm | 50 | Gravitation, underground iron mains, gutta percha hose, and jet pipe | 3 16 5 | 0 5 8¾ | 0 1 4¾ | 0 7 0¾ | 12 stacks per annum previously; 80 stacks last year. |

from the formation of wide-spread and long-standing evaporating surfaces; the exposure of decomposing matter, or manure, being reduced to the minimum, the principle of the process being in fact the same as that of the ordinary watering of gardens, only on a large scale.

The new mode of distributing sewage, whether by gravitation or by steam power*, gives a new arm to the agriculturist, of prompt and varied action, according to the exigencies of culture.

The chief advantages apparent from the use either of iron or earthenware pipes or the flexible hose with lateral openings, either as water or manure carriers over the water meadows may be thus recited:—that the surface now occupied by fixed carriers for water-meadows would be saved; that the flexible hose may be carried across depressions or over undulations of surface, with closed lengths, without the expense of permanent works; that with these tubular carriers less water will suffice, and therefore less waste from evaporation; that the apparatus may be at once removed for the adaptation of the land to arable or varied cultivation; that by means of the hose with lateral openings, or sets of shifting pipes, liquid manures may be distributed between ridges and growing plants, regularly and accurately. The hose may be carried over hedges, ditches, or even small streams. With a slight covering, it may be carried temporarily over a road, or under it through a road drain. The method of distribution by shedding, instead of by jet, is peculiarly applicable where it is required to raise manure or water high lifts.

When the several specified advantages of the pipe distribution are considered, they appear to the engineering inspectors who have examined the different works, to preponderate greatly, even for common agricultural purposes, over the cheapest methods of distribution by catch-water

* In respect to the application of water, stored at high levels, and its advantages even over steam for intermittent applications of power, vide Report of the General Board on the Supply of Water to the Metropolis, p. 261 to 264. The distribution by the hose and jet admits of various modes of appliance with steam power, from the heaviest fall of a thunder shower within the range of the jet, to a shedding in the shape of a mist by a skilful operator, or the shedding in various full streams upon the ground. Horticulturalists deem various niceties in watering essential to good production. In the practice of the new distribution on a large scale these points of skill appear to have been little, if at all, attended to; and although crops now deemed extraordinary were got without them, it is probable that, with them, further increase of production will be attained.

meadows, and to induce a far higher and more profitable order of cultivation. When indeed the question relates to land which is valuable from its contiguity to a town, and to a cultivation yielding 10*l.* or 20*l.* per acre or more, the annual cost of the land occupied by the water carriers alone exceeds the annual cost of a complete system of iron pipes. Thus in the newly formed water meadows at Edinburgh, the open gutters occupy about one thirty-seventh of the area irrigated, and in many places a greater proportionate space is occupied for the purpose. As the rent of the land is there 20*l.* an acre, the annual value of the space devoted to gutters is 10*s.* 9*d.* per acre, or about equal to the average annual working expenses, including interest on capital, of the pipe distribution; and it would be clearly a saving to the owners of those meadows, and of several others, as may be seen in the foregoing table, to fill up the gutters, to abandon the practice of distribution by submersion, and to adopt that of pipe distribution. Besides saving land, filling up the gutters would be removing impediments to the passage of carts and numerous other agricultural operations. Where a sufficient fall is obtained for pipe distribution by gravitation, it is cheaper than the common catch-water meadows.

The works for the distribution of manures by means of pipes and hose or jets, it is to be observed, are also available for the important object of the distribution of simple water. In several instances of the production of great effects by the distribution of liquid manure on a large scale, there is little doubt that a considerable portion of the effect obtained in dry weather would have been produced by the application of water simply; indeed that the arrangements are to be regarded as subservient to the object, the importance of which has been so emphatically expressed by De Candolle, serving, at one and the same time, for manuring and for watering.

The power derivable from the prompt applications of plain water to arable cultivation may be said to be unknown to the agriculture of this country, and very little known in that which has heretofore been distinguished, with little foundation, from general agriculture, namely, "market garden cultivation;" and it is only imperfectly practised in horticulture. Under particular circumstances wheat has been watered with great success. In the market garden cultivation at Naples and Paris, effects are stated to be produced by skilful watering which are unknown in this country. At

Naples the water is distributed by regular channels of irrigation. At the market gardens of Paris it is skilfully distributed by hand labour by the use of the scoop; at great expense indeed but for which the extra produce compensates. Some of the more eminent market gardeners would, however, appreciate the advantages of any appliances for the cheap distribution of water as well as of the manure. A quantity of water equal to the fall from a heavy thunder shower may be distributed by engine power at an expense not exceeding a few pence per acre.

The cheap power of distributing water may often be of importance to the agriculturist, to facilitate the working of the land at those times when it is hardened by drought, and when, for ploughing or other work, extra labour, often more than double the ordinary amount, is necessary. On such occasions, labourers wet the ground to facilitate the working with the spade. When water is available, and when the ground may be thoroughly wetted at a trifling expense, the farmer may by such an application work with two horses where otherwise four would be required.

With the solid manure, applied as top dressing, the farmer frequently spreads the larvæ of devastating insects, or provides for their deposit and sustentation. By the distribution of manure in the liquid form this mischief is abated. Moreover, the fixed distributary apparatus will be, on a large scale, what the garden engine is on a small scale to the horticulturists, a powerful arm to agriculturists against insect devastators, by the rapid distribution in water of cheap substances which are destructive to them.*

Steam or hydraulic power and machinery, for the distribution of water as well as manure, is found of great use in cleansing, and in the internal economy of the cattle sheds and of the farm.

For cleansing the surfaces of yards, roads, and pavements in towns, water applied under powerful pressure by the jet is preferable to cleansing by the broom or the brush;—for the broom only reduces the bulk of the filth, and does not remove it all. When ordure is adhesive or semi-fluid, the broom spreads it over a wider surface, and stirs it up, thus increasing the extent of the offensive evaporation. Water applied by the jet removes the whole at once, and cleans the surface

* Mr. Neilson, who has availed himself of the use of steam power and the jet for the distribution of liquid for this purpose, says that "nothing disturbs the fly on turnips more than a shower of muck water."

completely. It had for this reason been recommended for cleansing as well yards as stables in towns, because it saved much manure, as well as performed the cleansing quickly and effectually, without raising any offensive dust. Mr. Neilson has adopted the principle for cleansing his own farm-steading, and washes his cattle and pigs with the jet, as he reports, with great advantage.* *Vide* Mr. Lee's report.

Where a tank or sump is used for the reception of water or liquid manure, one important convenience is the rapidity with which substances may be mixed up in it, and conveyed away for distant distribution, and the matter diluted or concentrated, according to the state of the soil as to moisture, or the use to be made of coming showers in aiding the process.

On the expenditure for the formation of tanks and the alteration of the cattle sheds required on a farm for a cultivation based on a system of liquid manure, as recited by Schwerze, it may be observed that such alterations, implying the keeping of the sheds in a more cleanly and better sanitary condition, will have a money value in the improved health of the stock. If, however, the objection in respect to the outlay required to place farms on the most productive footing were well founded, and if the outlay for pipes and fixed apparatus had not in every instance proved to be remunerative, that objection would not be in the least degree applicable to the proposed system of the distribution of sewer manures of towns; for those manures must be received in covered reservoirs constructed on a large scale, or under circumstances which will supersede the necessity of any tanks at the farms on the lands supplied with sewer manure.

From these tanks or sumps, or from the engine-houses connected with them, pipes should be carried along the roads and the byeways skirting the farms and gardens to which it is proposed that supplies of the liquid manure shall be extended. From these pipes, furnished with plugs and stop-cocks, either fixed branch pipes of the nature of the tenants house service pipes in the case of water supplies to towns, should be extended, or temporary branch iron pipes laid on the surface, in the same manner as those used at Glasgow; or, for shorter distances, flexible hose of canvass and gutta percha would be used.

* Mr. Neilson stated, that his pigs manifested a decided partiality to this mode of cleansing, and would lean with the shoulder towards the jet, and when one side had been cleansed by it would turn round the other for the completion of the operation.

These moveable surface pipes will be transferred from field to field, from meadow to meadow, or from farm to farm; and on the part of the consumer no fixed capital, no new outlay whatsoever would at first be needed, and in all cases it would be good policy on the part of the Local Boards to render such outlay unnecessary. It is desirable and proper that they should be liberal and accommodating to the farmers, and postpone the determination of the pecuniary returns until the fertilizing powers of the manure and the convenience of the distribution, which they will probably have had no opportunity of witnessing, have been demonstrated to them by actual results.

Where common or waste lands are within the jurisdiction of the Local Board, or lie near the town, the Board should enter into agreements with the parties interested, and seek powers for inclosing and draining them, and for laying down distributary apparatus, and for reletting the improved land, with the right of a sufficient supply of the town manure for its full cultivation.*

* It has been suggested for consideration, that contractors might be encouraged to undertake works for the distribution of sewage; who might, with great profit, besides irrigating accessible farms, purchase land conveniently situated for irrigation, and relet it at the increased value effected, as is done at Edinburgh; or, instead of purchasing such land, they might rent it on long lease, with a stipulation to be allowed at its termination the estimated increased value they have produced. One advantage of this plan would be, that while the demand for sewage is limited (as must be expected at first), it would not be necessary either to let it run to waste, or to apply to the land of those who will not pay for it as the excess for which there is no sale may be applied to the contractor's own land, so as to produce the richest soil that is practicable, and thereby obtain such rents as are obtained at Edinburgh, by what must be considered an excessive supply of manure upon a limited field for its application. It is also suggested, that Local Boards might secure for the public a share of the profits arising from the application of the sewage, by stipulating that a portion of all profits arising, beyond what is sufficient for paying a certain per-centage upon the capital embarked, should be expended in such local improvements as shall be approved of by the Local Board. Such an arrangement would entirely relieve the Local Board of all responsibility or trouble about business arrangements, which would be best managed by persons acting for themselves,—would secure for the inhabitants a share, and a constantly increasing share, in the profits arising from the sale or use of their refuse,—and would act as a real limitation upon the profits of the contractors without destroying the motives for conducting the business in the most profitable manner, as a simple limitation of profits is apt to do. The Local Board and the public would also have an inducement to afford every possible facility to such contractors, as the local public would participate in the accruing profits. It was once expected that the London Sewage Manure Company would prove the pioneer to this sort of investment. Some of the causes of its want of pecuniary success up to this time are stated in Mr. Lee's report. (Appendix VI.)

The Local Boards of Health should bear in mind, in respect to the chief of the town manures,—of human excreta in particular,—that they cannot properly be made the subject of permanent saleable or heritable or vested and proprietary rights. In the instances where the semblance of proprietary rights to such refuse may have been allowed to arise, it has been for want of due consideration of the circumstances, and amongst others, this one,—that the producers of the manure cannot be confined to any part cular district, or prevented depopulating it. The Local Boards are trustees for the inhabitants collectively. This view of the collective rights of the inhabitants to the property of such refuse is not inconsistent with byelaws and regulations debarring single individuals from the separate use or sale of refuse (as is frequently done by statute in respect to dust and coal-ashes in towns), inasmuch as the separate sale or use implies the separate retention of the ordure, and its removal, in such a a manner as to pollute the air, and become a cause of injury to the health, not only of every inmate of the particular house, but of the general population. A large part of the value of the refuse, or the property itself, is indeed created by concurrence in the arrangements on a large scale for the removal of refuse, by which, in the case of removal in tubular drains, and by a self-acting system of water-closets, two thirds or three fourths of the labour and expense of separate removal is saved, and consequently becomes clear again.*

It may be proper to observe, upon cases of undue exactions, founded upon supposed necessities for the use of land immediately adjoining to towns, or lying with convenient falls beneath them, that under the new system of distribution by pipeage and with steam power, there will rarely, if ever, be such necessities; inasmuch as the contiguous land may be passed by, and an extended market ground or the

* Instances have arisen where the whole refuse of the town having been sold for the public benefit, the regulations to that effect were, in consequence of agitations for separate disposal and sale, abrogated; but the value, or the sums obtained to each inhabitant from the sales of the general collection of the refuse, were in all instances immediately reduced, and in many instances disappeared entirely and the inhabitants had not only to pay for the removal of the refuse, but incurred the nuisance of its retention, as well as the inconveniences and disorders of irregular cleansings. Parts of animals and offal are thrown away when cattle are slaughtered at the butchers shops in towns, as the sale of the separate parts will not pay for the labour of separate collections from the butchers shops; but where the cattle are slaughtered at public abattoirs, this labour of the separate collection is saved, and the parts turned to useful account.

most suitable soil selected, at little more additional expense than of the extra lifts for heights or of the extra lengths of pipes, which may, where there is an adequate demand, be stretched out for several miles; pumping in large quantities through eight or ten miles in length of closed pipe is in practice, and no limits have yet been ascertained to the possible extent of distribution by such means.

The results continuously obtained beyond all agricultural precedent, even of the highest market-garden cultivation, having been obtained, by means confessedly rude and imperfect, there is the less danger of failure from the prosecution of similar work by new and untried hands. But the determination of the best seasons and times, and with what degrees of dilution, liquified manures may be applied, and in what intervals of rain or of applications of simple water, —in what modes the ordinary deposits and much solid town manure may be liquified, and distributed with the soluble manure to different crops,—are points of skill to be acquired by further experience, for which at the present time the best guide is to be found in the practice of horticulturalists.

In respect to the time at which the liquid manures may be distributed with the most direct effect on vegetation, it may be stated that the best season is when the rootlets are out and sound, and the plant is in action, and at different stages of their growth.

On the grass lands near Edinburgh sewer water is delivered eight times a year to each plot of land, but it is being used constantly on a succession of plots. The best horticultural practice, however, as already stated, gives it twice a week, with one watering of plain water in each interval. With sewage sufficiently diluted, the intermediate watering, which is desirable when strong liquid is used, will be unnecessary. As already stated, the barrier to the adoption of this frequency of delivery in agricultural practice is the expense of the labour of delivery, which it has been the great object, as above expounded, to reduce. Whatever may have been achieved so far, reasons will subsequently be given for believing that by perseverance in trial works more than is now done in horticulture may be accomplished for agriculture. The best times for the application of liquid manure in agriculture are when the ground is not too dry, nor the sun bright, or the wind high, i.e. when the circumstances are unfavourable to rapid evaporation, and at hours when the *horticultural* experience of the place prescribes that plants are best watered, and at times favourable to the manure being carried into the earth, and when the weather, without being so excessively wet as to flood the manure away, is moist, and even showery, to assist in its absorption. In March and April the horticulturists water their plants during any hour of the day; in May, June, July, and August from five till nine in the morning, and from five o'clock until eight and nine o'clock in the evening; and in the Autumn and Winter at any time except towards evening. Such are the *best* times for its application, but at no time will its use be unattended with marked advantage.

Farmers who have observed none of these conditions in the application of guano, and have laid it on in bright windy weather, have had their manure evaporated by the shipload and their money blown away. They have then reported that "guano did not answer" on their land; and so with other manures.

The ordinary effects of guano, Mr. Kennedy states, have been doubled by distribution in solution with water at the right times by the new distributary apparatus. One important advantage of this apparatus is, that the solution may be varied in intensity with the state of the weather and of the soil, the manure being delivered in the greatest intensity at times when the rain will serve for dilution, and in more dilution in dry weather.

When liquid manure is thrown over grass land, it should either be done in showery weather to wash it down from the leaves into the earth, or the leaves should receive a washing of plain water by jet, to free them from the manure left on them. (*Vide* Appendix XIV., experience in Germany as stated by Sprengel.) But when the liquid is sufficiently diluted this is not necessary.

During the progress of improvement, in periods when liquid manure cannot be directly applied, and when it would have to be stored or allowed to run to waste,—in the cases where there is a surplus beyond what may be applied in the vicinity of the town, or where manure is required for small plots of land at great heights, or where, either from the distance or the small quantity consumed, the outlay for pipes or the machinery for distribution would not be remunerative, the practice of saturating any suitable substances with it may be resorted to, after the method suggested by His Royal Highness Prince Albert.

As *sanitary* results of the examination of the various means in practice of collecting, removing, and applying town manures, it appears, then,—

1. That it is preferable to incur the total loss as manure, of ordure and urine, or of animal and

vegetable refuse in towns, than to allow it to be retained for occasional removal, and, during the intervals of removal, to putrefy and create noxious gaseous impurities, amidst or near dwellings:

2. That there have been no trials of chemical substances, as "deodorisers" or "disinfectants," made on a large scale, which have been satisfactory as preventives; that impurities are created before such means can be applied, and when they are applied, the labour of applying them, and the expense of the materials used, equal or exceed the proper cost of effectual arrangements for the immediate removal of all offensive matter:
3. That it is a primary condition of salubrity that all ordure or town refuse should be immediately removed from beneath or near habitations, and that this object may be the most completely as well as economically effected by removal in water:
4. That it is far less injurious to the public health to have the refuse of towns in water in the next river than underneath or amidst dwellings:
5. That the application of manures to the surface of land by means of irrigation is less injurious than the application of the same quantities of manure in the common method as top-dressings; but that the common practice of irrigation with plain water is often productive of ague, and, when conducted near dwellings, is otherwise injurious to health; and that the creation of largely extended evaporating surfaces from sewer water near towns (though still far less injurious than the retention of refuse, and its decomposition within towns and underneath habitations,) ought to be avoided:
6. That the necessity of any such exposure is avoided by the conveyance of sewer water in closed impermeable pipes underground, and by its distribution by steam power, or by gravitation, through pipes, by jets, after the method of distribution of garden watering, or by shedding from a hose, whereby the extent of exposure to evaporation is so far reduced in amount and time, and the absorption by the land so immediate, that it is, as in garden cultivation, inappreciable in its effect on the atmosphere, or on the health of persons exposed to it.

As *agricultural* results, it appears from these examinations:

1. That the applications of a considerable proportion of the manures of towns in the liquid form, that is to say, as sewer water, have produced heavier crops than any other known description of manure; and that the superiority of a fourfold production of grass above the ordinary growth on similar soils has been maintained for upwards of half a century by means of the application of the sewer manure near Edinburgh and Milan:
2. That the like increase of fertility has been obtained by a similar application of the common farm manures, in the liquid form:
3. That the great increase of the fertilizing power of manures by their proper application in the liquid form has been displayed on various descriptions of soil, on sands, as well as on clays and loams, laid down with various descriptions of arable cultivation, but more particularly with green crops, and that the quality as well as the quantity of the produce have been improved:
4. That the ordinary augmentation of produce by the full application of the fertilizing powers of liquified or liquid manures on grass land has been four and five fold above the ordinary amount of production in this country:
5. That the chief advantages of the application of manure in the liquid form consist in the economy of the manure, in the promptitude of its action, in the prevention of the loss which occurs by its drying when applied in the solid form, in the like prevention of injurious emanations while it is preserved in solution in water, and in its being better fitted for quick absorption, and more readily carried beneath the surface of the soil to the roots of plants:
6. That the method of distribution of liquid manure by steam power through fixed and flexible pipes, by jets or by shedding, is cheaper and more effectual than any other yet practised, particularly for distribution on an extensive scale and at considerable distances:
7. That this mode of distribution has great advantage over the ancient method of irrigation by means of water-meadows:—in requiring less original outlay than the particular method usually available,—

in requiring less water, and applying the manure with less waste and with less danger to the public health,—in not impeding pasturage, in not confining the land to one description of cultivation, and in being applicable alike to arable and to grass lands:

8. That the apparatus for the distribution of liquid manure by means of steam or other power through fixed and flexible pipes will be equally applicable to the distribution of water on a large scale at a cheaper rate than by any other method yet known of supplying water to plants:
9. That by the provision of the apparatus for the distribution of the manures of towns on a large scale in the liquid form the necessity will be avoided of any considerable outlay for machinery or fixed capital on the part of the owners and occupiers of land, previously to the adoption of the improved methods of culture consequent on the use of sewer manures.
10. That whilst the proper drainage of the land diminishes the losses arising from an excess of moisture, from continued rain or excessive floods, the apparatus of under-ground pipes, and the surface apparatus for the removal and application of sewer water or liquified substances as manure, will equally serve for the application of simple water, and for the prevention or diminution of the losses and inconveniences which are occasioned to the agriculturist by irregular falls of rain and long-continued droughts.

The chief economical results of high cultivation, as in the examples cited, to the extent of a four or five fold produce, appear to be almost as if, for the payment of 6*s*. per acre of new annual charges for pipes, the fertility of three or four additional farms were put upon one; and also as if, at the same time, the fences and gates, and length of roads to be maintained, and the distance for the transport of materials and produce in the farm, and for other purposes, were reduced to one fourth or to one fifth of the ordinary proportions. In the neighbourhood of towns the economy of space for cultivation has peculiar advantages.

In respect to the money value of town manures, where payment is made for their removal (as in the majority of town districts), they cannot be properly said to have any money value whatsoever, their intrinsic value being counterbalanced by the labour and inconvenience of collection, removal, and application, and by the restriction, in consequence of the expense of removal, to a narrow field of application and a comparatively small market; but in proportion as the labour and consequent expense of collection and removal are reduced, and the conveniences and certainty of application of these manures are increased,—as they will be by systematised works which may be substituted under the Public Health Act,—their money value will be increased as compared with other manures which are at present more convenient for use. Even the instances, far more numerous than those herein cited, afford no definite tests of the probable value of the town manures, if only a proper system of collection, removal, and distribution be followed.

The results stated in this Report of increased crops from liquefied manures were frequently obtained on very ill-drained and ill-dressed land. There can therefore be no doubt that if the land had in all cases been properly drained, and had had good herbage, the yield, and still more its value, would have been greatly augmented.

As much of the land within the drainage areas and jurisdiction of the Local Boards will be land unoccupied by houses, suburban villa land, or land in arable or pasture, and inasmuch as its proper drainage should be promoted for sanitary purposes, and will be facilitated by the outfalls which it will be the duty of the Local Boards to provide, a separate paper, setting forth the information as to the experience obtained on that topic, will be prepared for their use.

The several papers, reports, and communications contained in the Appendix may all be commended to an attentive perusal, as comprising highly valuable information on this most important subject of the means of applying the refuse of towns.

By Order of the Board,

HENRY AUSTIN,

Secretary.

*Whitehall,*
*30th December* 1851.

# APPENDICES.

## No. I.—Communication to the Royal Society of Agriculture from His Royal Highness Prince Albert.

Sir, *Buckingham Palace, April 12th,* 1850.

The subject of turning the sewage of towns, which is now the cause of disease and pestilence, into a source of national wealth by its application to purposes of agriculture, has, along with the general interest which it has lately excited in the public, become also a matter of interest and study to His Royal Highness Prince Albert; and I am commanded by His Royal Highness to bring through your medium, before the Council of the Royal Agricultural Society, for their consideration and inquiry, (should they think the subject worthy of it,) what has struck His Royal Highness as being a simple plan for effecting this object.

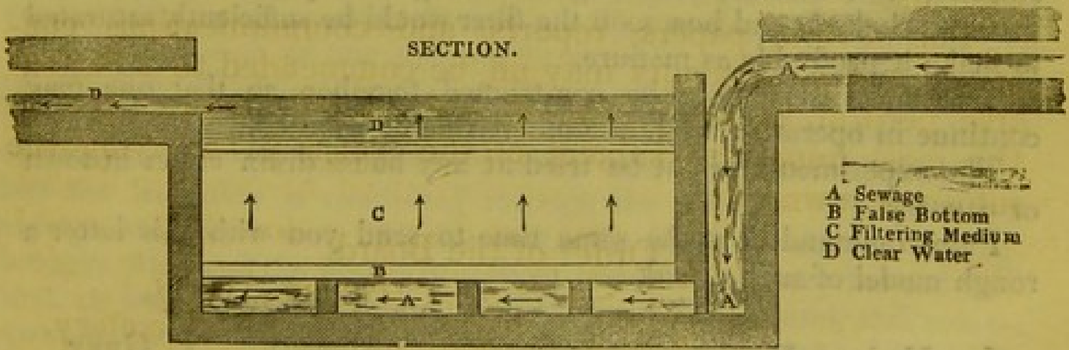
Leaving it to more competent judges to decide whether the sewage should be used as a liquid manure or solidified, upon which point His Royal Highness wishes to give no opinion himself, he has confined his consideration to the latter mode of application, for two causes:

First, that in that shape it could be more easily transported; and,

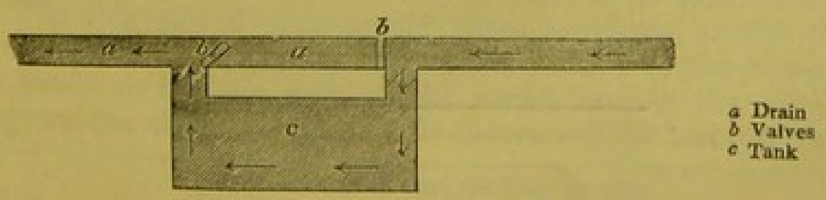
Secondly, could be obtained at the least possible expense.

The plan which His Royal Highness proposes is simply this: to form a tank with a perforated false bottom, upon which a filtering medium should be laid, and to admit the sewage into the tank *below* the false bottom, when, according to the principle of water finding its own level, the sewage will rise through the filters, and will run off into the drain, if the filtering medium has been of sufficient thickness and of the proper nature, as clear and clean as spring water.

SECTION.




GROUND PLAN.



This medium will then have absorbed all extraneous matter, and consequently become the richest manure, which, when the further supply of sewage matter is stopped, can be taken out by a common labourer with a shovel, and carted or shipped wherever desirable.

The means of letting the sewage matter into the tank, or shutting it off when necessary, can be effected in the simplest manner by common valves.

This plan might be applied to every existing arrangement of sewers, without requiring any alteration in their structure.

The solid matter held in suspense by the sewage will probably form a very rich deposit, of a substance approaching guano, at the bottom of the tank, and the false bottom can easily be made to lift up or take out, so as to admit of the extraction of that matter.

His Royal Highness has tried the operation on a small scale with apparent success, being in fact nothing more than an upward filtering apparatus, similar to those used by the Thames water companies.

The medium which His Royal Highness has used is charcoal, gypsum, and burnt clay, substances in themselves highly useful as manures.

Charcoal is admitted to be the most perfect filter for drinking water, and is known to retain effectually extraneous matters.

Chemists describe as one of the chief uses of gypsum as a manure its property of fixing ammonia and other volatile substances.

Burnt clay, from its aluminous ingredients, has a similar property, and, in addition, the power of extracting ammonia in the alkaline salts present in manure, and is cheaply procured.

Supposing the plan to be right in principle, its advantages in an economical point of view can only be ascertained by practical experience, and it is on this account that His Royal Highness wishes to submit it to the consideration of the Agricultural Society, who may be better able to carry out the necessary experiments.

It will remain to be decided what is chemically the best, and what the cheapest substance for the filter; what the best and cheapest construction of the tank; how long the sewage will pass before the filter becomes choked; and how soon the filter would be sufficiently saturated to make it profitable as manure.

Two tanks may easily be constructed together, so that one may continue in operation while the other is being emptied.

The experiments might be tried at any house drain either in town or country.

I am commanded at the same time to send you with this letter a rough model of such a tank.

I have, &c.

(Signed) C. Grey.

Jas. Hudson, Esq.
&c. &c.

## No. II.—Letter descriptive of the Cultivation by Sewer and Liquid Manures in England and Scotland, by the Hon. Dudley F. Fortescue.

My Lords and Gentlemen,

Having been requested by one of the Members of your Board, my friend Mr. Chadwick, to aid him in further investigating some of the agricultural results of the application of liquid manure which the pressure of the engagements of the Board prevented him from examining for himself, I had much pleasure in devoting a portion of my leisure this year to that object. Of a visit I made in his company, together with Mr. Ranger, Mr. Rawlinson, and Mr Rammell, three of your Engineering Inspectors, to some of the more recent and important examples in Scotland of the application of sewer water and of the distribution of farm manure in the liquid form, I beg to present to you the following details.

The first farm we visited was that of Craigentinney, situated about one mile and a half south-east of Edinburgh, of which 260 Scotch* acres receive a considerable proportion of such sewerage, as under an imperfect system of house drainage, is at present derived from half the city. The meadows of which it chiefly consists have been put under irrigation at various times, the most recent addition being nearly 50 acres laid out in the course of last year and the year previous, which lying above the level of the rest are irrigated by means of a steam engine. The meadows first laid out are watered by contour channels following the inequalities of the ground, after the fashion commonly adopted in Devonshire; but in the more recent parts the ground is disposed in "panes" of half an acre, served by their respective feeders, a plan which, though somewhat more expensive at the outset, is found preferable in practice. The whole 260 acres take about 14 days to irrigate; the men charged with the duty of shifting the water from one pane to another give to each plot about two hours irrigation at a time; and the engine serves its 50 acres in 10 days, working day and night, and employing one man at the engine and another to shift the water. The produce of the meadows is sold by auction on the ground, "rouped" as it is termed, to the cow-feeders of Edinburgh, the purchaser cutting and carrying off all he can during the course of the letting, which extends from about the middle of April to October, when the meadows are shut up, but the irrigation is continued through the winter. The lettings average somewhat over 20*l.* the acre; the highest last year having brought 31*l.* and the lowest 9*l.*; these last were of very limited extent, on land recently denuded in laying out the ground, and consequently much below its natural level of productiveness. There are four cuttings in the year, and the collective weight of grass cut in parts was stated at the extraordinary amount of 80 tons the imperial acre. The only cost of maintaining these meadows, except those to which the water is pumped by the engine, consists in the employment of two hands to turn on and off the water, and in the expense of clearing out the channels, which was contracted for last year at 29*l.*,

* One fourth more than the English acre.

and the value of the refuse obtained was considered fully equal to that sum, being applied in manuring parts of the land for a crop of turnips, which, with only this dressing in addition to irrigation with the sewage water presented the most luxuriant appearance. The crop, from present indications, was estimated at from 30 to 40 tons the acre, and was expected to realize 15*s.* the ton sold on the land. From calculations made on the spot we estimated the produce of the meadows during the eight months of cutting at the keep of 10 cows per acre, exclusive of the distillery refuse they consume in addition, at a cost of 1*s.* to 1*s.* 6*d.* per head per week. The sea-meadows present a particularly striking example of the effects of the irrigation; these, comprising between 20 and 30 acres skirting the shore between Leith and Musselburgh, were laid down in 1826 at a cost of about 700*l.*; the land consisted formerly of a bare sandy tract, yielding almost absolutely nothing; it is now covered with luxuriant vegetation extending close down to high-water mark, and lets at an average of 20*l.* per acre at least. From the above statement it will be seen how enormously profitable has been the application in this case of town refuse in the liquid form; and I have no hesitation in stating, that, great as its advantages have been, they might be extended four or five fold by greater dilution of the fluid. Four or five times the extent of land might, I believe, be brought into equally productive cultivation under an improved system of drainage in the city and a more abundant use of water. Besides these Craigentinney meadows there are others on this and on the west side of Edinburgh, which we did not visit, similarly laid out, and I believe realizing still larger profits, from their closer proximity to the town and their lying within the toll gates.

The next farm visited was in the immediate vicinity of Glasgow, where the supply of liquid manure is derived from another source, and distributed in a different manner. The supply is from a dairy of 700 cows, attached to a large distillery; the entire drainage from the former flows in a full continuous stream into a tank containing 30,000 or 40,000 gallons, whence it is pumped up immediately by a 12-horse power engine, and forced through 4-inch iron pipes, laid about 18 inches under ground, into large vats or cisterns placed on the highest points of the land to be irrigated. From these it descends by gravitation through another system of pipes laid along the ridges of the hills, finding an outlet through standcocks placed at intervals, from which it is distributed through moveable iron pipes fitting into each other, and laid along the surface in whatever direction the supply is required. The land thus irrigated consists of three farms lying at some distance apart, the farthest point to which the liquid is conveyed being about two miles, and the highest elevation 80 feet above the site of the tank and engine. The principal use to which the irrigation has been applied has been to preserve the fertility of the pastures, the general appearance of which was at first rather disappointing, but this was explained by the fact that they are fully stocked, and that the cows rush with avidity to those parts that have been last irrigated, and eat them down quite bare. As is the case in other instances, however, by far the most profitable application has been found to be to Italian rye-grass, of which 15 (Scotch) acres were under cultivation, some with seed supplied by Mr. Dickinson, whose successful cultivation of it by similar means near London has long been known. The first cutting of this had yielded about 10 tons the acre, the second nine, and the third, which was ready for cutting, was estimated at eight or nine more. Some crops of turnips and cabbages were pointed out to us in a state of vigorous growth, and with more than common promise of abundance; these were raised by a dressing of ashes and refuse (of little fertilizing value, having been purchased at 2*s.* 6*d.* a ton,) conjoined with four doses of liquid, one after the preceding crop of oats had been carried, one prior to sowing, and two more at different stages of growth. The enterprising gentleman who has carried out these works at his own expense, and in spite of the discouragement arising from partial failure in his earlier attempts, though speaking cautiously, as was natural in a tenant on a nineteen years lease, of the pecuniary results of this undertaking, imparted some facts which leave little doubt that it must have been largely remunerative Besides maintaining, if not increasing, the fertility of the pastures, to which the solid manure from the byres was formerly devoted, at a heavy expense of cartage, (the whole of which is now saved,) he is enabled to sell all this manure, of which we estimated the quantity at about 3,000 tons a year, at 6*s.* a load. For a good deal of the Italian rye-grass not required for his own consumption he obtained upwards of 13*s.* a ton, the profits on which, taking into account the yield before stated, may easily be imagined.

These results fall infinitely short of what might be done by carrying out the same system on an improved scale; the urine, instead of being diluted, as has been found most expedient in practice, with three or four times its bulk of water, is delivered on the land in nearly its full strength, or with not more than one third of water, thereby occasioning an enormous waste, greatly increased by the impervious nature of the soil of the pastures, from the surface of which it flows off in large quantities, to the loss of its fertilizing effects and to the pollution of the waters of the neighbourhood. The breaking up and cultivating more of this land in Italian rye-grass and root-crops would add immensely to the productiveness of the farm. I must mention that the mode differs in applying the liquid to the pasture and to the cultivated land: on the former it is distributed from a hose of gutta percha or vulcanized caoutchouc, on the latter a succession of short lengths of iron pipe, 3 feet long, 1½ inch diameter, laid down between the drills, are added on almost as quickly as a man can walk, and the liquid is thus shed about the roots of the plants, without touching the leaves, so as to be capable of innocuous application, if desired, at the latest periods of growth. It is interesting to know that these works were undertaken under the combined influence of the late Mr. Smith of Deanston's representations of the immense waste of valuable material that formerly took place, and of the remonstrances of parties in the vicinity, to whom the flow of refuse into the adjoining canal was an intolerable nuisance.

The next place visited was the farm of Myer Mill near Maybole in Ayrshire, the property of Mr. Kennedy, who adopted and improved on the method of distribution just described. On this farm, about 400 imperial acres of which are laid down with pipes, some of the solid as well as the liquid manure has been applied by these means, guano and superphosphate of lime having been thus transmitted in solution, whereby their value is considerably enhanced. This is especially the case with guano, the use of which is thus rendered in great measure independent of the uncertainties of climate, and it is made capable of being applied with equal advantage in dry as in wet weather. In some respects this farm labours under peculiar disadvantages, as water for the purpose of diluting the liquid has to be raised from a depth of 70 feet, and from a distance of more than 400 yards from the tanks where it is mixed with the drainage from the byres. These tanks are four in number, of the following dimensions respectively: 48 × 14 × 12; 48 × 14 × 15; 72 × 14 × 12; 72 × 17 × 12. They have each a separate communication with the well from which their contents are pumped up, which are used in different degrees of "ripeness," a certain amount of fermentation induced by the addition of rape-dust being considered desirable. The liquid is diluted, according to circumstances, with three or four times its bulk of water, and delivered at the rate of about 4,000 gallons an hour, that being the usual proportion to an acre. The quantity to be applied is determined by a float-gauge in the tank, which warns the engineer, whose business it is to watch it, when to cut off the supply, and this is a signal to the man distributing it in the field to add another length of hose and to commence manuring a fresh portion of land. The pumps are worked by a 12-horse power steam engine, which performs all the usual work on the farm, threshing, cutting chaff and turnips, crushing oilcake, grinding, &c., and about 6-horse power is the proportion required for the service of the pumps. The pipes are of iron; mains, submains, and service pipes, five, three, and two inches in diameter respectively, laid eighteen inches or two feet below the surface. At certain points are hydrants to which gutta percha hose is attached in lengths of twenty yards, at the end of which is a sharp nozzle with an orifice ranging from one to one and a half inch, according to the pressure laid on, from which the liquid makes its exit with a jet of from twelve to fifteen yards. All the labour required is that of a man and a boy to adjust the hose and direct the distribution of the manure, and eight or ten acres may thus be watered in a day. There are now seventy acres of Italian rye-grass and 130 of root crops on the farm. The quantity they would deliver by a jet from a pump worked by a 12-horse steam engine would be 40,000 gallons, or 178 tons, per diem, and the expense per ton about 2*d.*; but a double set of men would reduce the cost. The extreme length of pipe is ¾ of a mile, and with the hose the total extent of delivery is about 1,900,000 yards, or 400 acres. To deliver the same quantity per diem by water-carts to the same extreme distance would be impracticable. One field of rye-grass, sown in April, has been cut once, fed off twice with sheep, and was ready (August 20) to be fed off again. In another, after yielding four cuttings within the year, each estimated at 9 or 10 tons per acre, the value of the aftermath for the keep of sheep was stated at 25*s.* an acre. Of the turnips, one lot of swedes dressed with 10 tons of solid farm manure, and about 2,000 gallons of the liquid, having 6 bushels of dissolved bones along with it, was ready for hoeing 10 or 12 days earlier than another lot dressed with double the amount of solid manure without the liquid application, and were fully equal to those in a neighbour's field which had received 30 loads of farmyard dung, together with 3 cwt. guano and 16 bushels bones per acre; the yield was estimated at 40 tons the Scotch acre, and their great luxuriance seemed to me to justify the expectation. From one field of white globe turnips sown later, and *manured solely with liquid*, from 40 to 50 tons to the Scotch acre was expected. A field of carrots treated in the same manner as the swedes, to which a second application of liquid was given just before thinning, promise from 20 to 25 tons the acre. Similarly favourable results have been obtained with cabbages; and that the limit of fertility by these means has not yet been reached was clearly shown in one part of the Italian rye-grass which had accidentally received more than its allowance of liquid, and which showed a marked increase of luxuriance over that around it. The exact increase of produce has not been accurately determined, but the number of cattle on the farm has increased very largely, and by means of the Italian rye-grass at least *four* times as many beasts as before can be kept now on the same extent of land, *the fertility of the land being at the same time increased.* This plant, of all others, appears to receive its nourishment in this form with most gratitude, and to make the most ample returns for it; and great as are the results hitherto obtained, I believe that the maximum of productiveness is not yet reached, and that the present experiment must be carried yet further before we know the full capabilities of the manure. Of one important fact connected with this crop I am assured, that notwithstanding the rank luxuriance of its growth, animals fed upon it not only are not scoured, but thrive more than on any other kind of grass in cultivation. The cost of purchasing and laying down the pipes at Myer Mill has been at the rate of 2*l.* 10*s.* an acre, exclusive of 300 yards of gutta percha hose, with the distributing apparatus. This does not, however, include the cost of the engine, pumps, and tanks, which last, built of stone and arched over, were constructed at a cost of 300*l.* or thereabouts, stone for the purpose being procured from a quarry close at hand; the cost of the engine, &c. was put at 12*l.* per horse power. I must not omit to mention that though the direct application of the liquid manure to grain crops is not practised, its tendency being to induce rankness of growth and liability to lodge, such crops grown on land previously manured in this manner for grass or roots gave evidence of the full amount of fertility attained by the usual means remaining in the soil without the drawbacks I have mentioned. Whether such may be obviated by the practice of thin sowing and a more diluted manuring might be a desirable subject of experiment.*

* In some trial works near the metropolis *sewer* water was applied to land on the condition that the value of half the extra crop should be taken as payment. The dressings were only single dressings. The officer making the valuation reported that there was at the least one sack of wheat and one load of straw per acre extra from its application, on one breadth of land; in another, full one quarter of wheat more, and one load of straw extra per acre. The reports of the effects of *sewer* water in increasing the yield of oats as well as of wheat were equally good. It is stated by Captain Vetch that in South America irrigation is used with great advantage for wheat.—E. C.

The last farm that came under our notice was a small dairy farm belonging to Mr. Telfer, close to the town of Ayr. It consists of 50 imperial acres, a considerable portion of which was formerly a bare sandy waste extending to the sea shore; the fertility of the soil might be judged of from the appearance of the adjacent race-course. By the application of liquid manures with a three-horse power engine in the same manner as at Myer Mill, diluted occasionally with sea water, with which his well has a communication, he has raised the fertility of the soil to the extent of supporting 48 cows, where previously 8 or 10 only were kept. The chief crop is Italian rye-grass, from which he has obtained as many as 10 cuttings within the year, having manured somewhat more freely than Mr. Kennedy; he informed us that the produce of 3½ acres yielded keep for 36 cows for four months. To illustrate the extreme rapidity of growth, I may mention, that the difference between a part of the same field that had been cut on Saturday and another part cut on Monday was distinctly visible at some distance. The same treatment has been found similarly successful, though in a somewhat lesser degree as regards weight of produce, with the root crops grown on the farm; and in the garden we saw cabbages, cauliflowers, greens, onions, rhubarb, and other vegetables flourishing in an extraordinary degree after one dressing with liquid manure, which was the more remarkable as some of them had been set unusually late in the season. I may add one fact of great importance stated by Mr. Telfer, that besides the enormous increase in the quantity of the produce of his farm, its quality was so much improved, that he was obtaining 2*d.* per lb. above the current price in the district for his butter, this difference amounting to a sum more than equal to the whole previous rent of the farm.

The cases above detailed furnish some measure of the possible results attainable in cultivation, especially corroborated as they are by others which did not on this occasion come under our personal observation, but one of which I may mention, having recently examined into it, that of Mr. Dickinson at Willesden*, who estimates his yield of Italian rye-grass at from 80 to 100 tons an acre, and gets eight or ten cuttings, according to the season; and as there is no peculiar advantage of soil or climate (the former ranging from almost pure sands to cold and tenacious clays, and the latter being inferior to that of a large proportion of England,) to prevent the same system being almost universally adopted, they give some idea of the degree to which the productiveness of land may be raised by a judicious appliance of the means within our reach. When it is considered that such results may, in the vicinity of towns and villages, be most effectually brought about by the instant removal of all those matters which when allowed to remain in them are among the most fruitful sources of social degradation, disease, and death, one cannot but earnestly desire the furtherance of such measures as will ensure this double result of purifying the town and enriching the country; and as the facts I have stated came at the same time under the notice of the gentlemen I mentioned above, under whose able superintendence the arrangements for the water-supply and drainage of several

* The soil of this farm is the London clay.

towns are now in course of execution, I trust it will not be long before this most advantageous mode of disposing of the refuse of towns may be brought into practical operation in various parts of the country.

I have, &c.

General Board of Health. D. F. FORTESCUE.

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## No. III.—DESCRIPTION OF CULTIVATION BY LIQUID MANURE, AS PRACTISED BY THE REV. A. HUXTABLE, A.M.

I believe that next to the first principles of good cultivation on the farm, there is no subject so important to the progress of agriculture (especially to the increase of our green crops) as the efficient and economical distribution of the liquid manure. Hitherto the expense of cartage has been an effectual impediment to the application of the contents of our tanks, except to a few fields around the homestead; and therefore there has been, so far as I know, no systematic delivery of the precious fluid over all the farm. I have accomplished this, I think, both effectually and economically upon 60 acres of one of the farms which I occupy. It has been suggested that cast iron pipes would be the cheapest and best channels of conveyance, but I am confident that they would not long resist the corrosive action of the urine at the joints; in proof I appeal to the escape of fœtid gas from the pipes in every town. I commenced with wooden pipes carefully jointed, and I am very well satisfied with them where they have been tested by an adequate pressure of fluid, and doubt not that larch and elm thus bored will be very lasting. But subsequent inquiry and experiment have led me to prefer well burnt clay pipes, of at least an inch thickness, and properly prepared for the purpose, and capable of bearing 200 feet pressure without any symptom of moisture oozing through the pores. These pipes of one inch and seven eighths diameter are sold in the adjoining parish of Iwerne Minster for 7*d.* per yard. The joints, which are of a peculiar shape, are secured with cement. These pipes are placed about 2 feet under ground, and at every 200 yards is inserted an upright column, bored to the same gauge as the pipes themselves; on the top of these a spout, when uncorked, will deliver the liquid; if it be not wanted there, finding no vent, it rushes onwards to the next stump, 200 yards off.* How the pipes should be "set out" so that at every 200, 300, or 400 yards upon the farm a delivery column should be found, is of course an engineering problem,—practically there is no difficulty; and for a great and permanent improvement the expense is not great. If the farm yard be properly situated, the cost will not exceed 1*l.* an acre. I think that a delivery pipe every 400 yards is quite sufficient, as even the water carts or the hose need not extend beyond a radius of 200 yards. I have found all the hoses so perishable,—i.e., those made with canvas, (those in vulcanized indian rubber are too costly,) from

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* At Weymouth in the same county earthenware pipes have been in use upwards of twenty years for the distribution of an intermittent supply of water through the town, and the expense is one third that of iron pipeage, if the earthenware pipes be well made, strong and vitreous.—E.C.

friction on the land * and the caustic powers of the manure, that I have substituted 2 light broad-wheeled water carts, one of which is being filled from the delivery column or pipe, whilst a pony empties the contents of the other over the land. A really enduring hose however would be a great saving,—that of the pony to wit. But what an economy of power, even though a pony be employed, is implied in one man at the forcing pump, delivering at the distance of half a mile a continual stream of the richest fertilizing manure! Nor is the use of these pipes confined to the transmission of the proper contents of the tank, for if a good strainer be fixed to the bottom of the pump, dissolved bones, guano solution, solid manure brought into a fluid form, in fact water impregnated with any substances we please, can be laid upon the surface of our distant fields at the earliest moments of growth, and of the exact strength and consistency fitted for immediate absorption by the tender roots of our succulent plants. And who does not see that an extension of the same system offers a safe exit for the refuse of our towns to its manifestly intended end? Surely when the laws of the vegetable kingdom are understood, we shall, in the way here indicated, convert what becomes, by just judgment when left alone, the source of weakness, disease, and pestilence, into the elements of fruitfulness and increasing prosperity. And thus shall every additional quarter of corn imported to our shores contribute not only direct nourishment to the consumer, but also another element to the ever increasing fertility of our happy island.

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## No. IV.—Method of applying Solid Manures, in the absence of eligible Arrangements for the Application of Manures in the Liquid Form, in use by the Rev. A. Huxtable, A.M.

It may not be inappropriate here to notice a plan which I have successfully pursued in cultivating the land for both swedes and mangold wurzel:—immediately after harvest skim the stubble with a broad point put on to a common plough, removing the "turn furrow," and then "dress out" the stubbles and work the land very fine, which will cause all the annual weeds on the surface to sprout:—later in the autumn, plough with a deep furrow at such an angle that it will be exposed to the winter frosts. In the spring drag and harrow the land, and then proceed to put in the mangold wurzel in the following manner:—Let two men take long lines such as are used by gardeners, and stretch them from one end of the field to the other at 2 feet apart, along these lines the workmen proceed to hoe out holes 8 inches deep, each in its line one foot from the other. The farm horses will have carried the dung to the headlands, and also to the centre of the line. This dung is free from straw, made either by fattening sheep or pigs, and mixed with an equal bulk of burnt soil. The men in wheelbarrows convey this manure along the centre of the rows, and with a scoop deposit half a pint in each hole. A child with

* Mr. Huxtable's land has a large proportion of sharp flints. In other places well-woven flaxen hose has been in use six years.

its hand extracts from a bag suspended from the waist, a small "tinful" of one third of an ounce of guano and superphosphate of lime mixed together, she then covers the guano and the dung with a handful of soil, takes out 2 seeds from another little bag, covers this with a few grains of the finest dust, treads on the hole thus finished, and passes on. The cost of this process last season was 16*s.* an acre It offers many advantages,—first, the same quantity of manure and tillage being *exactly* apportioned to, and lying beneath each plant, will grow a much larger crop,—secondly, there is a considerable economy in seed,—thirdly, several ploughings will be saved,—fourthly, because by this arrangement you can get in a crop when it would be utterly impossible to sow it with the drill,—and fifthly, because by these means we can grow roots in steep hill sides and other places inaccessible to the plough. Mr. Graburn, in the superintendence of the Castle Hill Farm, belonging to the Earl Fortescue, and Mr. Gray, of King's Weston, Somerset, have greatly improved upon my somewhat primitive method; by using a cart to convey the manure from the heaps to the holes intended to receive it, and instead of garden lines, marking out the direction of the holes by the ruts left by the coulters of an empty drill passed over the field, they have reduced the cost of dibbling the manure and seed of the root crop from 16*s.* to 6*s.* or 7*s.* per acre.

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## No. V.—Description of the Irrigations with Sewer Water from Milan. Extract from a Letter forwarded to E. Chadwick, Esq., C.B., by the Count Arrivabene.

The city of Milan consists in three concentric circles, two of which are formed by canals constantly provided with flowing water, and the other by the town walls.

The inner canal, or Sevese, which is the most ancient, encloses the first nucleus of the city under the Romans, is all covered, and serves only for drainage. The other canal, or Naviglio, which forms the second circle, encloses the city as it was during the middle ages, is open, and serves for navigation as well as drainage. The Sevese carries off the drainage of the two inner circles, and the Naviglio that of the external.

All the streets of the city have along the centre a subterranean sewer in brickwork, and proportionate in its dimensions to the body of rain water it is intended to receive, considering the length of the street and the depth of the houses on its sides. The rain from the front roofs is collected in vertical pipes fixed to the walls of the houses, and runs through subterranean gutters into the longitudinal sewers of the street. The rain from the back roofs and courts, as also the waste water from offices, provided it be absolutely liquid, flows in the same manner into the street sewer. But the houses along the two canals discharge at once into these, not only their liquid drainage, but every sort of half-liquid material proceeding from waterclosets and laboratories.

The drainage of the city being thus carried to the Sevese and the Naviglio, either by the street sewers, or direct by the gutters of the neighbouring houses, the street sewers are levelled according to the depth of the canal into which they discharge their contents.

The administration of the drains of Milan is divided into three branches,—viz., the street sewers, the Sevese, and the Naviglio. Being myself the surveyor of the Sevese, or covered canal, I will give you an account of the administration of this department; that of the Naviglio being conducted nearly in the same manner.

The houses and premises emptying their drains into the Sevese form a district, and their proprietors form a society; the society is represented by a committee, elected by the proprietors. The members of the committee are renewed at the end of every two years. The committee consists of twelve members, and a president, who is changed every year. The president enforces the resolutions of the committee. The committee transact the ordinary business of the society by a majority of votes. Extraordinary business is referred to a general meeting of the proprietors. The committee is assisted by a surveyor, a cashier, a secretary, an overseer of the works, and a solicitor.

The assessment of the rate for the maintenance of the Sevese is made once in nine years; the surveyor inspecting all the houses of the district, and taking down the quantity and nature of the drainage, as well as the length and depth of each house fronting the canal, whenever any alteration has taken place in consequence of a division of property.

In order that the quantity of earthy deposit may be easily ascertained, the level of the Sevese is marked by a number of blocks of granite fixed along the bottom. The Sevese is cleansed twice a year, in April and September, periods at which the water of the canal is turned off. The cleansing is executed under a tender, by piece-work, and not by measure. The repairs are also done under tender, but at so much per given measure, and for each separate work.

The estimate of expense for these works is made every nine years, by the surveyor, upon the sum spent during the nine years preceding, and on present emergencies. The rates are proportionate to the quantity of drainage. The assessment of rates for the maintenance and cleansing of the canal is deduced from these three points:—1. The estimate of expense for the next nine years. 2. The divisor of the estimate. 3. The resulting quota which forms the unity of assessment. The divisor of the estimate is proportioned to the frontage of the houses placed along the canal, and to the quantity and nature of the drainage discharged by all the other houses of the district, the drainage being represented by a certain number of square feet constituting the quota of each house. The houses are, therefore, assessed in proportion to their frontage, and to the particular nature of their drainage. Accordingly, a slaughter-house for oxen is rated 76 feet; a slaughter-house for cows and pigs, 56; dye-houses, water-closets, hotels, dairies, and generally all premises not comprised in the first two categories, 38 feet; a stable, containing from 1 to 4 horses, 19 feet; a stable, containing from 4 to 8 horses, 38 feet; ditto, containing from 8 to 16 horses, 56 feet; a private house, 19 feet; a court-yard, 11 feet; a pump, 7 feet.

According to an old custom, founded on the greater or lesser use of the canal, the houses facing the canal in the most populous quarter of the city are assessed in proportion to their actual measure in feet; the houses fronting the canal in the less populous part are assessed at two thirds of their actual measure; and the houses built over the canal are ruled as a double frontage in the some proportions.

The Sevese derives its water from the Naviglio by means of three inlets, one of 17 inches, the other of 10, and the third of 6, in three separate spots. These waters are then collected by another canal, called Vetra, which, after receiving another contribution from the Naviglio, assumes the name of Vettabbia.

The Vettabbia flows out of the southern part of the city, and, after a course of 10 miles, discharges itself into the river Lambro, fertilising prodigiously a considerable extent of meadow land. It can be easily conceived what must be the fertilising quality of the Vettabbia, as it carries off all the filth of a city of 150,000 inhabitants, and the quantity of fertilising matter borne along by its waters raises in such a manner the surface of the meadows it irrigates, as to render it necessary that from time to time the deposit should be removed from the meadow in order to preserve the level of irrigation. The deposit is by itself an excellent manure, and is bought by the neighbouring agriculturists as a fertiliser. The Vettabbia possesses also the valuable peculiarity of protecting from frost the meadows it irrigates, owing to the high temperature it receives in its passage under the town.

The Cistercian monks were the first who turned to a profitable use the slimy waters of the Vettabbia, and introduced the system of irrigation, which forms a most important branch of the agriculture of Lombardy.

The waters of the Naviglio, after receiving the drainage of the remainder of the city, are also applied to the irrigation of an extensive surface of land.

It may, perhaps, not be useless to add a short description of the water-meadows, which in Lombardy are called *marcite.* These meadows are divided into various rectangular zones, about 22 feet wide, by means of rectilineal channels, which serve alternately, one for irrigation, and the other for draining. These zones are arranged so as to have a slope of about six inches from the channel of irrigation to the draining channel. The waters of the feeder, which is placed on one of the sides of the meadow, at a right angle with the channels of irrigation, flow into these, and through the whole of their length spread over the zones on both sides, covering them, as it were, with a watery veil, which preserves the life of the plants and promotes their vegetation. The water of the draining channels is then collected again into another channel, which conducts it to irrigate another meadow in a similar manner. The *marcite* are irrigated in summer during a certain number of hours about once a week; and from the end of September to the end of March they are irrigated permanently, the water being only turned off when the grass is cut. During winter the irrigation of the meadows is also carried on with spring water, which landowners are authorized by law to conduct to their lands through the lands of their neighbours. To this very ancient law a great portion of the agricultural wealth of Lombardy is to be ascribed.

Some of the meadows irrigated by the sewerage water of Milan yield a net rent of 21*l.* per *tornatura* (a measure of 10,000 square metres, equal to about two acres and a half), besides a land tax of 61 francs 10 cents, the expenses of administration, repairs of buildings, &c. These meadows are mowed in November, January, March, and April, for stable-feeding; in June, July, and August they yield three crops of hay for the winter; and in September they furnish an abundant pasture for the cattle till the beginning of the winter irrigation.

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## No. VI.—Report on the Application of Sewerage Water and Liquid Manures to Irrigation and Agriculture. By William Lee, Esq., Superintending Inspector.

9, *Duke-street, Westminster,*
25 *Dec.* 1851.

My Lords and Gentlemen,

At the numerous preliminary inquiries made under your direction in England and Wales during the last three years, with a view to the application of the Public Health Act, I have frequently referred to the facts then known respecting the great fertility produced by sewerage water and liquid manures in Scotland and other places. Such statements I have observed to be received with the greatest incredulity by farmers and landowners; and on more than one occasion the enunciation of facts, far less astonishing than what I have witnessed in my recent journeys, has sufficed to throw discredit upon all other arguments in favour of sanitary improvement. Men who have tilled the ground as their forefathers for generations tilled it, too frequently feel themselves insulted by the reflection that others have taken more comprehensive and scientific views, and that the results have been successful.

After my former report on this subject one of the Members of your Honourable Board, in company with some of my co-inspectors, visited several localities in Scotland, in order to examine what had been done there in the application of sewerage water and liquid manures. Having been called upon, as consulting Engineer, to advise the Local Boards in several towns under the operation of the Public Health Act, it was with regret that an official inquiry at Dudley prevented my forming one of the party, but I have since, by your direction, gone over the same ground, and also visited many other places in all parts of the kingdom, and beg now to lay before you the result of my investigations.

I need not occupy any of the time of your Honourable Board with the importance of returning to the land the elements of that food upon which the life of man and beast is dependent, because without these elements continually applied, food cannot be produced;—nor, on the necessity of removing from the vicinity of human habitations the residuary elements of consumed food and other organic refuse, because without such removal life cannot be long continued.

The plain practical questions I have now to bring before your notice are:—

1. The comparative extent to which sewage water, town refuse, and liquid manures are valued in some of the towns and places in which I have been directed to make special investigation.

2. The modes of its application.

3. The first cost of apparatus, and working expenses of such application.

4. The agricultural, financial, and sanitary results.

5. The facilities for more extended application.

I take the localities nearly in the order in which they have been visited, and purpose to state the facts connected with each; to comment upon such facts; and to offer such suggestions and conclusions as may render its application more profitable to the farmers and to the inhabitants of the towns.

In the preliminary inquiries and reports made with a view to the application of the Public Health Act, comprehending necessarily all subjects connected with the sanitary condition of the inhabitants of the places visited, this special branch of the subject could not be treated of fully, without an appearance of undue prominence. My former report on the use of sewage manures in the places so visited contained, therefore, only a brief glance of the subject; and, while it showed the immense value of town refuse in a liquid form, comprehended, of necessity, much that was imperfect and erroneous as to the mode of application. These later investigations, however, having been made solely for the purpose of collecting information on this important point, have enabled me to enter at large into the details of the various modes of applying liquid manures in different parts of the country. I trust that the facts collected will promote the object which your Honourable Board have so anxiously in view, and be of some value to the towns under the operation of the Act.

It is unnecessary that I should re-state the facts contained in the Report of the Hon. D. F. Fortescue, who so shortly preceded me in Scotland; and therefore I shall only refer to the same points, so far as may be necessary to give continuity of arrangement.

The Craigentinny Meadows at Edinburgh.—In examining this locality I was accompanied by George Buchanan, Esq., Civil Engineer, and Mr. Bryce, resident manager; to them I am indebted for such information as did not come under my own observation.

It will be understood that in speaking of superficial area, the Scotch acre is always intended. It contains 6,084 square yards, equal to 1·271 acres English,—or rather more than an acre and a quarter.

The old meadows, irrigated by the Foul Burn, have been in existence probably 60 years, and contain about 180 acres. They are not laid out so methodically as the more recent part of the work. Mr. Buchanan has a plan of the whole, showing the open gutters and panes, on a scale of four chains in an inch. The more recent portions are the sea meadows, and the high level, which is irrigated by means of a steam-engine.

The soil of the old meadows is a hard clay. Some of it had been underdrained before the irrigation began, but the drains were found to carry off the irrigation water, and were also in the way of the levelling operations, and were therefore destroyed.

The sea meadows were formed in 1826, upon what was a mere series of sand-hills and beach, without any soil at all. What little soil there is now has resulted from the application of the sewage water.

About 50 acres are above the level of the "Burn," and for them the sewage water is lifted 15 feet by a steam-engine of eight-horse power at Southside farm.

Having ascertained that the irrigation goes on upon the high level for the same length of time, and is repeated after the same intervals, as in the portions where no artificial power is used, the steam-pumps become standard measures by which to ascertain the quantity of town sewage water capable of producing such great fertility.

The engine is capable of irrigating a very much larger surface, but it is used also for thrashing and other farm purposes. The cylinder is 10 inches, working with from 30 to 40 lbs. pressure, and making 46 strokes per minute. There are two pumps with 18-inch barrels, making 14 strokes per minute, and having alternate action of 2 feet 9 inches, or 3 feet 6 inches. I find the quantity raised to be 93½ cubic feet per minute. The engine works night and day, but the time occupied for irrigation amounts to about 224 days of 12 hours each. Two tons of fuel are consumed per 24 hours, at 5*s.* 3*d.* per ton; and there are two engine-men and two water-men, who attend to the gutters. I ascertained that the ordinary working expenses of the engine, including wear and tear, amounts to 10*s.* 6*d.* per 12 hours.

The result, when reduced to a practical shape, is strongly against the economy of surface irrigation by open gutters and surface shedding, when compared with the effects produced by pipes and jet, hereafter to be considered. In this case the quantity of fluid applied is so enormous that a very large portion of it must escape into the sea without being productive of any good. The amount, calculated from the pumping power, is equal to 66 inches in depth over the whole surface during the course of the year; or, 8,886 tons per acre, taking the specific gravity of the sewage at 66 lbs. per cube foot. During the present season the whole of the meadows have been watered, according to the statement of Mr. Bryce, eight or nine times, so that each application was equal to 1,000 tons per acre. It must be remembered that these quantities refer both to the irrigation by steam power and by gravitation.

The total area irrigated by the "Foul Burn" is about 260 acres, and I find the average discharge of sewage water from that part of the city draining into it to be about 220 cubic feet per minute. Exclusive of Sundays, this would give a quantity equal to 11,232 tons per acre per annum; but taking the number of days during which the process of irrigation goes on at 224, as in the former calculation, the net quantity laid on will be 8,042 tons per acre per annum

When it is considered that some of the fluid is used more than once, and that storm-water requires some margin, these two statements of quantity corroborate each other in a remarkable manner.

The laying out, levelling, gutters, and sluices, in the old meadows would, in the opinion of Mr. Buchanan, cost nearly 15*l.* per acre; but it was done piecemeal, and in a very irregular manner.

The 30 acres of sea meadow cost 700*l.* laying out; equal to 23*l.* 6*s.* 8*d.* per acre. The ground was very rough,—absolutely worthless,—and the work expensive.

The remaining part, including the high level, varied from 30*l.* per acre to 6*l.*, but the average was about 15*l.* per acre.

With respect to the high level, the steam-engine was already upon the farm, but its value, and also that of the pumps, must be taken into account. A deep open gutter of about 250 yards long, and a tunnel of about the same length, had to be driven to convey the sewage to the engine well. These two cost upwards of 1,000*l.*

The working expenses for the irrigation by gravitation may be taken at 13*s.* 3*d.* per acre per annum, including the cleansing of the open gutters. The following, therefore, appears to be the cost of the open gutter system:—

| High Level. | £ | s. | d. |
|---|---|---|---|
| Forming 50 acres, at 15*l.* - - - - - - | 750 | 0 | 0 |
| Engine and pumps, say - - - - - - | 250 | 0 | 0 |
| Tunnel and gutter - - - - - - - | 1,000 | 0 | 0 |
| | £2,000 | 0 | 0 |
| Annual interest and depreciation, 7½ °/ₒ - - | 150 | 0 | 0 |
| Wages, fuel, &c., 224 days, at 10*s.* 6*d.* - - - | 117 | 12 | 0 |
| | £267 | 12 | 0 |

Equal to rather more than 5*l.* 7*s.* per acre per annum.

| Sea Meadows. | | | |
|---|---|---|---|
| Annual interest, &c., per acre - - - - - - | 1 | 15 | 0 |
| Annual working expenses - - - - - - | 0 | 13 | 3 |
| Per acre - - - - | £2 | 8 | 3 |

| Old Meadows, &c. | | | |
|---|---|---|---|
| Annual interest, &c., per acre - - - - - | 1 | 2 | 6 |
| Annual working expenses - - - - - | 0 | 13 | 3 |
| Per acre - - - | £1 | 15 | 9 |

The total capital invested is about 5,400*l.*, and the annual working expenses, exclusive of interest, 256*l.* 14*s.* 6*d.*

Before making a few remarks on the value and produce of these meadows, I must observe that their great fertility is extrinsic, and entirely independent of the nature of the soil. There is no principle of vitality in the mineral particles of clay and sand, but when the elements of vegetable substances are largely applied in a state of solution to the germs and roots of plants, an unprecedented state of fertility is produced, equally upon lands of the most opposite character. Some of these meadows are heavy undrained clay, which, in a state of nature, would be almost sterile; and others are porous sea-sand, absolutely worthless only a quarter of a century ago, yet both at the present moment are yielding upwards of ten times the average value of agricultural land in this country. These remarks as to the character of the soil, are of course applicable to all the places visited, and in fact to soils generally.

During a careful examination of these meadows, I could not observe any difference between those nearest to the city and those adjoining the sea; but it appeared that generally the oldest meadows were the most fertile. On inquiry, I was informed by Mr. Bryce, that the action of the sewage-water is not a sudden impetus, followed by reaction and exhaustion, but the land goes on increasing in value, according to the length of time the system has been in operation.

I observed no stench at all on the meadows or the carriers; I could distingush it, however, where the tail-water of the burn, after passing through a sluice, tumbles down a roughly-paved incline. The weather was cool at the time.

The fifth crop of grass since April was being cut off these meadows at the time of my visit in October.

A very fine crop of turnips, expected to realize about 25*l.* per acre, had been manured by a dressing of the liquid before sowing, with the addition of about 24 loads of the cleansings of the gutters, and 16 loads of farmyard litter per acre.

Mr. *Bryce*, the manager, said,—

"I would prefer for turnips even the cleansings from the gutters, with farmyard manure, to guano with farmyard manure, because the sewage refuse has more durability than guano. I shall have a good crop of barley after these turnips without further solid manure; and then sow down for grass. I could not do that with guano."

A very small plot of this land is let at present at 9*l.* per acre, but in general terms the inferior meadow produces 11*l.* The highest rent this year is 31*l.* There are several lots let at 30*l.* per acre, and the average of the whole is more than 20*l.*

I have only to mention one additional fact respecting the value of these meadows. The Leith Branch of the Edinburgh and Dalkeith Railway passes through the meadows formed about 25 years since out of worthless sea-beach. The value of the land had to be settled by a jury, who, after hearing all the evidence on both sides, awarded 33 years purchase at 20*l.* per acre, making 660*l.* per acre as the value.

Mr. Skirving's Meadows at Edinburgh.—These are situated near Leith Walk, and only consist of about 10 acres of grass. The ground is laid out in the same manner as at Craigentinny; and it is, therefore, unnecessary for me to say more than that the present rents vary from 32*l.* to 34*l.* per acre.

Mr. Thompson's Meadows at Edinburgh.—These are on the west of the city, and comprise about 30 acres. The same plan of fertilising has been adopted, with similar results. The rents now extend from 26*l.* to 30*l.* per acre.

Catch-meadows at Pusey.—I have much pleasure in communicating to your Honourable Board the facts collected during a very recent examination of some irrigation works on the estate of Philip Pusey, Esq., M.P., of Pusey.

Mr. Pusey has within the last few years converted about 100 acres of land, lying eastward of his mansion, into irrigated meadows. The land is flat, and I cannot better describe the principle upon which the works are laid out, than in his own words:—

"The Catch-meadows were used chiefly until lately in Devon-"shire. The gutters being drawn along natural slopes, the water "falls from the upper one to that immediately below, which spreads "it anew equally over the surface lower down. Hence the name "Catch-meadow.

"This system, originating in an almost mountainous country, has "been of late years transferred to land almost level; quite as level as "any on which the ridge water-meadows were made in Wiltshire."

In front of Pusey House is a small ornamental lake of about two acres, the overflow from which supplies the upper part of the meadows; and at Pusey Lodge Farm, and Cherbury Camp, two other small streams are brought under tribute for the fields in their vicinity.

The whole body of water is, however, so small that I should think there is probably no other instance in which an equal quantity is turned to so profitable an account.

Mr. Pusey says, that in summer they are very short of water, and can only let the fluid penetrate six inches into the soil, so as to damp it; at that time the earth is so dry that when the water goes in, and sinks through the worm-holes, the ground sings. In winter the operation is going on continuously, in one part or other.

The geological formation at Pusey is the coral rag of the oolitic system, and the meadows in the vicinity of Cherbury Camp were, only a few years since, sheep-common, covered with emmet-hills, brambles, rushes, &c., and worth about 5*s.* per acre per annum.

The whole of the work has been done within the last four years, but at different times. That first commenced included the greatest amount of earthwork, and the several contracts contained diminishing quantities of labour, which will account for the differences in the following prices, with which I was favoured by Mr. Pusey:—

| | | | |
|---|---|---|---|
| 20 acres at 4*l.* 10*s.* per acre | | - | £90 |
| 20 acres at 4*l.* | ,, | - | 80 |
| 30 acres at 3*l.* | ,, | - | 90 |
| 30 acres at 2*l.* | ,, | - | 60 |
| 100 | | Total | £320 |

The amount is equal to 3*l.* 4*s.* per acre, on the average; but this did not include the sluices, which are of oak, and cost about 2*s.* 6*d.* each. In the earlier and middle parts of the work I found these to average about ten to the acre; but in the portion most recently irrigated the sluices are not yet put down. Clods are used instead; but they sometimes burst, and always tend to deposit soil in the gutters, besides occupying much more time in placing and removing than the management of sluices would. It is but fair, therefore, to add the cost of sluices to the capital account; making altogether an average of 4*l.* 9*s.* per acre.

Since my visit Mr. Pusey has had an account taken of sluices made and required, and finds it 600. This would give 15*s.* per acre for sluices; but he adds, "There is further some expenses in "diverting the stream, so that the estimate cannot be far wrong."

Mr. Pusey, however, is anxious that this outlay should not be regarded as representing the ordinary expense of forming catch-meadows for common agricultural purposes; as in Devonshire, the common estimate is about 2*l.* per acre for the average cost; and a Devonshire gutterer, Mr. Dobbs informs him, has lately executed many such works in the Isle of Wight at a cost in no case, as he states, exceeding 1*l.* 10*s.* per acre. Draining, however, which is often required, must be taken as a separate item of expense. The cost of diverting streams and putting in sluices would also have to be added.

Mr. Pusey says, that the cleansing of the gutters in autumn is about 5*s.* per acre.

One labourer, whose wages are 10*s.* weekly, attends to the irrigation. During harvest he assists in getting in the corn; and he is also engaged with the men who clean out the gutters, but from October to Lady Day he will be fully occupied in the irrigation, and also during a great part of the summer. It would be a very reasonable estimate, therefore, to take half his annual wages as working expenses.

On the data thus obtained, the following would seem to be the average annual charges per acre of the Catch-meadow upon Mr. Pusey's estate:—

| | *s.* | *d.* |
|---|---|---|
| Interest upon 4*l.* 9*s.* at 7½ per cent. - - - | 6 | 8 |
| Cleaning gutters - - - | 5 | 0 |
| Labourer - - - | 2 | 7 |
| | 14 | 3 |

Before proceeding to describe the very high rate of fertility on these meadows, I ought to state that Mr. Pusey has not only used the natural fertilising powers of the water, but has also drawn incidental advantage from any farmyard manure or other refuse within reach of the irrigating stream. The water is dark during and after rain, from the washing of the manure of farmyards, or of organic refuse from the houses in Pusey, and in other parts white from the washings of the roads. Mr. Pusey says, both the dark and the white waters are more beneficial than the clear stream.

The Parsonage House is close to the first meadow irrigated, and the drainage from the buildings, with the excreta of two or three cows, four horses, and above 20 pigs, flows through a grating into the principal carrier. There are also plantations close by, and a large quantity of leaves fall into a small pond which feeds the carrier.

Mr. Bernard is a tenant-farmer under Mr. Pusey, and holds about 700 acres of land. His buildings are in the same locality, and drain towards the same stream. He keeps about 12 or 14 horses, 6 oxen, 70 or 80 pigs, and 1,000 sheep, which are in the yard at lambing time. He has no liquid manure tanks, but has the yard made hollow, and covered with straw for the purpose of making solid manure. I was informed that after rain there is always some overflow from the yard to the irrigated meadows.

The next farm premises are called Oxpen; consisting of a yard and cattle-steading in Mr. Pusey's own hands. The yard is covered with straw and litter, and I was informed that from 200 to 300 sheep now come there to eat, but do not remain long. The year before last Mr. Pusey fattened 20 heifers at this place. The surface of the yard slopes, and all along the bottom there is a channel or drain which conveys the liquid manure and rain-washings into the main carrier for the higher part of the land first irrigated.

The Winchester meadow in this part has one corner too high for the fluid, and I was much struck with the contrast between the irrigated and non-irrigated land. The line of demarcation was as strongly marked as if two pieces of cloth, one bright green and flossy, and the other brown and thread-bare, were seamed together.

At Pusey Lodge farm, which is in Mr. Pusey's own hands, the stock consists of six horses, about a dozen pigs, and the ewes, about 700 or 800 of which lamb here in winter. By great care and skill a gutter has been cut, by which a small rivulet from a spring in Buckland grounds can be diverted, during the periods of irrigation, about 100 yards wide of its natural course, and passed through the farmyards. The rivulet receives the washings of the Old London Road during rains. These farmyards are, as before, covered with straw and litter. The lowest level is along the side of one yard, and obliquely through the other. Along this line of level there is a hollow paved channel, about two feet wide at the top, one foot at the bottom, and one foot deep. Below the farmyards a square open gutter, nine inches deep and nine inches wide, puddled and pitched with stone, conveys the fluid through some cottage gardens to the fields where it is to be used. My informant said, "When we are about to irrigate we cut the solid "manure out of the channel in the farmyard, and, the sluices being "drawn above, the manure from the yards is draining into the "channel all the time the water is passing through. We find it "very beneficial. At first it runs quite coloured, but after awhile "becomes clear."

Excuse me for re-adverting to a few of the points in this, as it appears to me, beautiful process. Here is an arable farm with much surplus straw, some poor grass land, and a small rivulet of water. All the arrangements being made, the stock, while feeding, convert the straw into solid manure,—the stream liquifies it,—gravitation conveys the nutrition and stimulant to the roots of the grass; while the after or clear stream washes it in, and prevents any injury from being done to the herbage by the acridity of the first runnings. The only attention required throughout the whole operation is the opening and shutting of the sluices.

As to the length of time during which the fertilising streams are on the land, I have already said that Mr. Pusey is very short of water. In hot weather, when the water is deficient, it is only laid on six hours at a time, just to run over the sheep-dung, which it melts and carries down to the roots. When the supply will not even admit of so much, the sluices are drawn for an hour or two at a time twice or thrice a week, to damp the soil. At the present time it will remain on the Italian rye-grass three days. In winter, when there is no frost, the course of the whole 100 acres is, to be a week dry and a week wet; but during frost it is allowed to remain covered the whole time,—a month if necessary, to protect the vegetation from cold. The operations on Mr. Pusey's estate are confined to grass crops entirely. The land had been under-drained some years previously to the irrigation in most places where drainage was required.

Of the beneficial results, Mr. Pusey says in a letter to Mr. Chadwick, speaking of the last part of the work executed:—"The land "is very poor, but has this year given five crops of grass, the four "first very heavy crops. There is also a promise of a sixth. I will "not trouble you with the details, but moderate as is the outlay, "and recently as it has been made, the land has been more than "doubled for the Income Tax assessment; being raised, even in "these times, a pound an acre; nor have I any reason to com"plain of the rise."

Before the irrigation was commenced the herbage was what Mr. Pusey calls "carnation grass," a large, coarse, sour-looking production, disliked and avoided by cattle. The irrigation has destroyed all that, and brought instead a soft, silky, nutritious grass, very similar to that on the Edinburgh meadows

The whole of the annual produce from any of this land has not been either measured or weighed; but Mr. Pusey said, while we were examining the part first irrigated, that two years back the first crop cut was estimated at 1½ tons to the acre. Sheep were then turned on repeatedly, and the whole annual produce was estimated to equal the keep of 36 sheep per acre during five months.

Some sheep fed upon this land have become lame. Mr. Pusey says, that opinions are divided as to whether this lameness is attributable to the irrigation or not. I believe, however, that none have rotted. The practice of cutting the second crop, after feeding the first, before turning in sheep again, is a precaution taken to prevent that disease from appearing.

I have already spoken of the former sterile condition of the part brought under irrigation only two years since. Within that time 28 acres of it have been sown with Italian rye-grass. My informant said, that this year there had been five crops of grass, each as high as the sheep-pens. A sixth crop is nearly ready for the scythe. He added:—"If the old men who died twenty years since were to "come to life again, they would never believe that this was "Cherbury."

I cannot conclude this brief notice of what Mr. Pusey has done without saying that after having visited and examined all the most important examples of irrigation, and the application of sewage waters and liquid manures in England, Scotland, and Wales, I have derived great pleasure from my recent visit to Pusey. The land was poor and of little value; the available means for its improvement of very limited extent; the mode of operation has only been the simple but ill-understood science of making the best of everything; and the result is such as may well be satisfactory to Mr. Pusey, and to all persons interested in agricultural improvements.

I feel bound to add, that although the cost in this case is greater than that of fertilising by iron pipes and flexible hose and jet pipe, it is yet the most economical instance I have met with of irrigation by open gutters and surface shedding.

The Duke of Portland's Meadows at Clipstone Park.—I do not propose to give a minute account of these celebrated meadows; they are referred to in numerous reports on sanitary reform, and there is an excellent article on the subject, by John Evelyn Denison, Esq., in the Journal of the Royal Agricultural Society, vol. i. p. 359. From a recent and careful examination, I am able to corroborate Mr. Denison's statements, and I have referred to his essay for such particulars as do not appear to come within the scope of my duty to your Honourable Board.

The course to which I have adhered throughout these investigations has been to avoid as far as possible purely farming questions: to consider the various modes of applying town sewage waters and liquid manures on a large scale; the cost of the various modes of application; and the result in improved value and produce of the land. While doing this, and not losing sight of the very great agricultural importance of the question, the object kept in view has been the removal of town manure, instead of keeping it in cesspools and dung-heaps, in the midst of houses, to evaporate and waste at the expense of the health and lives of the inhabitants.

The present is strictly a case in point. The town of Mansfield contains nine or ten thousand inhabitants, situate in a naturally healthy district, but with very defective sanitary arrangements; and, as a necessary consequence, there exists much preventible disease. The drainage is inefficient, but there are some public sewers leading to the natural outlet of the town. The rain-fall upon the surface of the town of course culminates to the same point as the underground drainage; and both carry with them a very considerable portion of such animal and vegetable refuse as is capable of being so removed. It is scarcely hypothetical to say that but for the washing of the rain, and the present inefficient sewers, there would be a still larger amount of preventible disease;—or, that if a complete system of drainage were constructed for the immediate removal of all dead organic matter from the town, preventible disease among the inhabitants would be comparatively unknown. This is the town view of the question.

About thirty years ago, his Grace the Duke of Portland commenced those extensive operations, a short distance below the town, which have resulted in what are known everywhere as "the Clipstone Water Meadows." The stream is the little river Maun, which passes through Mansfield, and forms the natural outlet for all the sewage and drainage of the inhabitants. These water-meadows now contain about 400 acres, and form the most fertile tract of country, of equal extent, in the midland counties of England. But for the scientific application of the Maun streams, they would still have continued an unprofitable waste and bog. With perfect drainage of the town, and the immediate removal of all the night-soil and other organic refuse, a still higher state of fertility would be attained; or else, a much larger area might be brought under the influence of the sewerage waters.

The mutual interest of town and country in the removal and application of sewerage waters is so apparent in the case of Mansfield, that I have no hesitation in saying, the inhabitants of the town would have been gainers at this moment if they had, thirty years ago, efficiently drained the town, and constructed economical irrigation works upon the Duke's property, for the mere privilege of disposing of what was injurious to them, without any other return than that of general improved health. So, on the other hand, his Grace the Duke of Portland would have been a gainer, if he had, at his own cost, thoroughly drained all the buildings in the town of Mansfield, and provided water-closets for removing the soil, with the sole object of increasing the fertility of his agricultural land.

A large flood-dike about four yards wide takes the whole stream of the river, and conveys it, by contouring, a distance of $5\frac{1}{2}$ miles on a perfect level. The whole area of this long channel acts as a reservoir, and there is no current except to the points where the irrigation may be going on at the time. The contents of this flood-dike are about 1,000,000 cubic feet. At the end farthest from the town, the dike has attained an altitude of 49 feet above the river, so that it commands a considerable area of ground.

The great flood-dike ceases at a field called the First Dam-side Breck Meadow, and from that point a new flood-dike commences, on the other side of the Maun, and extends about a mile and a half, passing the village of Clipstone, and receiving the refuse of the houses there.

The mode of irrigation is similar to that on the higher level,—by sluices and open catch-work gutters. The centre carriers are at right angles with the flood-dike and the river, and have a quick descent. They supply a great number of cross carriers, branching off on each side, so as to form figures, like what is known by the term "herring-bone." The cross carriers are level, and shed the stream over the surface from one to the next carrier successively, until it has done its work, and reaches the river.

The carrying gutters at Clipstone are not cut out by vertical spits below the level of the ground, but are hollow dished channels, two or three feet wide, upon which the grass grows almost as freely as upon the other parts of the meadows. This has two important advantages; there is no loss of producing surface, and the cost of cleaning gutters is almost saved.

I derived much information from Mr. Robert Tebbett, who has been water-bailiff to the Duke about 30 years. The irrigation was just commencing at that time. He has seen every meadow laid down except one, and has had charge of the whole ever since. He furnished Mr. Denison with information for the essay on these meadows, and believes that the figures as to the cost of the system are correct. Several additions have been made since Mr. Denison wrote, so that the whole area now would be very little short of 400 acres. The cost per acre, and also the working expenses, may be fairly taken, however, at the same proportion as in Mr. Denison's figures. Exclusive of drainage, therefore, the average cost of formation per acre is at least 120*l.*, which taken at 7½ per cent., gives an annual charge of 9*l.* on the capital account. Superintendence, &c., at 10*s.* per acre per annum, must be added, making the whole 9*l.* 10*s.* per acre per annum.

Besides the sewage and refuse of the town of Mansfield, and, in the lower part, of the village of Clipstone, a large quantity of fertilising matter is obtained from the farm-buildings along its course. Mr. Tebbett, says, "he keeps 3 milk cows, and the drainage of all " his premises goes into the water." At the New Buildings there are 8 farming horses kept, and on the average 4 blood horses, 6 pigs, 26 cows or oxen in summer, and about 50 in winter. No sheep are kept. There are also 2 cottages with families, and a drain from the yard conveys all the liquid from the premises to the flood-dike. There is also a drain to convey the liquid fertilising matter from Cavendish Lodge, or Clipstone Park farm. The upper flood-dike stops nearly opposite, and this drain falls into the river Maun, serving the lower level. At the farm, there are 28 horses, about 50 horned cattle, and 6 pigs. The village of Clipstone, draining into the same level, contains about 34 houses. Mr. Tebbett says, the Duke gets all the wash, refuse, sewage, and liquid manure he can into the flood-dike.

There is always a small black sediment left on the surface of the ground in the upper part. In the lower it gradually changes to a brown colour. This is no doubt finely-divided manure brought in suspension, and the soil acting as a filter separates it so as to deposit a top-dressing. Mr. Tebbett considers it highly beneficial to the herbage. There is some dye-wash in the sewage of Mansfield, but it is not found at all injurious to vegetation. The working of the mills in and above the town so varies the flow, even at different parts of the same day, that I found it impossible to make any calculation as to the quantities of fluid used.

Taking into account the extent of land irrigated,—the comparatively large supply of fertilising matter from the sewerage of the town, and the auxiliary supplies taken in along the course of the flood-dike and carriers,—I do not think I have seen any instance, except Edinburgh, in which so large a quantity per acre is applied.

From the great inclination of the surface the fluid passes rapidly off, and yet I have not met with anything more pleasing than the perfect manner in which it is filtered, both mechanically by the soil, and chemically by the living plants. The fact that the flood-dike and the river-course run parallel to each other, with only the meadows intervening, is peculiarly favourable for observing the transmutation.

At Old Mill Lane, the end nearest the town, the flood-dike abstracts the whole stream of the Maun, so that in forming the next two meadows its original course was perfectly obliterated. Shortly, however, its course became necessary to convey the water after it had been used for irrigation. At the point where its channel again begins, two land drains have their outlets. Besides these the whole stream, for a distance of more than four miles, is entirely derived from the water flowing in after it has been used for irrigation. This explanation is necessary to a full understanding of what follows.

The carriageway passes along the bank of the flood-dike for about two miles, and I could not but observe that the combination of sewage and dye-water, without any flowing current, had a very forbidding unpleasant appearance. The fluid was so nearly opaque that objects became invisible at a depth of about three inches. The leaves of the long grass growing on the banks appeared brown and burnt, where they had been dipped into it; and in several places I observed swarms of small flies such as I have often seen hovering over gully-gratings, cesspools, and other places giving off deleterious gases. I have frequently mentioned these flies in my reports to your Honourable Board under the name of the "plague-fly." I did not observe any unpleasant effluvium, and think that probably the dye-water has some antiseptic properties, but the whole aspect of the flood-dike strongly reminded me of the Lethean stream.

At the New Buildings the road turns directly across the meadows, and follows the river-course, where the stream, as I have already stated, is the same water after it has been used for irrigation. The bed of the Maun has an inclination of about 10 feet to the mile, with a sandy bottom, and there I was delighted to find the water as clear as crystal, with great numbers of fine trout and grayling, and producing large beds of water-cresses, which are cut daily by poor people for the Mansfield and other markets. I think there could be no stronger proof of the facility and rapidity with which plants will take food, when it is offered to them in a state of solution, than the contrast of these two streams;—nor could any more complete demonstration be given that the pollution of rivers in the vicinity of towns may be avoided, by simply returning the causes of such pollution to the suburban lands. That the land is grateful for the care thus bestowed upon it scarcely any one will now deny; but it becomes my duty before closing this account to show briefly that such is the fact in the present instance.

Mr. Tebbett, speaking from recollection, informed me that all the upper portion of the land was a wilderness covered with gorse and heather, among which a few sheep wandered. Of the lower,—on the margin of the river,—that it was certainly land, but that was all that could be said. It was such a bog as to be utterly worthless. No animal but those of the feathered tribes could get on it: it was a haunt of wild ducks and snipes. The whole area of what is now water-meadow would have been well let at 3*s.* to 5*s.* per acre.

Of its present value and produce, such of the land as is let irrigated produces a rental of 4*l.* 10*s.* per acre. Mr. Tebbett says:—" We " reckon to mow three times for green eating, and then turn on " cattle to feed; or we mow twice for hay, and then feed. In the " beginning of May we can cut eight inches of fine grass, after " which we irrigate as soon as possible. In eight weeks we can " cut again a similar or rather heavier crop, and again in eight weeks " a third crop equal to the second. It is then fed off with either " beasts or sheep, and will support three bullocks or fourteen sheep " for every two acres, from August to the latter end of November."

Mr. Denison gives statistics of the produce, showing the average annual value per acre to be not less than 12*l.* 4*s.*

Before the irrigation was commenced the Duke of Portland's annual account for bone manure alone on the estate was about 1,400*l.* per annum. The solid manure produced on the farm, and the irrigation, are now quite sufficient to fertilise the whole, and no bones are purchased.

I have dwelt at greater length than I had intended upon the Clipstone meadows because they are a prominent example, within a few hours distance of almost any part of England, of the great fertilising powers of town sewerage waters. The town is but small, the drainage of it very inadequate for the removal of the most fertilising refuse, and the mode of application exceedingly expensive in its first cost as compared with distribution by pipage; but the results as to the enormously increased produce and value of the land are such as I have just stated. Bearing in mind all these considerations, and the small expenditure at which sewerage waters may now be distributed with the hose-pipe, without any disturbance of the natural surface of the soil, I would recommend any persons interested in the subject to examine the water-meadows at Clipstone.

There is a further objection to open gutter irrigation that I have not alluded to, and I have not space to go fully into the consideration. I refer to the tendency to rot among sheep pastured on meadows so irrigated. In the essay already named, Mr. Denison quotes some very valuable remarks from the Duke of Portland himself, who had personally bestowed great attention on this point. He says:—" None of the irrigated meadows can be said to be quite "safe for sheep in autumn, not even those which are on the land "naturally most dry." He thinks it probable that more complete drainage of the land would decrease the liability to this disease, and I believe that such has been found to be the case; but when the ground is so completely saturated as it must be with the open gutter system, I do not think that any arrangements for drainage can obviate all risk. It may, however, fairly be assumed that the tendency to rot is owing in part to the land being naturally a bog.

Where the irrigation is carried on by means of pipes and hose, and the distribution by jet, the ground is never saturated, because the fertilising fluid is so perfectly under command that the same effect can be produced by a much smaller volume of water. I have never heard of the least tendency to rot where the pipe and jet system is in use.

Irrigated Meadows in Wiltshire.—From the vicinity of Salisbury, along the valley of the river Wiley to beyond the town of Warminster, a distance of 22 miles, is an almost continuous series of meadows irrigated with water and the refuse of the towns and numerous villages in the valley. The whole area of such meadows is not less than from 2,000 to 3,000 acres, belonging to various owners.

The mode of irrigating is the same throughout; the ground is levelled and thrown up into beds of ridge and furrow. The water of the river is admitted by sluices into open gutters called carriers, which convey it a sufficient distance to reach the altitude required; it is then distributed by smaller sluices into gutters formed along the ridges of the bed-work; from thence shed on each side over the surface of the bed, and received by gutters cut in the furrows. In small estates or holdings it is returned by these to the river, but where the operations are more extended the carriers convey the stream to a higher altitude, and the same water is used several times over, by connecting the gutters, carrying it off from the higher beds, with other carriers which convey it to beds at a lower level, where the same operation is repeated.

It will be obvious that the cost of forming such meadows, providing sluices, cleansing gutters, and working expenses, must be considerable, irrespective of the large area of land occupied by the open carriers and gutters.

The following information has been given by Mr. R. S. Waters, an experienced surveyor, as to the expense of construction and working of water-meadows in Wiltshire.

1. What would be the ordinary expense of the formation *de novo* of a tract of water-meadows; including carriers, &c., for 50 acres;—100 acres, or any other convenient tract, might be taken as the basis of the estimate?—The cost per acre of forming water-meadows will vary from 15*l.* to 50*l.* per acre, according to the amount of soil to be moved, and as high a sum as 100*l.* per acre I have known paid in forming water-meadows.

2. What would be the annual expense of keeping them in repair? —The question depends entirely on the nature of the formations of

the meadows; and whether they are formed to catch the water after the first time using, to water with again, or not; whether much hatchwork is made use of; and whether the hatchwork is made of wood, bricks, stone, or iron. Stone should always be used for hatchwork walls if possible, with iron hatches.

3. What would be the annual expense of watering them, each time, and the total expense of working them per annum?—2*s.* per acre per annum is generally paid for watering the meadows, and 5*s.* per acre per annum for cleaning out the watercourses and carriers, and placing and levelling the soil.

4. What depth of water is usually required for watering?—From a quarter to half an inch over the surface.

5. How many times in a year is the water usually put on?—The first watering, viz., during the autumn and first winter months, the meadows should be watered seven days and nights in succession, and then the water turned off for the same time, and so continued. In the second turn or watering, or from the month of February, it should be four days and nights instead of seven, both for watering and turning off; but in frosty weather the meadows should if possible be always covered with water, and on the breaking up of the frost the water turned off as usual. In the first summer months the watering should be for three days and nights in succession, and then turned off for the same period, and then three days and nights watering should be followed by six days and nights turning off the off-water.

During the course of the present year I have had an opportunity of examining the whole extent of these meadows, while in the pursuit of my duty to your Honourable Board, and feel it right therefore to explain what might be otherwise misunderstood from Mr. Waters's answer as to the quantity of water used. The "quarter or half an inch in depth over the surface," does not mean the whole water laid on at each application, but the actual depth being shed over the beds at any given moment of time. The distinction is an important one when taken in connexion with the answer to the next question, as to the length of time the water is on. It not only shows, as an agricultural fact, the enormous quantity of water requisite to produce a high state of fertility on the open gutter and bed system of irrigation, but also, that for about half the whole year these meadows are under water. The first "turn" is during winter, seven days on and seven days off. The second "turn" in spring, four days on and four days off. The third in summer, three days on and three days off, then three days on and six days off. In every "turn," except the last, the periods of irrigation are equal to those during which the water is shut off, but during frost the water is kept on, if possible, altogether. These "turns" include night and day. The whole of these meadows, therefore, during about half the year, form one large evaporating surface, as much as would be the case if the whole area constituted an immense lake. Even when the water is off, the ground is so saturated that the evaporation must still be going on. No fen or morass in any low-lying, ill-drained district of the country would, I apprehend, impart, area for area, an equal amount of moisture to the atmosphere. The consequence is such as might be expected:—ague is extensively prevalent in this valley, and in some spots so general that scarcely any of the inhabitants, rich or poor, young or old, escape it.

The soil of the high lands is chalk, and the winds that sweep over Salisbury Plain are peculiarly dry, and have a large capacity for moisture. Were it otherwise, the disease would be more general through the valley than it now is, while some localities would be uninhabitable. Where the free motion of the air is prevented by trees or other obstacles, there ague is present every year, and its effects may be seen in the dejected, haggard appearance of the inhabitants, and in the contrast between the amounts dispensed as poor-rates in such places, and in neighbouring parishes of equal population, but not subject to the influence of malaria.

I beg leave to recall the attention of your Honourable Board to the striking proof of this adduced before me in the course of my investigation into the sanitary condition of the parish of Longbridge Deverill, near the town of Warminster, and stated in my Report. In one portion of the parish, the large village of Crockerton, scarcely any of the inhabitants have escaped ague, and on comparing the poor-rates for seven years back with those of the parishes of Corsley and Horningsham, of about equal size, and in the same Union, it is found that the charges for sickness in Longbridge Deverill are nearly double. Time will not permit me to go more at large into the question here, but the figures are tabularized, and the evidence is given in my Report. I quote, however, two brief reports from the medical officer to the Board of Guardians; it will be seen that two years intervened between the former and the latter.

"GENTLEMEN, "*Warminster*, 12*th July* 1849.

"In my report to you on Monday last I omitted to state "that I considered the practice of irrigating the meadows at "Crockerton below the pond, with the almost stagnant water from "the pond, is amongst the causes producing ague in that locality; "and I strongly recommend that the meadows be made dry.

"I am, Gentlemen,
"Your obedient Servant,
"GEORGE VICARY."

"*To the Board of Guardians*
"*of the Warminster Union.*"

The other is as follows:—

"GENTLEMEN, "*Warminster*, 30*th July* 1851

"I am sorry to report that Crockerton still continues in a "very unsat'sfactory state, and I trust that every effort will be made "to restore it to a state of health by sanitary measures.

"I am, Gentlemen,
"Your obedient servant,
"GEORGE VICARY."

"*To the Board of Guardians*
"*of the Warminster Union.*"

The cost of the system of irrigation by open gutters and beds may be drawn out from Mr. Waters's statement. 15*l.* per acre appears to be the minimum, and 100*l.* the maximum, for formation alone. I am convinced from my own examination and inquiries that 20*l.* per acre would be a very low average. At 7½ per cent. for interest, and for repairs of sluices, hatches, &c., and depreciation, the account for capital and working expenses per acre would stand as follows :—

| | £ | s. | d. |
|---|---|---|---|
| Annual interest, &c. on 20*l.*, at 7½ per cent. - | 1 | 10 | 0 |
| Annual cost of watering - - - - | 0 | 2 | 0 |
| Annual cleaning of water-courses - - - | 0 | 5 | 0 |
| | £1 | 17 | 0 |

All the land so irrigated is grass land, and four heavy crops can be cut in the course of twelvemonths. The constant state of dampness would preclude grazing to any extent, and this is a serious drawback in a district of country where sheep-farming is perhaps more extensive than in any part of England.

Irrespective of all other considerations, however, a comparison will show that the gutter and bed system costs from two to three times as much as will produce the highest state of fertility yet known, by means of iron pipes and flexible hose and jet distribution.

The Duke of Bedford's Irrigated Meadows at Tavistock.— My journey to Tavistock, for the purpose of examining the meadows irrigated during the last five years, was in consequence of a correspondence between his Grace the Duke of Bedford and your Honourable Board, from which it appeared that some meadows in the vicinity of that town had been recently brought to a high state of fertility by the application of sewerage water.

Premising that the Duke of Bedford has, at his own cost, simultaneously constructed the town sewers, for the collection and conveyance of the sewage, and also the irrigation works for applying the sewage so collected to his land, I think it best at once to quote the documents furnished by direction of his Grace.

" Answer of Mr. Benson, the Duke of Bedford's Devon Steward, to the inquiry by the General Board of Health, relative to irrigation by means of the sewage refuse of towns.

" The sewers at Tavistock were commenced in the year 1846, but not finally completed until 1850.

" The preparation for irrigation was commenced in the year 1847, and completed at Lady Day 1851.

" The total cost of the sewers has been 1,590*l.* 11*s.* 9½*d.*

" The cost of the irrigation works has been, partly formed in beds, and the greater part catchwork, 1,183*l.* 1*s.* 9*d.*

" The extent now under irrigation is 90 acres.

" Owing to the recent construction of a considerable portion of the work, which has not had the benefit of the water, the increased value cannot be stated with certainty ; but the first 20 acres formed, and which is not by any means the most favourable for the purpose, has been increased from 35*l.* to 100*l.* a year. It is proper, however, to state that this portion has the advantage of being nearest the mouth of the sewer, where the water is the best; but on that account there are deposits formed in the levels, which, when cleared out, are sufficient to afford manure for five acres above the levels of the sewers. It is thought that the increased value per annum of the remainder of the meadows will ultimately not be less than 2*l.* 10*s.* per acre; but it will require a few years successive watering to make them of that value. The working expenses may be calculated at about 15*s.* per acre.

"*Bedford Office, Tavistock,*
*12th Sept.* 1851." "JOHN BENSON."

"MR. BENSON'S ANSWER to the further inquiries by the General Board of Health.

"There are only 50 waterclosets in Tavistock which are supplied by water, and which communicate with the sewers. There are, however, a considerable number of privies, the drainage of which goes more or less into the sewers; as does also the drainage from various stables, pigs-houses, slaughter-houses, and other premises. It would, however, be impossible to estimate the proportion of fertilising matter which the occupiers secure to themselves, and how much is allowed to escape into the sewers. It is, however, supposed that the greatest portion of the privy-soil, and the whole of the housewash of about 500 dwellings is carried into the sewers; a great portion of the houses having drains from the premises direct to sewers, while others are merely drained on the surface, and the waste arrives at the sewers with the wash of the streets.

"*Bedford Office, Tavistock,*
*25th Sept.* 1851." "JOHN BENSON."

It will be seen from the above that the irrigation is of very short duration; and this should be borne in mind while considering the increase in value and produce that has already taken place.

The part of the meadows formed into beds has been much more costly per acre than the catch-meadows; but the latter form the bulk of the whole. I have been unable to obtain the amounts separately; but taking the statement given for the whole 90 acres, the following would be the annual charges on account of the improvement. I exclude, of course, the cost of constructing sewers in the town:—

| | £ | s. | d. |
|---|---|---|---|
| Annual interest, &c. upon 1,183*l.*, at 7½ per cent. - | 88 | 14 | 6 |
| Annual working expenses, at 15*s.* per acre, upon 90 acres - - - - - | 67 | 10 | 0 |
| | £156 | 4 | 6 |

This amount, divided by the number of acres, is equal to 1*l.* 14*s.* 8½*d.* per acre per annum.

In my local inquiry I received all the assistance and information that could be given me at the Bedford Office in Tavistock.

The Duke is the owner of about nineteen twentieths of the land upon which the town stands; and I was informed the population is from 7,000 to 8,000.

The works were laid down according to plans made by the Duke's surveyor, and the town sewers are triangular in form, the sides being of brick and covered with flat stones. The system of drainage did not extend to the house and building drains; these have been voluntarily formed by the leaseholders themselves.

The house drains are 6 or 8 inches square, of rubble, set in lime.

No earthenware pipes have been used in the town drainage, although good pipes are, I believe, made in the county.

Some of the lessees have neglected and refused to drain into the sewers, but not many. In other cases the drainage is not complete for the removal of the night-soil, &c., but such houses as have no accommodation behind have been drained, with the intention of conveying everything away from the premises. When the sewers were laid down, gratings were let into the sides at the points where all the house drains should enter. I was not surprised to learn that some of the house drains had become choked by these grates, and have had to be opened.

Where the houses are adjacent to the river Tavy, it is still made the receptacle of refuse. The sewers are not deep enough to prevent this. It will be apparent from what I have stated, that a considerable proportion of the fertilising refuse of the town does not find its way to the irrigated meadows; still the whole of the fluid used is town sewage water. All the sewers empty into the irrigation carriers.

There were some sewers in Tavistock before the commencement of the Duke's operations in 1846, but the drainage was very inadequate. All the principal streets are now supplied with sewers.

As a proper water supply is necessary to efficient town drainage, and also to any systematic application of liquid sewage manure, I feel it right to say, that simultaneously with the construction of the drainage and irrigation works, a constant supply of good soft water, with a tap in nearly every house, was provided at the cost of the Duke. For this supply the charge is only 3*d.* in the pound upon the rateable value of the houses.

The water is obtained from springs at a great altitude above the town, and the pressure is such as to afford a jet 40 feet high in the centre of the town. My informant stated that the clear income for water is about 4 per cent. on the outlay.

The Duke holds about 25 of the 90 acres irrigated; the remainder is in the hands of tenant-farmers. In consequence of the short time during which the irrigation upon those portions has been in operation, no increased rental has yet been charged.

About 10 acres of the land is under-drained 6 feet deep, with stones placed edgewise, and covered with slabs. These drains are about 40 feet apart. I could not ascertain the cost of such drainage. Rushes grow in tufts on the land undrained, and I cannot doubt that drainage of such parts would add to the fertility.

The meadows laid out in beds appear to have much greater slopes than is necessary for the shedding of the water, and besides being much more expensive in the first instance, I do not think they are equal in fertility to the catch-water meadows.

The sewage water is laid on immediately after the first cutting of the grass in May, and remains flowing 48 hours; it is then taken off for a month or five weeks, during which a new crop grows. It is again cut and watered in a similar manner, and the second crop taken about July. The process being repeated, a third crop is cut about September. In October the gutters are cleaned up, and the sewage put on for about three days, after which the irrigation ceases until Christmas, when it is laid on again for three days. There is no further irrigation until the ewes and lambs are removed, about the 1st of April, when the sewage is again applied preparatory to the first cutting in May. One man is constantly employed and another more than half his time.

The improvement in the land corroborates the experience of all the other places visited. The whole 90 acres is kept in grass, and was so before the irrigation commenced. I was informed that it was badly farmed previously, but that, if it had been well farmed, it would have been worth about one fourth only of its present value. The fertility of the land is not only constantly increasing, but the grass is also improving in quality. Speaking of that portion only recently brought under irrigation, and in the hands of one of the Duke's tenants, my informant said—"My experience here is, that "in a few years Mr. Gill's meadows will be as good as these are "now, and ours will be still better."

I am able to show the yield of the 25 acres in hand. Between the 20th of May and the 20th of September this year, a part of the grass was cut and sold green in the market at 12*s.* 6*d.* per ton, realizing 70*l.* A rick of hay, which I examined, was also made at the same time, and is valued at 45*l.* During the same period there were 14 cows feeding, for which 3*s.* 6*d.* each was paid per week. The remaining eight months the same number of cows pay 1*s.* 6*d.* each per week. In spring there is an addition of 100 ewes for a month, at 8*d.* each per week. A horse, belonging to the Duke, is kept upon the grass and hay all the year round; he has no other food. The value of his keep is 5*s.* per week during the six months summer season, and 2*s.* per week in winter. In addition to all this stock, there are occasionally as many as 13 bullocks for a month, at 3*s.* per week each; and at the time of my examination there were 88 sheep for two weeks at 3*d.* each. This extra stock is necessary to keep down the crop, still rapidly growing in the month of November.

The following statement, therefore, exhibits the annual money value of these 25 acres, which have been longest irrigated with the town sewage:—

| | £ | s. | d. |
|---|---|---|---|
| Grass sold | 70 | 0 | 0 |
| Haystack | 45 | 0 | 0 |
| 14 cows, 17 weeks, 3*s.* 6*d.* per week each | 46 | 13 | 0 |
| 14 „ 35 „ 1*s.* 6*d.* „ | 36 | 15 | 0 |
| 100 ewes, 4 „ 8*d.* „ | 13 | 6 | 8 |
| Horse keeping | 9 | 2 | 0 |
| 13 bullocks, 4 weeks, 3*s.* each | 7 | 16 | 0 |
| 88 sheep 2 „ 3*d.* each | 2 | 4 | 0 |
| | £230 | 16 | 8 |

This amount, divided by the number of acres, gives 9*l.* 4*s.* 8*d.* per acre per annum, as the value of the grass produced upon land that has only been irrigated four years.

By a comparison of the annual charges for this mode of irrigation with that by pipes, hose, and jet, it appears that this instance of bed and catch-work is at least 1*l.* per acre in excess; but, notwithstanding, there remains (after deducting the large sum of 1*l.* 14*s.* 8*d.* for interest and working expenses) 7*l.* 10*s.* per acre per annum as the net produce from the application of the town sewerage water.

Exmoor Catch-meadows.—The attention of your Honourable Board was directed to this locality by a letter from Mr. Pusey, and also by an excellent article on the subject in the Journal of the Royal Agricultural Society (vol. 12, part 1., No. 27).

Exmoor is an extensive hill property, of many thousand acres in extent; and while the mountain district seems to defy the hand of the husbandman, the table-lands and moderate hill-slopes invite his attention. It is situate in Somersetshire, about ten miles to the north-west of South Moulton, about 15 miles easterly from Barnstaple, and nine miles to the south of Lynmouth (Bristol channel); on the eastern line of water-shed are the sources of the river Exe; and the higher parts of the district, although within ten miles of the Bristol Channel, are about 1,000 feet above the level of the sea.

Until this property was purchased by the late John Knight, Esquire, the hand of the cultivator had scarcely touched the district for miles; its lofty table-land and steep hill-sides afforded sustenance only for Exmoor sheep and ponies. Not a tree nor a fence was visible; and the only produce was heath, gorse, rushes, moss, and sour forest-grass. The hill-sides in many instances were bare of soil, with frequently the rock staring through the surface, and the contracted valleys were quaking bogs.

Exmoor is the property of Frederick Winn Knight, Esq., M.P.; and Mr. Robert Smith, the author of the essay already referred to on "The Formation of Hill-side Catch-meadows, on Exmoor," is one of the Council of the Royal Agricultural Society; is also resident land-agent to Mr. Knight, and occupies a farm of 700 acres, upon which he resides.

With great energy and courage in the application of the principles of agricultural chemistry, Mr. Smith has, in about two years (in addition to the general cultivation of the table-lands on the higher portion of the farm) *manufactured* a flourishing and comparatively fertile range of catch-meadows out of the stubborn materials above described, *with the addition only of liquid and liquified manures.*

As far as my experience extends, this instance of fertilising is unique in its object, in its success, and its cheapness.

In Mr. Smith's essay he has scarcely done justice to himself. A cursory reader might conclude that these were simply water-meadows of a more cheap construction than usual, and that the conveyance of soils and manures was at the most accessory to the primary object of water irrigation. A careful examination of the system, made in company with Mr. Smith, evidences a much higher object. The water becomes only an agent—necessary, but subordinate—in the fertilisation of the land. Mr. Smith fully agrees in the following as a brief, definitive description of his operations :—

"Demonstration that soils, loam, clays, peat, lime, and manures of all kinds, mineral and organic, soluble and insoluble, may be carried and applied to any part of an extensive farm, within reach of a stream of water,—at a much less cost, and with far better agricultural results,—in suspension and solution with such stream, than by any other agency whatever."

Within the very brief space which this Report must occupy, I cannot enter fully into the details of what Mr. Smith has done, and must therefore respectfully refer your Honourable Board to his essay; but I must remark, in order to the better understanding of his account, that this is a tenant-farmer's improvement, that the period since its commencement is short, and that the whole of the arrangements described are not yet completed, though fully contemplated and determined upon. The water-wheel, as a motive power, has not yet been erected. The ponds for liquifaction of manure, and their accompanying cattle-sheds in various convenient parts of the farm, have not been yet constructed; and no sluices or hatches have yet been put down upon the carrying-gutters. In the absence of all these arrangements for perfecting the system, it would be manifestly unfair to make comparisons as to the pecuniary cost and charges with other modes of applying liquid and liquified manures. A brief extract from Mr. Smith's essay will show the true position of his movements and intentions :—

"If it be desirable that the work should be extensive and the outlay gradual, the work may be extended over a breadth of time, by the general plan being agreed upon,—thus completed as the meadows improve; this is precisely my own case and intention as a tenant."

In Mr. Smith's case we have only yet, as certain data, the cost of cutting the gutters and the wages of labourers. The area at present irrigated is about 100 acres, the guttering of which was done at 10*s.* per acre. The wages of the waterman and his assistant are together 20*s.* weekly, for the winter half-year; this includes the cutting out of moderate springs, the manuring by the throwing in and washing of soil, &c., to the meadows. The waterman's time in changing the water only would amount, say, to *half* a day throughout the water season.

The gutters vary from 3 feet wide and 6 inches deep, to 18 inches wide and 5 inches deep: they are carried by contours along the sides of the hills from the brook stream, and receive in their course the waters of several springs, which Mr. Smith has "tapped" for the purpose of draining bogs. The water, manure, soil, &c. is shed over the lower side of the carrying-gutters, and received into the next lower level, to be again used in a similar manner. All the carriers are so connected that the fertilising fluid can be shed over at least 80 acres of the 100 acres at will, to the exclusion of the remainder.

It must be remembered, as an astonishing fact, that the greater part of this land has not been ploughed, levelled, drained, or in any way broken up from its original or native state. The liquid and liquified manures have been turned upon the moss, heather, gorse, rushes, and weeds, destroying them all into decayed vegetable matter, and producing instead a sweet and luxuriant grass. I can best state Mr. Smith's proceedings by one or two quotations, which shall be brief.

"The majority of these water-carriages being laid out upon the forest hill-side, and the land taken in hand as nature formed it, I find the better plan (to eradicate the moss, &c. and encourage the grasses) is to let the water flow over it freely for five or six days in succession, a continued rush of water being certain to effect the desired change."

"By the circuitous route of a water-carrier in a hilly country, passing as it does from hill to hill, around and across the valleys, a splendid opportunity is afforded for re-conveying any quantity of the accumulated soil in the valley to the poor and neglected hill-side, which has been robbed for ages of this deposit by the continued and ungoverned washings of the rainy seasons. In valleys, when drained, the soil quickly decomposes and dries, forming a rich black mould, which is dug from the upper side of the carriage, and when chopped rather small, is thrown into it; then, if a rapid fall can be given to the water for a short distance, it will reduce itself so small as to mix with the stream. The waterman is in attendance at the meadow that the soil may be properly distributed, and to change the rush of soil and water further on as the work proceeds. The same plan may be adopted on the flat meadows at the foot of the hill, a heavier soil being used when it can be had, as these bottoms are chiefly composed of black or other friable soil."

The process for the application of manures is similar, and the appropriateness of the term "carrier" to what would otherwise be simple water irrigation is in this instance very striking.

Upon a poor hill-side, fully a quarter of a mile from the farm-buildings, and an equal distance from the "soil-valley," I found deposited on the moss, besides the liquid and liquified manure, and the earth and dung-paste, a large quantity of the decomposing straw of the long dung, and rounded lumps of soil 5 or 6 inches long and 4 or 5 inches diameter All this fertilising matter had been carried and applied by the *simple* gravitation of water. Mr. Smith says:—

"Nothing can exceed the loss of a hill-farmer, if the fine particles of soil, manure, lime, or ash, be washed to the bottom of the hill by collecting currents,—never, alas! to be regained; while no pleasure is so great as to witness a collection of these agents (on their way) in a pond or reservoir, with every facility to remove them at will, when and where we like."

This quotation from a scientific farmer has great force. Its application is equally weighty to the immediate object of your Honourable Board—the economical and profitable disposition of town sewage. It is but necessary to substitute for the words "a hill-farmer," in the first lines of this paragraph, the words "a town population," in order that the identity of interest between the two may be seen, and the present loss to towns from the waste of manures be made strikingly apparent.

Such is Mr. Smith's opinion upon this head that main and branch drains are laid in every direction of the farm and courtlage to collect *every* drop of water and sewerage about the place, to be conducted to "the meadows."

On cutting out a spit of soil upon what was a bare hill-side only a season and a half since, and which had received two liquid dressings of three days each, I found a deposit of fine black compost and mould amidst the roots of the grass an inch and a half thick. In another place, where only one dressing had been given, the thickness varied from half an inch to an inch. This was what had been carried in suspension—the fertilising matter in solution had already been converted into beautiful verdure. I was much struck with the practical distinction made by the waterman between the suspended and the dissolved parts of the manure. On turning up the suspended soil with his spade, he handed me a portion of black deposit, and remarked, "This is what I call brewer's grains—the land takes the best in as liquor."

I have already stated that some parts of the valleys were quaking bogs. These Mr. Smith tapped, and the same water abstracted from one part, where its presence is injurious, is used as the agent for fertilising other parts where it is needed, thus doing double work.

In one of these valleys, within two years of the present time, the rushes were above two feet high, and the moss and bog so soft as to be impassable. The whole piece was not worth a shilling per acre. In this instance a *single* spring was doing the whole injury to a well-formed sloping valley. This spring was tapped, and the fertilising fluid turned on, but changed from time to time; and without anything further the character of the soil and its produce so changed, that this year a crop of good hay equal to about a ton per acre has been housed; and Mr. Smith estimates the grass since eaten off at 10*s.* per acre.

On another valley piece of 10 acres, which in the forest state would not keep a sheep to the acre, a liberal dressing of the "valley soil" was washed on to it, and the water, after 10 days had elapsed, again turned on to liquidise the remaining soil; this was done without anything further in the way of cultivation, and this year, after about seven tons of hay had been cut, the water was again turned over it for a few nights,—the effect being remarkable; it then sustained about twenty head of cattle for two months, and is now under the process of watering for early feed for ewes and lambs.

In connexion with these springs, there is a fact that bears strongly upon an opinion I have already submitted to your Honourable Board; namely, the great probability that the fertilising powers of town sewage, and liquid manures may be considerably increased, without additional expense, wherever the distribution is effected with steam power and pipes, by the injection of a jet of waste steam into a tank, so as to raise the temperature of the liquid a few degrees above that of the atmosphere at the time. Mr. Smith attaches much importance to the principle of "warmth," and describes it in his prize essays on the management of sheep and grass lands, as "nature's law, by which the increased production both in the animal and vegetable kingdom is governed." Again, in reference to spring water, it is found that "warm springs" are best for irrigation; and that the best spring for irrigation he has found upon the Exmoor Forest is at an altitude of 800 feet, with a temperature of 48 degrees; the atmosphere when taken being only 40 degrees, and the river Barle, at a distance of 200 yards below the spring, 42½ degrees, the spring water gradually assimilating itself to the atmosphere, and the decreasing effect of vegetation being very perceptible until it reach the passing stream.

I have since received the following communication, in which he again alludes to the temperature of the water :—

"Sir, "*Emmett's Grange, South Moulton, Dec.* 27*th*, 1851.

"As regards your inquiry the other day about the land on the native hill-sides, which has not been broken up from its original state, I find that the hay crop of the last summer covered every expense incurred in the laying out and cutting of water-carriages in the two previous years; that the succeeding eatage has realized 12*s.* per acre, and that the land is now worth from 20*s.* to 25*s.* per acre to rent, and is daily improving.

"Previous to the water being turned over these hill-sides land it was *valueless*, growing alone a very short grass and weeds, and the bottoms were covered with high rushes and moss, before the water was taken *out* of them; this done, it is conducted on for irrigation.

"A further remark upon the temperature of waters may confirm your observations; viz.—in the last winter I found that the snow *remained* in the carriage conveying the uncultivated hill water to the meadows, while in the carriages conveying the same water *after* draining, the snow melted as it fell—the temperature being improved. I was much struck with your remark upon applying "waste steam" to improve the temperature of liquid manure in a tank, previous to use, having seen the practical effect of improved temperature in our waters.

"With respect, I am, Sir,
"Your obedient Servant,
"Robert Smith."

"*Wm. Lee, Esq.*"

A stream of water is brought through the farm buildings and yard, and all the manure capable of being liquified is removed by water. The chief work upon a stock farm like this is done in summer, and during the season Mr. Smith had equal to 1,000 sheep, in addition to his corn, hay, and root lands. He says he shall be able to keep 2,000 sheep next year. The present, or winter stock, furnishing manure, consists of 4 milk cows, 50 feeding cattle, about 20 horses, besides 30 more in the fields, 200 sheep, and about 100 feeding pigs. The large pigs lie on boards, a stream of water is conducted through the turnip house to wash the roots, then passes under the piggeries, cart-horse stable, and at the foot of the cattle in the sheds (the latter is an *open* drain), under the nag stable, and subsequently delivers its collected sewerage to the meadows below the house, which have at this time a verdant appearance, and it is truly interesting to view the process which is daily carried on—the effect of town sewerage in miniature. The solid manure made in the piggeries is swept every day into the passing stream. The bedding of the cattle is all shaken over the solid manure thrown into the watercourse, and only the long straw taken to the manure heap.

Mr. *Smith* says :—

"The water which passed through my yard upon the above plan, has been used upon a selected portion of hill-side land, (as an experiment,) which, in its natural state, was partially covered with rough grass and heather, while on some parts not a plant of any kind was ever seen to grow, as may be seen by reserved spots above the present water-carriages; while that below, upon which the water has been used, is now covered with green and daily improving grasses, the chief of which is the white or Dutch clover; and, singular to state, not a single seed has ever been sown upon the land."

Mr. Smith pointed out to me this contrast, described in his essay; and if time and space permitted, I might mention numerous others which came under my observation. I quote, however, only one instance :—On the higher parts of the farm the land is top-dressed with solid stable manure. Some of the land thus manured is above the reach of the irrigating gutters, and the highest gutters of course contain the smallest quantities of water. In one sloping field the gutter runs obliquely across, one side being above the irrigation, and the other below. The land on both sides of the gutter had been equally dressed with solid manure. The water had been shed over the lower part immediately, and the manure washed in, leaving only a few straws on the surface; while on the upper side, above the water, the manure had clotted into hard cakes. On the upper side the exposed herbage was brown and coarse; on the lower, a more beautiful green colour could not be imagined. I turned up several large lumps of the solid manure on the upper side of the gutter, and found the grass beneath a sickly yellow colour and almost destroyed. Kicking away some of the straw residuum on the lower side, the grass was even more luxuriant than where exposed. This I attributed partly to the protection afforded during the previous night's frost. The light and air had access to it, and it was still growing vigorously at Christmas. I next directed the waterman with his spade to turn up a spit of earth on the lower side, and found a fine black soil or deposit from the manure amidst the roots of the grass, upwards of half an inch thick, and the soil darkened by the liquid several inches below; this extended over all the ground below the gutter. A similar spit was turned on the upper side, but the whole soil was found of one character from the surface downwards,—a pale ashy-grey colour, without any appearance of the manure having penetrated it in the slightest degree.

I need not comment on these contrasts presented by the same grass, in the same field, with similar quantities of similar manure, separated by a water gutter only 18 inches wide, but the manure on the lower side liquified, while that on the upper remained in a solid state.

On a retrospective view of the Exmoor example of liquid fertilisation, I am convinced, notwithstanding the small cost of cutting the gutters, that if all the adjunctive arrangements of ponds, cattle-sheds, hatches, sluices, &c. were completed, the interest upon outlay, added to the wages for labour, would amount to a larger annual sum per acre, than the ascertained cost of distribution by tanks, underground pipes, and hose with jet-pipe. But I do not think that the operations for the conversion of land absolutely worthless into immediate profitable cultivation—in fact, the making of a farm—would fairly constitute an *à fortiori* case for comparison or contrast with the operations upon farms already in a comparatively high state of fertility.

As a tenant-farmer, investing his own capital under the most disadvantageous circumstances, with only the light of scientific knowledge to guide him, Mr. Smith has demonstrated the great fact, that many millions of acres of land in this country, hitherto considered as waste, may be immediately, profitably, and cheaply cultivated by the distribution and application of soils, lime, and manures in solution and suspension in water, moved in channels to any part where they may be required, and on numerous situations where plough or cart could not penetrate. Hence they have been laying (as very properly described in Mr. Smith's essay) "waste, "growing alone 'heather and weeds,' which might be profitably "brought into good cultivation, by the aid of capital, enterprize, and "good water, and the hitherto neglected waste no longer left to "nature's clothing, but covered with green and nutritious grasses."

Mr. James Kennedy, Myer Mill Farm, Ayrshire.—In visiting the farms in Ayrshire I derived much information and assistance from Mr. Young, engine-maker of Ayr, who accompanied me. The irrigation works here, and also at Mr. Telfer's dairy farm and Mr. Ralston's farm, have been constructed under his management. He is now engaged in laying down similar works on a home farm of 60 to 80 acres, belonging to the Marquis of Ailsa, about nine miles south of Ayr, on the sea coast.

Myer Mill farm is an instance in which the application of liquid manures, and, indeed, all other arrangements for scientific farming have been carried to great perfection.

The land, consisting of 400 acres, was formerly drained only 18 to 20 inches deep, but it is now being drained from three to four feet all over the farm. I need not enter into a full description of the works, because that has been done by others who had previously visited the place. Pursuing my object, however, of making the question one of figures, and of bringing out the result in pounds, shillings, and pence, it may be necessary to say, that the stock consists of about 200 feeding bullocks and other horned cattle,* 140 pigs, 1,200 to 1,400 sheep, 20 horses, and 4 or 5 dairy cows. The urine and drainage from all the farm buildings,—from the house,—and the percolations and washings from the solid manure, are received into large covered tanks.

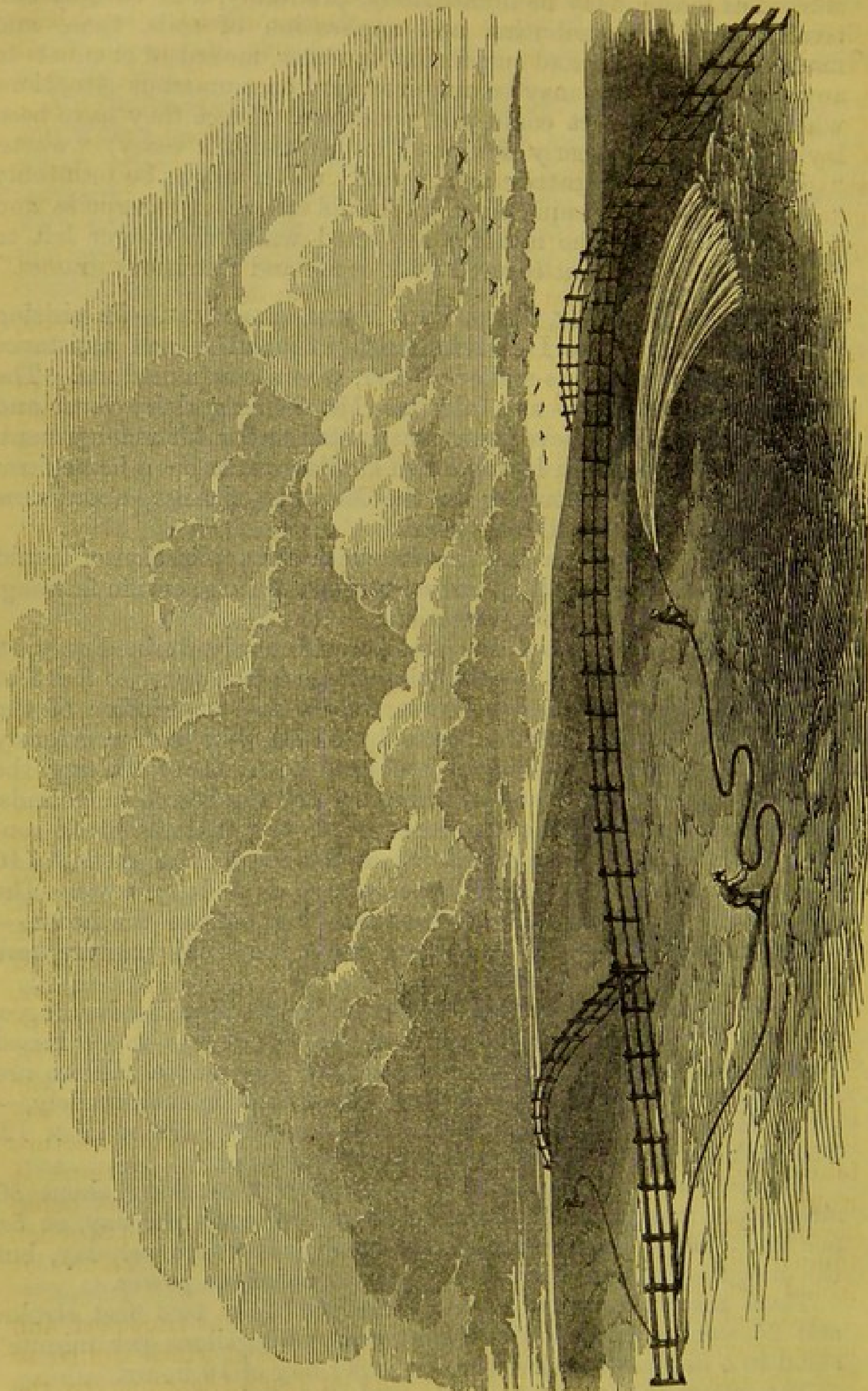
In some respects this farm labours under peculiar disadvantages, as water for the purpose of diluting the liquid has to be raised 70 feet, and from a distance of more than 400 yards. There are four manure tanks, of the following dimensions in feet, namely,—48 × 14 × 12 ; 48 × 14 × 15 ; 72 × 14 × 12 ; 72 × 17 × 12. The tanks, with the agitators, cost about 300*l.*

There is a steam-engine of 12-horse power, working about 50 strokes per minute, and consuming 15 cwt. of coals per day, at 5*s.* per ton. The engine works on the average 10 hours per day, but the irrigation does not require quite one half of the power.

There are two pumps with five-inch barrels, two feet stroke, and 25 strokes per minute, raising about 80 gallons per minute ; equal to a discharge of 48,000 gallons per day of 10 hours.

The steam-engine cost 150*l.*, and the irrigation-pumps 80*l.* ; making 230*l.* together.

* Dry cows give considerably more urine than milch cows, especially while feeding on turnips.



Mode of distributing Liquid Manure by Hose and Jet Pipe at Mr. James Kennedy's Farm, Myer Mill, Ayrshire, 10 Acres per Day.

The iron pipes and hydrants in the fields throughout the farm cost 1,000*l.*, equal to 2*l.* 10*s.* per acre.

The distribution from the hydrants is by lengths of gutta percha pipe, connected by union joints, so as to obtain a reach of upwards of 300 yards every way round the hydrant. The discharge is from a brass hand-pipe, such as is used for fire-engines. The jet reaches the ground in the form of a shower at a distance of 40 or 50 feet from the man in charge of the pipe. It will be obvious from this that the capability of distribution is very great; and I find that a man with the discharge-pipe, and a boy to move the flexible hose, can cover 10 acres in an ordinary day's work.

Taking the discharge, therefore, as given above, the quantity laid on at each dressing would be 4,800 gallons per acre.

The accompanying sketch (see preceding page) made at the time, shows the mode of distribution.

With such an economical distribution Mr. Kennedy is able to dilute the fluid in warm weather to three or four parts water and one of liquid manure, and to lay it on the land six or seven times per annum, much more cheaply than the two applications given at Glasgow, and described herein-after.

In wet weather, when the ground is comparatively saturated, the irrigation is still carried on, but with equal parts of water and manure.

The advantages resulting from this varying dilution fully prove the propriety of what is urged on the subject in a subsequent part of this report. In wet weather manure in a soluble state is added to the water from the clouds, and in dry weather, when the ground is parching, the operation combines both watering and manuring.

There is a man to attend the engine, and a man and boy distributing. Their united wages are less than 2*l.* per week. The gutta percha pipe is bought by weight, and when broken or worn out will sell at 8*d.* per pound. There are 300 yards of two inches diameter, which cost 3*s.* 1½*d.* per yard run; but the article is cheaper now, and 50 yards of pipe, 1½ inches diameter, cost only 2*s.* per yard. Some of the pipes in use at the time of my visit were purchased two years ago, and will still last a considerable time. They appear, however, to be stronger than necessary, and this extra strength gives an amount of rigidity sufficient to cause crinks here and there, from folding and unfolding the lengths. On every occasion the pipes give way again at the same points, and this goes on until the tenacity of the material is destroyed, and a transverse fracture takes place, about half the circumference of the pipe. I think it would be well to substitute canvass hose pipe for this, as being cheaper and more durable, but if gutta percha be preferred, a much thinner pipe would suffice, and being more flexible, I believe it would last longer, besides being cheaper.

A considerable saving would also be effected in the transport and management of the hose, by the adoption of a hand-winch similar to that described and figured in my Report on Town Cleansing, by the hose and jet, printed in the Reports of your Honourable Board on Water Supply.

Taking into the irrigation account the whole cost of the engine, and the whole of the fuel and wages,—although half these might have been deducted,—the following appears to be the capital account and working expenses for fertilising Myer Mill farm:—

| | £ | s. | d. |
|---|---|---|---|
| Tanks complete - - - - | 300 | 0 | 0 |
| Steam engine - - - - - | 150 | 0 | 0 |
| Pumps - - - - - | 80 | 0 | 0 |
| Iron pipes, laying, and hydrants - - | 1,000 | 0 | 0 |
| Gutta percha distributing pipes, &c. - | 56 | 0 | 0 |
| | £1,586 | 0 | 0 |
| Annual interest on 1,586*l*., and wear and tear, at 7½ per cent. - - - | 118 | 19 | 0 |
| Annual wages - - - - | 104 | 0 | 0 |
| Fuel - - - - - | 58 | 10 | 0 |
| | £281 | 9 | 0 |

This amount, divided by the number of acres, is equal to the annual sum of 14*s*. per acre.

I now come to the practical result of so cheap a mode of fertilising land.

Mr. Young informed me, that in one of the fields he had himself measured the growth of Italian rye-grass, and had found it to be two inches in 24 hours; and that within seven months Mr. Kennedy had cut from a field we were passing at the time 70 tons of grass per acre. Where the whole is cut, four or five heavy crops are thus taken; but upon some of the land during the last two years 20 sheep to the acre have been penned in hurdles, and moved about the same field from time to time; after each remove the fluid has been applied, and immediately followed by an abundant growth of food. There is not the slightest appearance of exhaustion in the land,—its fertility appears to increase. I was informed, that before the liquid manure was used the land would not keep more than a bullock or five sheep to an acre; now it will maintain, if the crops are cut and carried in, five bullocks or 20 sheep to the acre. Some beans, bran, and oil-cake are bought for the stock, but, on the other hand, one third or more of the farm is kept in grain, notwithstanding the great number of live stock.

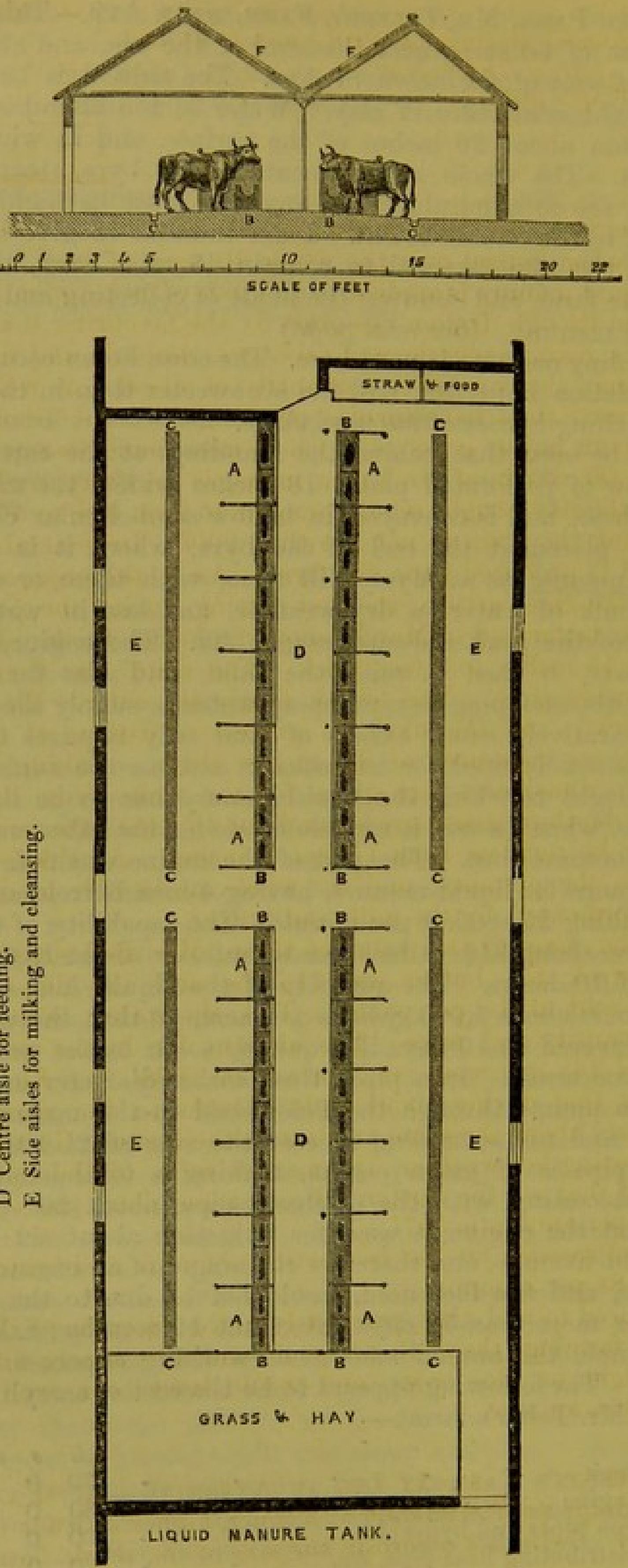
I took plans of some of the farm buildings, apparatus, &c., on this farm, intending to show how admirably everything is arranged in the way of economy and efficiency, both as to materials of every kind and labour; and how many ingenious contrivances have been adopted by the owner and his tenant for the comfort and health and happiness of horned cattle and sheep and pigs. Such arrangements have been made not merely from humane feelings, but from a prudent regard to the pecuniary interests of both landlord and tenant; and in this latter respect it would have been difficult to find a better investment.

CANNING PARK, MR. TELFER'S FARM, NEAR AYR.—This is a small dairy farm of 40 acres, near the level of the sea, and about a mile and a half west of the town of Ayr. The subsoil is beach gravel with a slight admixture of clay. Water is too abundant. It lies dead within about 20 inches of the surface, and in winter nearer than that. The whole arrangements of the byre, steaming-room, dairy, &c. are so admirable that any one must be highly gratified by a visit to the establishment. I am induced to give a plan and section of the byre, erected to contain 48 milk cows, the number kept on the farm, and showing the mode of collecting and conveying the liquid manure. (*See next page.*)

No bedding or litter is used here. The cows lie on cocoanut mats. The ventilation is perfect, and the air sweeter than in the majority of the dwelling-houses of human beings.

It will be seen that behind the standings of the cattle there is a long row of perforated plates 18 inches wide; the urine passes through these, and is conveyed in hollow semi-circular channels to the tank, placed at the end of the byre, where it is diluted in the same manner as at Myer Mill farm, with three or four times its own bulk of water in dry weather, and less in wet weather. The cost of the tank did not exceed 30*l.* The engine, of three-horse power, is used to raise the fluid, and also for churning, grinding oats, chopping hay, pumping water to supply the cattle, &c. The comparatively small extent of land only requires the engine to be occasionally used for irrigation; and, as the surface is flat, and the height to which the liquid manure has to be lifted small, the engine, when in use, is capable of doing the other work of the farm at the same time. The cost of the engine was 60*l.*, and there are two pumps for liquid manure, having 4-inch barrels, and 14-inch stroke, making 25 strokes per minute. The capability of the pumps is therefore about $31\frac{3}{4}$ gallons per minute, or about 19,000 gallons per day of 10 hours. The quantity of the liquid laid on at each application is about 5,000 gallons per acre, so that the whole farm could be covered in 10 days if required, so far as the power of the pumps is concerned. Iron pipes three inches diameter extend from the engine pumps through the fields, laid in the manner already described, and not exceeding in cost the sum of 2*l.* 10*s.* per acre. The hose-pipe is of gutta percha, making a total length of 150 yards, and costing, with the discharge-pipe, about 20*l.* I was informed that the engine is used for irrigation about six hours per week on the average, and therefore the wages of an engine-man and distributor, and the fuel used, would not be due to the irrigation account for more than 31 days out of the 12 months; taking them for that time, the annual amount of working expenses would be about 11*l.* The following appears to be the cost of carrying out the system at Mr. Telfer's farm:—

| | £ | *s.* | *d.* |
|---|---|---|---|
| Tank - - - - - | 30 | 0 | 0 |
| Engine - - - - | 60 | 0 | 0 |
| Iron pipes and hydrants - - | 100 | 0 | 0 |
| Distributing hose-pipe, &c. - - | 20 | 0 | 0 |
| | £210 | 0 | 0 |




REFERENCE. A Standings for two cows each.
B Stone feeding troughs.
C Perforated metal plates, with drain under to receive liquid manure.
D Centre aisle for feeding.
E Side aisles for milking and cleansing.

| | £ | s. | d. |
|---|---|---|---|
| Annual interest on 210*l.*, and wear and tear, at 7½ per cent. - - - | 15 | 15 | 0 |
| Wages and fuel - - - - | 11 | 0 | 0 |
| | £ 26 | 15 | 0 |

This amount, divided by the number of acres, is only 13*s.* 4½*d.* per acre, when spread over the whole 40 acres of land.

The liquid manure is applied to all kinds of crops upon Mr. Telfer's farm; and though Italian rye-grass is the favourite, it is also used for turnips, mangle wurzle, and cabbages, rhubarb, and fruit.

In summer the cows have a quantity of oil-cake, as well as grass; and in winter they have turnips or mangle wurzle, bean or barley meal, and cut hay or grass; the whole mess being steamed together. Miss Bell, the cousin of Mr. Telfer, manages the dairy, and said, that last year the hay bought would amount to from 30*l.* to 40*l.*, and she should think the grain to not less than 200*l.* In general terms, the other food is produced upon the farm. As to the produce of grass, which is the chief article, the first cutting during the present year was in the latter end of March, about 18 inches thick. The second was from 18 inches to 2 feet thick. The third was from 3 feet to 4 feet 6 inches thick. The fourth nearly the same. The fifth was 2 feet thick; and the sixth, in process of cutting at the time I was there, we measured at 18 inches thick. Taking the mean, where two dimensions are given for the same crop, I find the aggregate depth of grass, grown and cut off this farm, within seven months, to be not less than 14 feet 3 inches. All this is, however, eaten upon the premises, and the whole marketable produce of the farm is represented by the milk and butter.

As to the quantity and value of these, Miss Bell stated, that the previous week the butter was 114 lbs. and 120 lbs., — together 234 lbs.; sold at 1*s.* per pound. This, she stated, was about the average quantity and price. The amount for butter would therefore be 11*l.* 14*s.* per week, or, per annum, 608*l.* 8*s.* She informed me further, that during about eight months in the year, the cold milk realizes about the same amount as the butter. In the summer months, during hot weather, the market value of the milk is only about half that of the butter. From these data, the amount for milk sold per annum is 507*l.*

The total receipts for the two articles of milk and butter amount to 1,115*l.* 8*s.* per annum.

I only need to add, that, previously to the adoption of the present system of farming, these 40 acres of land were barely sufficient to support eight or nine cows, and would have been well let at a rental of 30*s.* an acre.

Mr. Ralston's Farm at Leg in Ayrshire.—At this farm the cattle-steadings are fortunately at a much higher altitude than some of the land. I did not ascertain the size of the whole farm, but the public road divides it into two parts. Travelling northward from Maybole towards Ayr the road winds along almost parallel to the seashore ; sometimes at a distance of 500 or 600 yards, and at other times not more than 300. On coming to Mr. Ralston's farm, the buildings and part of the land are on the right hand, while on the left he holds about 40 acres sloping rapidly down towards the beach. It is to these 40 acres that the system of liquid manure fertilisation has been applied. There is no steam-engine at present. Mr. Ralston may ultimately erect one for the higher parts of the farm, but the irrigation is now carried on by gravitation, and with a pressure varying from about 25 to 70 feet. The higher part of the ground is always dressed while the tanks are full. The liquid used is the urine, &c. from the cattle byres, all carefully collected in proper drains, and then conveyed by an earthenware pipe for a distance of about 200 yards, where it is received successively in three circular tanks of brick-work, 18 feet each diameter, and 12 feet deep. The aggregate capacity is rather more than 57,000 gallons. The cost was about 12*l.* each, and the earthenware conveying pipe, and laying, about 25*l.*

From these tanks, iron pipes of three inches diameter, are laid through the 40 acres, at a cost of 2*s.* per yard, and the outlay, in pipage and hydrants, was rather less than 2*l.* 10*s.* per acre.

The mode of distribution is by flexible hose-pipe and jet, the same as at Myer Mill farm, and Canning Park.

The distributing pipes would not exceed 30*l.*, and as a man and boy, at 13*s.* per week wages, would cover the 40 acres in four days, the amount per annum for eight dressings will be only about 3*l.* 10*s.*

The capital account, and working expenses in this case, will stand thus :—

| | £ | *s.* | *d.* |
|---|---|---|---|
| Feeding pipe from byres to tanks - - - | 25 | 0 | 0 |
| Tanks - - - - - - | 36 | 0 | 0 |
| Iron pipes and hydrants - - - | 100 | 0 | 0 |
| Distribution apparatus - - - - | 30 | 0 | 0 |
| | £191 | 0 | 0 |
| Annual interest on 191*l.*, and wear and tear, 7½ per cent. - - - - - - | 14 | 6 | 6 |
| Annual wages - - - - - | 3 | 10 | 0 |
| | £17 | 16 | 6 |

This divided by the number of acres irrigated, is only equal to 8*s.* 11*d.* per acre ; or not more than the cost and application of a ton and a half of solid manure, but producing effects three times greater than an annual top-dressing of 20 tons of such manure.

Mr. Ralston has only occupied the farm three years, and the whole of the arrangements for the application of liquid manure have been made during his brief occupancy. The previous tenant of the farm never had more than 12 stacks in a year. Mr. Ralston had 80 stacks off the same land last year.

Another fact, which I should have been almost ready to doubt, had I not seen it myself, was the mowing of two successive crops of grass, at the same time, in the same field. The field contains, probably, 10 acres. About one fourth from the bottom nine inches thick of grass was being cut,—three fourths of the field having been cut and lead. Near the top, a second mowing was going down, about six inches thick. This was during the present month of October.

New Ark, The Marquis of Ailsa's Property, near Ayr.—At this place about 30 acres have been brought under irrigation recently, in a similar manner to that at Mr. Ralston's farm, by gravitation. I notice it briefly, because the field-pipes from the tanks are all of earthenware, glazed, and made of fire-clay. The work was contracted for, and the contractor was bound to maintain the pipes for 12 months. They were said to have been tested, but gave way, principally at the joints, and never could be got tight under only 30 feet of pressure. The contractor, however, has relaid the whole, and at present they are at work.

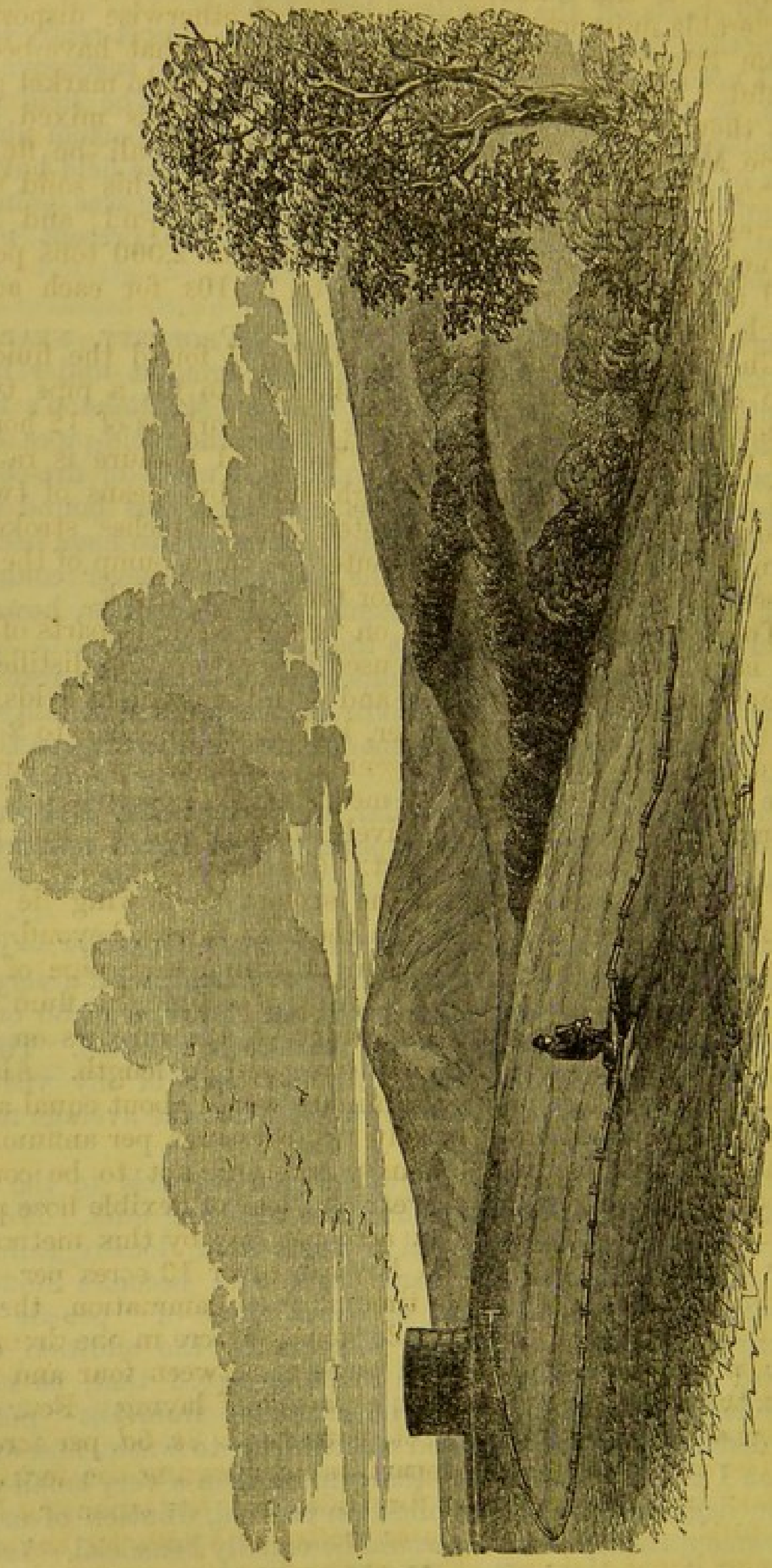
It will be interesting and important to know the result of the experiment,—the causes of failure in the pipes first laid down,—and the means adopted to prevent fracture and leakage in those now in use.

The land here is very similar to that at Mr. Ralston's farm, and a similar result from the application of liquid manure is fully anticipated.

Mr. Robert Harvey's Dairy Farm, near Glasgow.—This farm consists of about 400 acres of cold heavy land, with a very uneven contour, and the highest parts are at an elevation of 80 or 90 feet above the point where the liquid manure is collected. There is no meadow ground on the farm. At the time of my visit to the byres there were about 1,000 cows kept, but the average number is 700.

The urine of these cows flows in open channels to the doors of the byres, and then under ground to a receiving tank. Mr. Harvey has a distillery close by, and a waste fluid, locally called "pot-ale," also flows into the same tank, and becomes mixed with the urine in the proportion of about three of "pot-ale" to one of urine. There is a further dilution by the addition of about a third part of water. It is to be expected that, as nearly as possible, all the virtue would be extracted from the "pot-ale" in the distillery, before the fluid was thrown to waste, and on examination I think it contains nothing more than a very small quantity of mucilage, and that for application to land, dilution of urine with the same quantity of water would be equally beneficial. Indeed, for much of the strong land on Mr. Harvey's farm, urine diluted with water would probably be better.

Until 1844 the liquid drainage from Mr. Harvey's premises



Mode of distributing Liquid Manure by Short Iron Pipes at Mr. Robert Harvey's Farm, Glasgow,
1 Acre per Day.

flowed into the Caledonian Canal, and was complained of as an intolerable nuisance. The necessity of otherwise disposing of it, I am informed, suggested the experiments that have been so successful. For awhile some of the fluid was sold to market gardeners, but they would not take the "pot-ale," unless mixed with cow urine. Mr. Harvey has for a long time retained all the fluid for use on his own farm. He now sells the whole of his solid manure to farmers and others, who are wasting their liquid; and I was informed that the quantity is not less than 2,000 tons per annum, sold at about 6*s.* per ton,—equal to 1*l.* 10*s.* for each acre of the whole farm.

On examining the pumping station I found the fluid running into the tank with a stream sufficient to fill a pipe two inches diameter. The engine is used for other work, is of 12 horse power, and works 18 hours per day. The liquid manure is raised about 100 feet into tanks on the high land, by means of two forcing pumps, each of 5 inches diameter and 18 inches stroke, making from 30 to 35 strokes per minute. A third pump of the same size raises "pot-ale" to the byres for the cows to drink.

The receiving tanks, placed on various elevated parts of the farm, are large vats similar to those used by brewers and distillers. They communicate with each other, and with the different fields, by means of iron pipes 4 inches diameter, laid from 20 inches to 2 feet deep. Hydrants are placed at convenient distances on the iron mains. The mode of distribution by means of short iron pipes, 1½ inches diameter, carried and successively added, will be best illustrated by a sketch made upon the spot. (See preceding page.)

The pipes through which the stream is flowing lie along the ridges—the pipes to be added in the next furrow beyond. The man occupied about half a minute in attaching each pipe of three feet long, and fetching the next. During that time the fluid was pouring out and spreading from the ridge to the furrows on each side, about six yards in width and one yard in length. Allowing for changes, 12 square yards per minute would about equal an acre per day. The ground has generally two dressings per annum.

I think this method a clumsy one, and not to be compensated by any probable amount of wear and tear of flexible hose pipe.

One man can manure an acre per day by this method, but by the hose and jet a man and boy can cover 10 acres per day. According to the flow at the time of my examination, the quantity laid on would be from 30 to 35 tons per acre in one dressing.

The length of underground pipes is between four and five miles, and the cost 2*s.* 3*d.* per yard, exclusive of laying. Four and a half miles at 2*s.* 6*d.* would be 990*l.*, equal to 2*l.* 9*s.* 6*d.* per acre.

The engine power and apparatus for pumping the fertilising fluid would be amply provided for 250*l.*, and the tanks and loose pipes by 210*l.* This would make an outlay of 1,450*l.* for the application of the liquid manure. Two engine-men are employed, one during the day, and another at night. Three men at 10*s.* each per week are employed distributing the fluid on the land. The engine consumes a ton of coals at 2*s.* 6*d.* in 12 hours, making per day 3*s.* 9*d.*

Taking all the wages of engine-men and fuel as applicable to the irrigation, the working account stands as follows :—

| | £ | s. | d. |
|---|---|---|---|
| Annual interest upon 1,450*l*., and wear and tear, 7½ per cent. - - - | 108 | 15 | 0 |
| Two engine-men, each at 20*s*. per week - | 104 | 0 | 0 |
| Three distributors, at 10*s*. each per week - | 78 | 0 | 0 |
| Fuel - - - - - | 58 | 10 | 0 |
| | £ 349 | 5 | 0 |

This, divided by the number of acres, is rather less than 17*s*. 6*d*. per acre annual working expenses.

The operation of the system throws out upon the market solid manure realizing 30*s*. per acre, so that there is a clear annual saving of 12*s*. 6*d*. per acre, over and above the necessary tillage of the farm, and irrespective of the amazing increase in the crops of grass, grain, roots, &c., produced.

The field in which the irrigation was going on at the time of my visit was stubble, from which a heavy crop of wheat had been cut. The land was dressed with the liquid before sowing; and was now being prepared for turnips. For this crop there would be added 16 to 20 loads of the sediment, mixed with ashes until it was sufficiently consistent to be carted.

On this farm the liquid manure is applied with great advantage to all crops. It produces fine oats, wheat, turnips, mangle wurzle, and cabbages, but the greatest effect is in Italian rye-grass. As to the quantity of produce, it was said :—

"We have cut on Pinkston-hill 10 feet of grass this season. The first cut was 4 feet high ; the second was 4 feet and 3 inches; and the third was above 18 inches. I measured it myself."

The fluid is applied immediately after cutting, and if cattle are turned upon it seven or eight days afterward, they eat most greedily, preferring any spots that may have received a larger dose than usual, and leaving entirely any part that may have been missed.

On inquiry at the byres and dairy, I was informed that Mr. Harvey buys most of the hay used ; but he also sells Italian rye-grass, which realises about 18*s*. per ton in the market.

The cows are fed upon the grass, hay, and produce of the farm, and upon the grains of the distillery. Each cow has also a quarter of a stone of bean meal per day.

Sixteen men are employed to feed the stock. Their wages are 12*s*. to 13*s*. per week each. There are 40 milkers, and eight dairy maids, who receive 4*s*. per week each. The cows are milked three times a day. The first and second milkings are sent to market. The third is set up for cream and butter. Churning is done by a horse.

Thirteen carts, each containing six barrels of 10 gallons each, are used to convey the milk to market, where it is sold at 5*d*. the Scotch pint, equal to six pints imperial measure. The income from milk would, therefore, be not less than 43*l*. 6*s*. 8*d*. per day, or 15,816*l*. 13*s*. 4*d*. per annum.

The information as to the quantity of butter was less satisfactory. The head dairymaid said that she had known as much as

100lbs. weight per day, but it fluctuated much, and she had known it as little as 20lbs. per day. At the same rate as the dairy farms in Ayrshire, the quantity of butter on Mr. Harvey's farm, at one meal per day, should range from 100 to 150 pounds weight.

Having seen a work by Mr. William Harley of Glasgow, published in 1829, on an improved management of dairy farming practised by him in that city, and its beneficial results, I made inquiry, and received the following information, showing the extreme backwardness of farmers in adopting improvements carried on even under their own eyes. My informant said :—

"I have heard of Harley's farm. His byres were in the town of Glasgow. He was one of the most extensive dairy farmers about here, and made a great deal of butter. He died more than 10 years ago. I do not know that any persons adopted his plan, unless it was Mr. Harvey himself. I do not think there is anybody about Glasgow who has adopted the irrigation system besides Mr. Harvey, unless it be on a very small scale.

"Mr. Harvey sells his solid manure to persons that have land, and ought to use liquid manure the same as he does. There have been some looking to the working of the plans he has laid down, but they have none of them adopted it, that I know of."

I have said much in commendation of the enterprise of Mr. Harvey, and the success of his arrangements. I am compelled, however, to add, that I perceived a considerable stench, both about the pumping establishment and the elevated tanks on the farm. This I attribute to the want of dilution with water. If two or three times the present bulk of water were added, and the fluid laid on more frequently, stench would be almost entirely avoided, and my experience brings me to the conclusion that a still higher state of fertility would be attained.

I have already said that the distribution by short metal pipes is attended with great loss of time, the labour being 10 times more than is necessary.

The byres, tanks, and other arrangements are of a rude kind, and there is a general want of tidiness about everything and place, except the dairy; such as to prevent one from pointing out the establishment as a model to be imitated.

There cannot be a doubt, however, that Mr. Harvey has effected great good by his efforts, or that the pecuniary result is highly satisfactory.

The Duke of Sutherland's Home Farm at Hanchurch, near Trentham, Staffordshire.—Some very important works have been lately constructed by his Grace the Duke of Sutherland, for collecting and distributing liquid manure at Hanchurch.

Nearly all the farm-buildings have been rebuilt on improved principles of water supply, drainage, and sewage application ; in other words, on sanitary principles.

A new cow-byre to accommodate 40 feeding cattle has under it, for the whole length, a narrow tank formed of bricks, and arched over, with trapped openings to receive all the urine and other liquid refuse from the horned cattle, and from 120 sheep contained in a room over the cows.

The result of my experience is, that a feeding bullock gives 10 gallons of urine daily, and that three sheep may be taken as equal to one bullock. Without any dilution, therefore, the stock in this building will produce 800 gallons of liquid daily. The washings of the floors would also liquify a quantity of the solid excrement of the cattle, so as to produce 200 gallons more, and this 1,000 gallons, diluted with three times its own bulk of water, would be sufficient for one application, with the hose and jet pipe, to an acre of land. Six to eight such applications will produce annually six crops of Italian rye-grass, averaging about two feet thick each, upon well-drained land.

I have been induced to digress, in order to bring into one view the data upon which it seems to me that such arrangements may safely be based, so that the size of tanks, the power of steam engine and pumps, the quantity of stock, and the number of acres irrigated, may all be adapted to each other, so as to yield a certain amount of produce, which may be ordinarily expected, without any material reference to the mineralogical character of the soil.

The tank at Hanchurch is capable of containing 20,000 gallons; but I did not hear upon what basis its size had been determined. A second tank is to be constructed to hold 25,000 gallons.

The farm contains 300 acres; but the iron pipage is only at present intended for about 83 acres contiguous to and surrounding the farm-buildings.

Besides the 40 feeding cattle already named, there will be room for eight more horned cattle, and 40 head of young stock. There are 12 horses and 15 pigs kept.

The drainage of all the buildings, including the house in which Mr. Dodd, the farm-bailiff, resides, will go into the manure tanks; and it is intended to water the solid manure, and run the washings into the tanks.

The steam engine is of 12-horse power, high pressure, and there are two pumps of five inches diameter each. The engine is used for grinding corn, cutting, crushing, chopping, thrashing, churning, pumping water, and all other purposes to which an engine can be usefully applied upon a farm. Scarcely one-sixth of the power of the engine will be required for the irrigation of the 83 acres of land, and that only at intervals.

The engine was estimated to cost 15*l.* per horse power, but some extras have increased the total amount to 250*l.* The pumps have been put down for 70*l.* The tank already finished has from local circumstances been more expensive than would generally be the case, having cost 90*l.* Wm. Steward, Esquire, the resident agent of the Duke of Sutherland, informed me that the weather was very unfavourable while the work was going on, and a rock had to be penetrated which was so hard as to require blasting. At the same rate the cost of the second tank, to contain 25,000 gallons, will be 110*l.* The two together being 200*l.* The 3-inch iron pipage is stated at 3*l.* per acre. There is only to be added, 200 yards of flexible hose-pipe of gutta percha, at 2*s.* per yard, and the capital account will stand as follows:—

| | £ | s. | d. |
|---|---|---|---|
| One sixth cost of steam-engine - - - | 41 | 13 | 4 |
| Two tanks, containing 45,000 gallons - - | 200 | 0 | 0 |
| Two steam pumps - - - - | 70 | 0 | 0 |
| Iron pipes, and laying - - - - | 189 | 0 | 0 |
| Hose-pipe - - - - - | 20 | 0 | 0 |
| | £520 | 13 | 4 |

The consumption of coal will not exceed 10 cwt. per day, at 6*s* per ton; and if the irrigation works be debited with one sixth of this, the annual amount would be 7*l.* 16*s.*

A man and a boy can irrigate 10 acres per day, and if employed a day each week, or one sixth of their time, as allowed for the engines, the land would get more than six applications per annum. At 1*s.* 9*d.* per day for a man, and 9*d.* for a boy, the wages would amount to the annual sum of 10*l.* 10*s.*

Allowing $7\frac{1}{2}$ per cent. upon the capital expended for interest and wear and tear, the following will be the annual charges as the cost of this instance of fertilization by liquid manures :—

| | £ | s. | d. |
|---|---|---|---|
| Annual interest, &c. upon 520*l.* 13*s.* 4*d.* at $7\frac{1}{2}$ per cent. - - - - - | 39 | 1 | 0 |
| Fuel - - - - - - | 7 | 16 | 0 |
| Wages - - - - - - | 10 | 10 | 0 |
| | £ 57 | 7 | 0 |

This amount, divided by the number of acres irrigated, will be equal to 13*s.* $9\frac{3}{4}$*d.* per acre per annum.

It will be seen that the amount is larger than in several other instances of pipe distribution, but that is attributable to the extraordinary circumstances connected with the construction of tanks sufficient for the fertilisation of 300 acres, while the pipes are at present limited to 83 acres.

I have been enabled to collect the different items showing the capital account and working expenses here, and the result is very satisfactory, as compared with any other mode of manuring; but the arrangements being scarcely completed, I cannot quote facts showing any increased fertility fairly due to the system of pipe distribution. Some fields have been irrigated with water in open gutters, and I believe that liquid manure has been applied upon parts of the farm, by carts, with great advantage, but in the present state of transition from one mode to another I think it better not to confound the results of the various operations, nor to attribute to the pipe and hose system that to which it may not be properly entitled.

From my examination of the works, however, and from a comparison with what I have seen elsewhere, I have not the slightest doubt that the operations will be highly successful; and that his Grace the Duke of Sutherland will, in a very short time, find that he has effected a most profitable investment. Liquid manures are highly valued in the district, and I have in my former report quoted briefly some facts as to the use of the sewerage waters from the borough of Newcastle-under-Lyme. The works at his Grace's home farm will therefore be looked to with much interest, and will probably lead to still more extensive operations in connexion with the Local Board of Health in that town.

Mr. William Machin, Clayton Farm.—I may briefly mention this as an instance in the same locality, illustrating what I have said above as to the growing conviction of the superiority of liquid manures.

This farm consists of 120 acres, and is 2 miles south of Newcastle-under-Lyme; about half way between that town and Trentham.

A large covered tank has been constructed, into which the stables, cow-houses, and solid manure pit, drain by pipes. The piggeries and farm-house are also about to be drained in the same manner. A pump is put down into the tank, and the liquid pumped into a cart, and so applied to the land; but there is a meadow below the farm-yard to which it has been applied by gutters, fed by a pipe with the overflow of the tank.

I examined the meadow, which consists of only two acres, and was informed that the liquid manure had not been applied since last March, but that shortly after the application 15 sheep and nearly 30 lambs were turned on for a month; in July a crop of hay was cut making about 3½ tons, at the market price of 3*l.* 10*s.* per ton; and in August the milk cows were turned in daily to graze, and it has produced them, and occasionally a few sheep in addition, sufficient food to the present time. The liquid manure was about to be applied again at the time of my visit.

On another part of the same farm one application of liquid manure by the cart has this year produced three good crops of clover.

Halewood Farm near Liverpool.—This is a farm of about 350 acres, eight miles east of Liverpool, held by Robert Neilson, Esquire, on lease under the Earl of Derby. About 120 acres of the land are fertilized with liquid manure, applied by steam engine, iron pipes, and hose and jet, and the extension of the system to the whole farm by additional tanks and pipes is fully intended. The geological formation is the new red sandstone All the farm has been drained not less than 3 feet deep, and 9 yards apart, with tiles and soles.

Mr. Neilson, who is also a merchant in Liverpool, has a taste for mechanics, and has been his own engineer. Having been among the first in this country to adopt what may, in its fullest sense, be called "farming by machinery," his establishment bears evidence of such improvements as have been from time to time suggested by experience. I have not seen anywhere so many contrivances to facilitate and perfect the various operations going on.

The steam engine was originally of 10-horse power, but it has been improved so that it can be worked up to 15 horses. It pumps water for the house and all the farm-buildings and stock, for washing and cleansing all the premises, and even for washing the cattle by hose and jet. The same means are used to liquify solid manure. The engine thrashes the corn, cuts hay and straw, grinds beans, crushes oats, churns, cuts turnips and mangle wurzles, and grinds corn, not only for the establishment, but for about 7 horses kept at Liverpool. It dilutes, mixes, and agitates the liquid manure in the tank, and forces it out for application to the land. Mr. Neilson has gasworks in the farm-yard for lighting the establishment, and all the tar and ammonia water, &c. is drained into the manure tank. Tram-roads are laid down, to facilitate the conveyance of food and the removal of solid manure; and the man who attends the engine is a blacksmith, employed upon the premises in shoeing horses and repairing all the farming implements. I might go on; but further notice of these numerous economical arrangements would lead me away from the main object of this report.

The steam engine is of high pressure, and cost originally about 150*l.*, but with the additions is worth 200*l.* The cylinder is 12 inches diameter, and 20-inch stroke. The steam was got up in order that I might see the application of the liquid manure by the jet, and it made 55 strokes per minute at 15 lbs. pressure on the square inch. At that speed it consumes only 5 cwt. of small coal in 12 hours. The coal costs 5*s.* per ton.

The two pumps are outside the engine house, and are worked by a beam. They are 8 inches diameter, with 24 inches stroke, and make 12 strokes per minute when the engine makes 55 strokes. At full speed the force of the pumps is equal to a column 300 feet high. At the time of my visit, the quantity of liquid manure discharged was only about 3,000 gallons per hour, while the pumps are equal to a discharge of 10,500 gallons per hour. These pumps were made by Mr. Michael Neville, Great Charlotte Street, Liverpool, and cost 78*l.*

The tank is built of brick, and is $18 \times 18 \times 24$ feet inside, giving a capacity equal to 48,460 gallons. It cost 135*l.* complete.

Earthenware pipes from Prescot were tried at first, but they burst, especially at the sockets. They have all been taken out, and replaced by iron.

The iron pipes for conveying the manure to the land are 3 inches diameter, jointed with cement. They were purchased by Mr. Neilson from the water company, and cost, including leading, laying, and jointing, rather less than 1*s.* 6*d.* per yard. There is a sluice cock, costing 2*l.* 17*s.* 6*d.*, and a hydrant, costing 1*l.* for every length of 200 yards of iron pipe, and at those distances a man and a boy can fertilise 9 acres per day with 100 yards of hose. The account, therefore, for pipes, sluices, and hydrants will be about 2*l.* 2*s.* per acre. The cement joints begin to weep with a pressure of 500 lbs., and burst at 760 lbs.

Mr. Neilson has tried numerous experiments with hosepipe, the result of which is a preference for that of gutta percha. He first had 100 yards of 2 inches diameter, made of canvas, without any previous preparation of the materials, by a person in the neighbourhood. This could be used with the hand pumps, but burst when attached to the steam pumps. That was four or five years ago, and there is only about 30 yards of it remaining now. Twelve months ago Mr. Neilson got about 200 yards of india rubber 2-inch pipe at 3*s.* 9*d.* per foot, but it was found to leak at the points where it was attached to the metal to form a union joint. Gutta percha has since been substituted at the joints, and now the india rubber pipe stands the pressure. At present only 50 yards of gutta percha hose is used, but as the india rubber becomes worn out or destroyed it is intended to replace it entirely with gutta percha. The cost of the latter, 2 inches diameter, is about 2*s.* 6*d.* per yard.

The discharge pipe used at the time of my visit had a flattened orifice, so as to distribute the manure in a thin sheet, and it fell within a short distance of the man in charge of it. I was informed, however, that it can be applied with a jet extending to a distance of 60 feet.

Mr. Neilson's bailiff said that a very small part of the engine-power was used for manuring.

"We scarcely ever use the engine for that purpose, except when it is doing other work, and it does not work at all more than about two days per week on the average."

This was afterwards fully corroborated by Mr. Neilson himself, who said that they had never yet used 3-horse pressure upon the pumps.

In stating, therefore, the capital account and working expenses, it will be necessary to make deductions for the time when the engine is not working, and also when it is engaged in its other multifarious duties. On these considerations, one ninth of the power and fuel would be a liberal allowance for the liquid manuring.

As 100 yards of flexible hose is required, and the india rubber is being displaced by gutta percha, I think it fair to allow equal quantities of each.

The capital account then would stand as follows :—

| | £ | *s.* | *d.* |
|---|---|---|---|
| Proportion of steam-engine - - - | 22 | 4 | 6 |
| Tank complete - - - | 135 | 0 | 0 |
| Pumps - - - - | 78 | 0 | 0 |
| Iron pipes, and laying - - | 252 | 0 | 0 |
| India rubber hose, 50 yards, at 11*s.* 3*d.* | 28 | 2 | 6 |
| Gutta percha hose, 50 yards, at 2*s.* 6*d.* | 6 | 5 | 0 |
| | £521 | 12 | 0 |

Mr. Neilson said that in round numbers the works had cost him 4*l.* per acre, and the above statement, made upon a careful analysis of the details, shows the accuracy of his estimate. The amount, divided by the number of acres brought under the jet, is equal to 4*l.* 6*s.* 11*d.* per acre.

The engine-power, tank, pumps, and hose being already provided, the contemplated extension of the system will be little more than a matter of pipeage and labour, reducing considerably the average cost per acre of the whole.

There is a man to attend to the engine, but that occupies very little of his time ; I was informed not more than half a day per week. He is the blacksmith, already named, who does all the shoeing and iron-work of the farm. Two shillings per week would therefore be much more than was due to the irrigation works ; but the amount is so small as not to be worth dividing.

A man and a boy distribute the manure, their wages being respectively 1*s*. 9*d*. and 10*d*. If we allow them to be so engaged two days per week, which is the whole time the engine is working, they would give more than seven applications in the year to the whole 120 acres, at an annual cost for labour of 12*l*. 18*s*. 8*d*.

The interest and working expenses may therefore be drawn out as follows :—

| | £ | s. | d. |
|---|---|---|---|
| Annual interest upon 521*l*. 12*s*., and wear and tear, at $7\frac{1}{2}$ per cent. - - - - | 39 | 2 | 5 |
| Fuel and engine man - - - | 6 | 16 | 6 |
| Wages for distribution - - - | 12 | 18 | 8 |
| | £58 | 17 | 7 |

This amount, divided by the number of acres, gives only 9*s*. $9\frac{3}{4}$*d*. per acre as the cost of a state of fertility stated to be equal to about 30 tons of farm-yard manure, the filling, carting, spreading, and harrowing of which quantity has been proved to be not less than 2*l*. 10*s*.

About a month previously to my visit, Mr. Neilson had sold the greater part of his live stock ; but on inquiring as to the average quantity kept, and contributing to the manure tank, I was informed that the usual number was 45 to 50 milk cows, 150 to 200 pigs, and 10 horses. All the stables, cowhouses, piggeries, dwelling-house, gaswork, and pit for solid manure, drain into the tank.

The dungheap is about 50 feet by 60 feet, and 8 or 9 feet thick. Close by it is a hydrant and about 30 yards of india rubber hose. A man gets upon the dungheap with a large three-grained hook or drag, and turns up the solid manure, while another applies a powerful jet of clean water upon the heap, and liquifies it. The stream percolates through, and drains into the tank a strong solution of manure.

The following illustration of sanitary principles, as applied to a farming establishment, I took down from Mr. Neilson, and give in his own words. Added to what has been already stated, it will be seen that he comprehends a constant supply of good water ; perfect under-ground drainage ; systematic surface cleansing by the hose and jet ; cleanliness of the dwellings, bedding, and skin, even of animals inferior to man ; the removal, liquefaction, and dilution of all organic refuse and manures ; the application of such liquid refuse and manures to the land ; the production of abundance of food for man and beast ; and a capacity in both, by the security of good health, to enjoy the food so provided.

He says,—

"A branch from the suction-pipe of the engine is led into a reservoir holding about 300,000 gallons, fed by a running stream. This gives abundance of good water to the whole establishment. A branch from the rising main enters the manure tank, and proceeds along the whole of the bottom of it, perforated with quarter inch holes. By a simple arrangement of stopcocks, when the tank has been emptied of liquid manure it can be filled with fresh water, which is discharged with such force as to stir up any sediment that may remain there. By throwing guano, soot, salt, or any soluble manure into the tank, the whole may be mixed with water in a similar manner, and at once applied to the land. By the same means the liquid manure may be stirred into agitation before it is pumped up, as by a slight alteration of the stop-cock it may be sucked from and discharged into the tank by each revolution of the pump. This I have found in practice to be extremely beneficial.

"In a similar manner a solution of lime may be added.

"When litter for the cattle is chopped up, it mixes readily with the dung, and rapidly decomposes. Twenty-four hours after a heap has been turned over, considerable fermentation has taken place, and if the stream of fresh water described above, instead of being diverted into the tank, is thrown over, and percolates this heap of dung, it becomes a valuable top dressing. It is found by experience that the whole mass may, by a repetition of the process, be applied as soluble manure.

"Nothing disturbs the fly on turnips more than a shower of muck water.

"During this summer I fed from 150 to 200 pigs, and they derived great benefit, especially during the hot weather, from being washed two or three times per week by fresh water drawn from the reservoir, and forced upon them by the steam pumps and jet. They got to like it so much that they would lean towards the jet of water, and when one side was washed would turn round and expose the other, so that their enjoyment was quite amusing.

"The fresh water jet has also enabled me to keep the shippons and every part of the yard and premises so clean that any one might have eaten off the floors. The washings were all added to the stock of liquid manure that went to the land, while the process secured and increased the health of the whole establishment.

"I consider that this may be made a landlord's question as to the first outlay, and that the result would leave an ample profit to the tenant-farmer, after paying his landlord 20 per cent. per annum for the investment."

With respect to the increased quantity and value of the crops from the application of manures in a liquid form, it has been used upon Halewood Farm almost entirely for turnips and Italian rye grass. I was informed that a piece of Swede turnips had no other manure than an application of liquid. The crop was very fine and good. Another piece of turnips had from 25 to 30 tons of farm-yard manure per acre, and the crops on the two were about equal.

There are about 42 acres of rye grass under the jet, and at the time of my visit the fifth crop since April was being cut. The first was about 18 inches thick; the second, 24 inches; the third and the fourth the same each; and the fifth about 12 inches. Total, 8 feet 6 inches, in seven months. The grass was still growing, and I found a good pasture where the fifth crop had been cut a week previously, although the frost had been severe during the interval. I was informed, that for grazing sheep it will always be good and fresh throughout the winter.

The farm bailiff says, that they find the land improving rapidly, and that the results are far greater than any solid manure would give. The process being nearly new, two applications are given after each cutting; but they expect that in a year or two the land will require a less quantity, and the crops will be still more abundant.

Liscard Farm, near Birkenhead.—This farm is situated about four miles westward of Birkenhead in the county of Chester, and contains altogether about 450 acres, 350 of which belong to Harold Littledale, Esq., the occupier, and the remainder, rented by him, consists of low poor land of comparatively little value.

The geological stratum is the lower new red sandstone, with a combination of diluvial drift, and the alluvium of the estuary of the Mersey.

Mr. Littledale has drained all the land capable of being drained. Both pipes and tiles have been used. Some of the drains are laid only 2½ feet deep, others 4 feet, and, latterly the depth has been 5 feet. The depth has been increased as the result of experience. The widths apart vary from 6 to 9 yards. The average would be about 7 yards. The cost was 4*l.* to 5*l.* per acre.

The arrangements for collecting and applying liquid manure are similar to those in Ayrshire, and Mr. Young, the engine-maker, of Ayr, has been employed in the construction of the works.

The tank is 60 feet long, 12 feet wide, and 13 feet deep, furnished with lever agitators, similar to those at Myer Mill Farm. The capacity of the tank is equal to 58,300 gallons, and the cost about 200*l.*

The steam engine is of 10-horse power, high pressure. The cylinder is 10 inches diameter, with a 30-inch stroke. At the time of my visit it was working 43 strokes per minute, with a pressure of 28 lbs. on the square inch. At full speed it works 60 strokes per minute. The original cost was 80*l.*; but it has been improved and altered, so that its present value may be stated at 150*l.* As in the other instances brought before you, this engine chops, grinds, crushes, steams, thrashes, churns, pumps water, and does all the farming work capable of being performed by machinery, in addition to the pumping and forcing of liquid manure.

Mr. Littledale's bailiff, Mr. Teasdale, said, that the engine cannot perform all these operations at the same time; but that the irrigation, when it is going on, scarcely requires four-horse power. As to the time occupied for this part of its work, I was informed that a blacksmith does all the shoeing, repairing, and ironwork of the farm, besides attending to the engine. The latter does not take up one-third of his time, as the engine only works two days in the week. It was also said that one day per week would be a liberal allowance for manuring. The wages paid to this man are 26*s.* weekly, and four tenths of one day would give 1*s.* 9*d.* as the weekly sum due to the irrigation. The distribution is conducted by a man and a boy, whose united wages are 20*s.* weekly. One day to the irrigation will be 3*s.* 4*d.* per week.

The engine, when working, consumes 10 cwt. of coals per day of ten hours, at a cost of 8*s.* per ton. The proportionate sum per week, therefore, due to the irrigation works for coals is 1*s.* 8*d.*

There are two pumps, each 4½ inches diameter, with 24-inch stroke, and working 25 strokes per minute. At this rate of working they are capable of raising 41,154 gallons per day of 10 hours. The cost of the pumps would be about 70*l*.

The liquid manure is conveyed by iron pipes 3 inches diameter, and the present extent is about 2 miles, serving for 150 acres. The pipes have been brought from Scotland, and the cost, including laying, is 1*s*. 9½*d*. per yard. There is a hydrant for every 300 yards of main, and the cost of each is 18*s*. The hydrants are so fixed that with 150 yards of hose the distributor and boy can irrigate 10 acres per day. This being an acre per hour, a reference to the quantity pumped will give 4,115 gallons per acre for each application.

The hose pipe is of gutta percha, and consists of 75 yards, 2 inches diameter, costing 2*s*. 6*d*. per yard, and 75 yards 1½ inch diameter, costing 2*s*. per yard.

The liquid manure is now sent out to a distance of half a mile, and the jet from a circular orifice of an inch in the discharge pipe will rise nearly 30 yards high, and falls like a shower at a distance of 25 yards from the distributor.

Mr. Littledale intends to have another tank of the same size as the one already constructed, so as always to have plenty of liquid manure in spring.

Following the course I have pursued throughout these investigations, I now proceed to draw out Mr. Littledale's capital account for the irrigation.

| | £ | s. | d. |
|---|---|---|---|
| Tank - - - - - | 200 | 0 | 0 |
| Proportion of steam-engine - - | 60 | 0 | 0 |
| Two pumps - - - - | 70 | 0 | 0 |
| Iron pipes - - - - | 315 | 6 | 4 |
| Hydrants . - - - - | 9 | 18 | 0 |
| 75 yards of 2-inch gutta percha hose - | 9 | 7 | 6 |
| 75 yards of 1½-inch ditto - - - | 7 | 10 | 0 |
| | £ 672 | 1 | 10 |

From the data already ascertained, the following will be the annual account for interest and working expenses :—

| | £ | s. | d. |
|---|---|---|---|
| Interest upon 672*l*., and wear and tear, at 7½ per cent. - - - - | 50 | 8 | 0 |
| Fuel due to irrigation - - - | 4 | 6 | 8 |
| Wages - - - - - | 13 | 4 | 4 |
| | £ 67 | 19 | 0 |

Divided by 150, the number of acres irrigated, the amount is equal to an average of 9*s*. 0¾*d*. per acre.

This mode of fertilising has not been long in operation at Liscard Farm, but liquid manures have been for a considerable time applied there by the more expensive and clumsy method of carting on the land. Like the Duke of Sutherland's, therefore, this farm is in a transition state, and I would not claim for the specific mode of application a degree of fertility that is primarily due to the nature of the fluid laid on. The liquid manure used being the same, however, in both methods of application, it is fair to conclude that an equal quantity laid on evenly, without poaching the land, would be at least as productive as if distributed from a cart.

The cost of the various modes of applying manures may be considered distinctly from the productive results; and the works being already in operation in this instance, I am able to state the outlay and working expenses as accurately as if the economy had been tested by the experience of years, instead of months.

It is exceedingly interesting to review occasionally the progress made in matters of public and national importance, and, after looking back at the original views of the promulgators of new doctrines in social economy, to see how far those views have proved correct, or have become modified by experience. About ten years ago Mr. Chadwick, recommending the collection of all fertilising matters in tanks, wrote,—

"The mode of emptying by a pump and hose, whatever may be the distance required for the conveyance of the manure, will be found to be much cheaper than the water-cart. With the hose the refuse may be got on to gardens, lawns, and places where the cart cannot go, and may be got at all times. With the force-pump it may be carried to all heights under 120 or 130 feet, and the hose may extend to half a mile or three quarters of a mile or more. Within such lifts as seven or eight feet, and over all descents, the labour of pumping which would be required to get the liquid manure into a water-cart would with the hose convey it to a considerable distance."

According to the estimates already given, the expense in fuel and labour for the distribution of 4,115 gallons of liquid manure by the hose and jet would be 8*d.* The quantity is equal to 20 loads, and the distribution by water-cart, including the pumping from the tank, carrying half a mile, and laying on, would cost 8*d.* for a load, or 13*s.* 4*d.* for 4,115 gallons.

I have stated elsewhere that the liquid manure produced a crop of Swede turnips equal to that produced by 25 to 30 tons of solid manure, which cost about 2*l.* 10*s.* for application. I need not therefore waste time by any further remarks on the comparative economy of laying on liquid versus solid. The facts are self-evident.

Mr. Littledale has had the farm about 11 years, and has erected all the present buildings, including a lodge, a house for the bailiff, and 8 cottages for the labourers.

A million of bricks were made out of two old marlpits close by, and the excavation was then converted into a water reservoir for the whole establishment. All the spouts of the buildings run into it. The water is pumped by the engine into a raised cistern of wrought iron, holding 10,000 gallons, and thence distributed by taps. The bailiff says the water is good and abundant, and now that they have got a large manure tank, they intend to apply water to the solid manure to liquify it.

The present live stock yielding manure consists of 81 milk cows, 2 bulls, nearly 100 pigs, and 12 horses. All the liquid from the stables, cowhouses, piggeries, yards, cottages, and the bailiff's house, drains underground to the tank.

As the general result of drainage, liquid manures, and other improvements effected by Mr. Littledale, I was informed that the yield of the whole farm is double what it was 10 years ago.

The liquid manure has been hitherto applied to nothing but grass. It is intended now, however, to apply it to other crops.

My informant said,—

"We have now 80 acres of Italian rye grass, and look to it first for food for the cows. We buy nothing for the cattle but malt grains, the annual account for which is about 130*l*. We sell a portion of the turnips at times, but shall have none to spare this year. We also sell some potatoes and straw, but generally the crops are consumed on the farm."

The Italian rye grass has had none but liquid manure, and has been cut three and four times during the summer and autumn. The crops averaged from 2½ feet to 3 feet thick each cutting. The fourth crop from one piece was weighed, and produced 10 tons per acre. That was the least of the four crops from the same land, but the whole produce of that piece was above the average.

Many calves are sold, but the value of young stock is low in the market, and I could not ascertain the sum realised.

From 50 to 60 pigs are killed per annum. Some few are sold as pork, but the greater part is made into bacon. The average weight is about 20 stones each, and the bacon sells wholesale at 7*d*. and the hams at 9*d*. per pound.

Two hundred gallons of milk per day, on the average, are sold to New Brighton and Seacombe, at one shilling per gallon.

The butter averages 180 pounds per week, and sells at 1*s*. 2*d*. per pound.

Taking the bacon and hams at 7½*d*. per lb. on the average, the annual produce of the farm in these three items alone is as follows:

| | £ | *s.* | *d.* |
|---|---|---|---|
| Bacon - - - - | 481 | 5 | 0 |
| Milk - - - - | 3,650 | 0 | 0 |
| Butter - - - - - | 546 | 0 | 0 |
| | £ 4,677 | 5 | 0 |

The farms occupied by Mr. Littledale and Mr. Neilson are 10 miles from each other, in a district very favourable for agricultural improvements, and within accessible distance from an immense population.

It might reasonably have been expected, therefore, that these examples would have induced a spirit of emulation throughout the district, and that steam engines and liquid manure tanks, &c. would have been almost as numerous as the farms.

I made inquiry, and found, that although the modes of farming have improved within the last 10 years, there is still very little of what is called high farming in the neighbourhood. The farms in general are small, and few are disposed to copy the examples set before them by Mr. Littledale and Mr. Neilson. I could only hear of one other steam engine, five miles distant from Mr. Littledale's farm, used for any agricultural purpose.

Porth Kerry Farm, Glamorganshire.—This is a home farm, consisting of about 300 acres, on the estate of the Messrs. Romilly, and in the occupation of one of the landlords, about 10 miles south-west of Cardiff, on the north shore of the Bristol channel.

The geological formation is the blue lias limestone, but it is covered mostly with a heavy cold subsoil, and the average rental of land in the neighbourhood is only from 7*s*. to 15*s*. per acre.

The surface is very hilly; the house is about 100 feet above the sea, and close to it, while some of the meadows about 150 yards distant, are not above high tide. The farm is about a mile inland, and some parts probably 200 feet above the sea.

At the bottom of the wood in which the house stands, there is a small tank built of stone, and covered over. It receives all the drainage and washings of the house, stables, and laundry, conveyed in earthenware pipes of 6 inches diameter, manufactured by Doulton & Co. of Lambeth. The tank is 24 × 7 × 6 feet, equal to 6,280 gallons. The liquid is raised by a hand-pump, and distributed by a gutta percha hose and jet pipe upon the meadow. The area reached in this way is, however, very limited. The meadow is about 32 acres in extent, and the herbage coarse and sour; its drainage is capable of improvement; and it would be a profitable investment to construct another tank higher up the hill, and from it to lay an iron pipe along the centre of the meadow, with hydrants, and a sufficient length of hose to bring the whole under the operation of the jet. The house drainage would not be sufficient for this purpose, but farm-yard litter, or guano, or other solid manure, might be liquified in the tank, and I have no doubt, after what I have seen in all parts of the country, that these meadows would in a short time support at least two bullocks to the acre. The rank sour produce would disappear, and give place, as at Edinburgh, Clipstone, Pusey, and other places, to a fine silky and nutritious grass. Mr. Alexander Fergus is the resident bailiff of Mr. Romilly, and informs me, that within reach of the pipes the fertility was greatly increased, but being only a small part of the 32 acres, he could not give the extra crops and stock fed. Immediately after irrigation the cattle will not feed upon it, but in a while they select and prefer the part that has been irrigated.

The principal operations with liquid manure have been at the farm. The works were partially completed in October 1849, and the liquid manure began to be systematically applied in the spring of 1850. At present, only 27 acres are under irrigation, but it is intended to lay down additional pipes, so as to irrigate 100 acres; and the pipes for 23 additional acres are upon the spot, and included in the statement of capital expended. The storage is calculated for a much more extensive application. There is first an open fresh-water tank supplied by land drainage, and holding about 56,000 gallons. There are three collecting tanks, and one for mixing. The following are their separate and aggregate dimensions:—

| ft. in. | | ft. in. | | ft. in. | | gallons |
|---|---|---|---|---|---|---|
| 13 3 | × | 7 0 | × | 6 6 | = | 3,855 |
| 31 3 | × | 7 0 | × | 6 0 | = | 8,703 |
| 46 6 | × | 7 0 | × | 6 0 | = | 12,171 |
| 22 1 | × | 7 0 | × | 6 0 | = | 6,781 |
| | | | | Total | - | 31,510 |

There is no steam-engine upon the farm; the present application is entirely by gravitation. Sluices are put down in the tanks, and when those are drawn in the fresh-water tank, and one of the collecting-tanks, the streams flow into a mixing-tank, and thence through iron pipes to the fields to be irrigated. In these fields Guest and Chrimes's patent firecocks are put down as hydrants at distances of 120 yards, and the distribution is by 60 feet of gutta percha hose, and a jet pipe with a flattened orifice, to discharge the stream in a thin sheet.

The whole of the apparatus, including tanks, pipes for 50 acres, hose, &c., cost about 300*l.* By reference to the aggregate capacity of the tanks, it will be found that they exceed those at Myer Mill, which are capable of fertilising above 500 English acres of land; and it would be therefore manifestly unjust in this case, where the pipes have only yet been provided for 50 acres, to distribute the whole of the storage over so small an area, and then compare it with other instances of *pipe* irrigation. Notwithstanding these disadvantages, however, I find it cheaper than the open gutter system. The capital, including all the tanks, only amounts to 6*l.* per acre; making a yearly charge, at 7½ per cent., of 9*s.* per acre.

Mr. Fergus says, the stock upon the farm, producing the liquid manure, is on the average, 36 dry and feeding cattle, 210 sheep, 9 working horses, 1 hack, 4 or 5 young horses, and 20 or 30 pigs. No houses contribute to the liquid manure, but all the cattle-steadings, stables, piggeries, and other farm buildings, and the percolations from the solid manure heap, goes into the liquid manure tanks.

My informant said, that one man whose wages are 2*s.* per day can empty the mixing-tank twice in a day, and in so doing will go over four acres. The quantity, therefore, laid on per day would be 7,710 gallons, say 8,000, equal to 3*d.* per 1,000. The working expenses are confined to the wages of this man, and the amount for each application would therefore be 6*d.* per acre. Eight applications per annum would be 4*s.*; which, added to the interest on capital, would make the present total charges 13*s.* per acre; every extension of the pipes will reduce this amount. The pressure is very little, and the jet issuing from the discharge-pipe does not reach more than 15 feet from the waterman. The application at Porth Kerry would be very much improved by the erection of a steam-engine, the extension of the iron pipes, and the use of a wider and longer hose pipe.

The land (the soil of which is only 12 inches deep on an average,) is underdrained with stones 2½ feet deep, and 12 feet apart. The stone was obtained on the farm.

In the month of December, and with a hazy atmosphere, the journey from Cardiff to Porth Kerry is dreary to any one travelling alone. The roads narrow and heavy,—the woods leafless and gloomy,—and the general aspect of vegetation in the fields brown and inactive. After a drive of nearly two hours, I saw, at a distance of nearly a mile, a large grass field of a most beautiful green colour. The contrast to everything upon which the eye had rested for many miles conveyed more pleasure than I had previously conceived possible from so simple a fact. I knew at once, that, at this season of the year, nothing but irrigation could clothe the surface with such verdure, and needed nothing else to direct me to Mr. Romilly's farm. I afterwards walked over that field, and saw the fertiliser—the jet—in operation. Observing that the blades of grass had been cropped off, I asked if sheep had been turned on, and was surprised to learn that it was only sown with Italian rye grass in September last. Game is preserved in the neighbourhood, and this field is a centre of attraction now for the hares, who come from considerable distances all round to feed upon its delicate and nutritious herbage. They had done ample justice to the productive powers of the liquid manure.

In 1850, Mr. Romilly applied the liquid to 25 acres of turnips, mixing it with about 2 cwt. of guano to the acre. About 12 loads of farm-yard dung per acre had been previously ploughed in. My informant states, that the crop was a very good one,—almost the best they have had on the farm,—the soil not being very suitable for turnips;—without the liquid they would have given from 25 to 30 loads of the solid manure for an equal crop. He added,

"Whether it was owing to the liquid manure or not I cannot say, but I never saw a heavy crop of turnips with so little tops. The tops were small, and the roots were large and good. It was the first instance in which I had seen liquid manures applied to turnips, and the result is such as to induce me to do it again where it can be done by pipes and hose. We found that by applying it after the turnips had been sown, the growth of the plants was so accelerated as to carry them out of the reach of the fly."

In the same field it produced an excellent crop of mangle-worzles. The remainder of the land to which it has been applied is Italian rye grass. By way of experiment, two or three ridges of the grass were sown with about 3 cwt. of guano to the acre; and Mr. Fergus says, the guano showed more distinctly than the liquid manure, but he cannot say that the difference in the crop was much. From some cause the Italian rye grass did not do well the second year, however manured. It was all cut three times, however, and a little of it four times. The first crop was about 30 inches thick; the second 30 to 36 inches; the third was chiefly seeded, and was the same thickness as the second. The part not seeded, and cut a fourth time, would be about 14 inches. In the autumn sheep were turned into it, but I could not ascertain the number.

There is something striking in the fact, that those who have become accustomed to the results of using liquid manures systematically, should consider as a partial *failure* the production of between nine and ten feet of grass in the course of a few months, with a residue of a tolerable aftermath for sheep.

In a communication from Mr. Romilly to Mr. Chadwick he says,

"The annual charge will be diminished by nearly one-half when the additional number of acres are brought under the system. My bailiff has estimated the value of a field of Italian rye-grass to which the liquid is now being applied at £230. This estimate is probably too high, and the works may be considered more substantial, and, therefore, more costly, than was necessary; but when it is considered how large a quantity of the most valuable manure will now be saved and applied to the land, in the most productive form, instead of running to waste in the ditches, there can be no doubt of the return, under proper management, being most ample."

The arrangements at Porth Kerry are capable of improvement, as I have already indicated, and the system may be greatly extended with most beneficial and economical results, but what has been already done, is sufficient to prove the general accuracy of the *modus operandi,* and the great fertilising powers of the liquid manure.

I made inquiry, and learnt that, as in many other places, there seems to be no disposition on the part of the farmers in the neighbourhood to copy the example of Mr. Romilly. The reply was, "The farmers are very difficult, and backward to move. Liquid manures have scarcely been used at all in the district."

Bulmarshe Court, Berkshire.—This estate, the property of James Wheble, Esq., is a short distance east of Reading, and the part to which my attention was directed consists of the home farm and part of the park, fertilised by liquid manure.

That part of the estate in Mr. Wheble's own hands consists of about 780 acres, but the works for applying liquid manures extend only to 200 acres.

The apparatus consists of four sunk tanks, a pump, steam-engine, an elevated tank or reservoir, iron pipes laid in the fields, and flexible hose and discharge pipe for applying the manure by jet.

Thus far the arrangements appear to be similar to those which have been herein-before commended as examples for imitation. I am compelled, however, to say, that in detail and in its results, the system here is very defective, after a much greater outlay than would have been required for efficient works.

The four tanks are wells, each of 9 feet diameter, and 12 feet deep, giving a total capacity equal to 19,028 gallons. If the manure were diluted with three times its own bulk of water, the quantity would be equal to one proper dressing for 16 acres of land ; but no dilution to that extent is effected. The tanks are under a cartshed, close to the door of one of the cattle steadings, and are only covered with loose planks. The effluvium escapes freely, and its pungency is at once a measure of the fertilising matter evaporated, and of the danger to the neighbouring cattle.

The steam-pump for raising the manure is only 5 inches diameter in the barrel, with 12 inches stroke, and making, as I was informed by Mr. Wheble's steward, about 10 strokes per minute. Without any deduction for loss, this pump would only lift 5,098 gallons per day of 10 working hours, and it would take between three and four days to empty the four tanks.

If this pump were kept working every day, except Sundays, throughout the year, without reference to the state of the weather, or the condition of the crops, and if three times the bulk of water for dilution were raised *by other means,* it would only afford about six ordinary dressings per annum to each of the 200 acres irrigated. The pumping power for liquid manure is, therefore, very inadequate.

The steam-engine is five-horse power, high pressure, works very smoothly, and does all the threshing, grinding, pumping, &c. of the farm. It would be quite capable of working additional pumps for liquid manure.

The raised tank is of cast-iron, and contains 20,000 gallons. It is uncovered, and placed upon a pile of excellent brick-work, at a height of 50 feet from the ground. The tank and tower must have cost a large sum of money, and are quite unnecessary :—direct action of the steam-pumps upon the under-ground pipes is much better, and I found that Mr. Wheble is now of that opinion.

There are about two miles of under-ground iron-pipes, with sluices and hydrants. The pipes are three-inch diameter, and Mr. Wheble said he thought the pipes and laying cost about 3*s*. per yard. The work could now be well executed at a maximum of 2*s*. 4*d*. per yard With this exception I failed to obtain any statement of the cost of Mr. Wheble's works, but the total amount would undoubtedly be very large, and, considered in connexion with the results, must render it the wisest economy, in all cases, to consult previously some one scientifically and practically conversant with the details of such arrangements.

The hose is 220 feet long, and is principally leather; but a small quantity is of canvas, coated with gutta percha. Mr. Wheble intends to have the patent canvas hose entirely when the leather is worn out.

I may mention that there is another tower upon the farm premises, 108 feet high, carrying a water-tank for constantly supplying all the farm buildings and the hall, which is about 300 yards distant. Mr. Wheble has also a gaswork of four retorts for lighting the hall, the steward's house, the cottages, shippons, stables, dog kennels, and all the farm buildings.

My informant said that the liquid manure was diluted from the water-main when too strong, but that *it was generally sufficiently diluted with the drainage from the steward's house.* This, and my examination, produced a conviction that the manure is generally used so much too strong as to surfeit the growing crops. The vegetation being thus for a while retarded, the fertilising power of the liquid manure is rendered so far nugatory that the produce is little, if at all, greater than that from ordinary tillage with solid manures. Any period of vigorous after-growth in the plants is only sufficient to compensate for the previous inaction, during which they were being relieved by drainage and evaporation from a stronger kind of food than they could digest. Land may be manured to sterility; and the point attained at Bulmarshe Court appears to be that at which the greatest fertilising agent known,—liquid manure,—produces very little more than farmyard dung. Frequent applications, with a much larger dilution of water, would have produced results similar to those realised elsewhere in various parts of England, Scotland, and Wales.

There is plenty of stock for the production of liquid manure. About 400 sheep are kept, 80 to 100 pigs, 10 milk cows, 10 feeding cattle, 10 young stock, 12 farm horses, 30 hunters, carriage horses, and hacks, and upwards of 100 hounds. All the buildings and the yard for solid manure drain into the tank.

I am able from experience to estimate the quantity of liquid and liquified manure due from this stock, and, by analogy, to state the produce, fairly represented by such manure properly applied, at not less than 10 tons of grass per day for eight months, and half the quantity for the remaining four months. This is a very moderate estimate from data already given in this Report.

The liquid manure has been applied upon this farm to grass, turnips, mangle wurzle, and for wheat before sowing. My informant said it had been tried against solid manure for mangle wurzles by giving three or four applications of liquid to one part, and about 25 tons of solid farm manure to another part. I believe the liquid was undiluted, and the crop was a little heavier upon the part where the solid manure had been used; but my informant said that the difference was very little, while the cost of applying the liquid was literally nothing compared to that of applying the solid manure.

It is unnecessary that I should quote further from my minutes in the absence of such statistics as would facilitate comparison with operations in other places.

METROPOLITAN SEWAGE MANURE COMPANY'S OPERATIONS.—Anticipating the possibility that this report might find its way to the towns interested, I thought it my duty to visit the works of the Metropolitan Sewage Manure Company at Fulham, to examine the market-gardens and other land to which the sewage *has been applied* there, and to ascertain from some of the consumers their opinions as to the result upon various crops. The company has a station on the west bank of the Kensington canal, at Stanley-bridge, where they have erected a steam-engine to pump the sewage water over the top of a stand-pipe 75 feet high. This altitude gives a sufficient pressure for the whole district, and the fertilising fluid is conveyed from the stand-pipe and distributed, by about 15 miles of mains and services, varying from 14 inches diameter at the works, down to 2 inches diameter in the fields and gardens where it is used. The consumers have plugs or hydrants fixed at convenient distances in their lands, and with their own servants, and hose and jet pipe, apply it when they please; *paying to the company the sum of three pounds ten shillings per acre per annum.*

Hitherto the company has only taken the Walham Green sewer water, which contains probably less fertilising matter than any other in the Metropolis, in consequence of the less density of the population within its area, and the great volume of the upland rain water. It is, however, the most conveniently accessible to the works. When the arrangements for using the Ranelagh sewer water are completed, it is expected that more beneficial results will be experienced. The first place I examined was a field from which two crops of grass have been taken during the year, and it is now a most excellent pasture.

I examined the large market-garden occupied by Mr. *George Bagley*, who said, in answer to my inquiries,—

"I have found that all crops grow faster and are healthier from the application of sewer water. The size of vegetables is increased in a fine season;

in some descriptions the quality is also better, and consequently they would obtain better prices. I may particularly mention vegetable marrow, a plant that requires much nutriment; it has produced a large crop in warm dry weather. In dry weather, the sewage is of great assistance to scarlet runners and French beans, but if rain were to come after its application, the consequence would be injurious. I have found it of great service to cucumbers, especially from the convenience of its application. I think, however, it is almost better for cabbage and brocoli, than anything else. I have not perceived any offensive effluvia at the time of its application or afterwards—not enough: if there had been a little smell, the manure would perhaps have been better than it was."

Mr. *Edward Bransgrove*, manager of Mrs. Harwood's extensive market-gardens, said :—

"We have used the sewer water ever since the company commenced. The improvement in the plants is very manifest; I think it helps to lessen the blight. The growth of vegetable marrow is much improved, also of scarlet runners, and the same of lettuce and celery. This plot was celery, and the liquid manure was applied to it. After the crop was got off, it was planted with cabbage, without any further application of the sewage, but the plants are still benefited by the former application. The next patch of savoys had it applied to them about three months since, and are a very good crop. There was very little smell either at the time of its application or afterwards."

I likewise visited the market-gardens of Mr. William Bagley, Mr. Richard Steele, Mr. John Crouch, and Mr. Joshua Bagley, to all of which, as well as many others in the district, the sewage manure has been applied. In one place, a field of cabbage plants was pointed out, and I was informed that the sewage manure had been applied to about one half and not to the other. Those to which it had been applied were darker in colour, larger, and much more vigorous than the remainder.

I have in my former report already considered the objection urged in the provinces, *that liquid manures could only be beneficially applied in* WET WEATHER, and have shown that the solution used was too strong. It is a remarkable fact, that the tenants of the Metropolitan Sewage Manure Company all concur in the statement, that *the greatest advantages are produced by its application in* DRY WEATHER, when manuring and watering are combined in the same operation. These facts, and my own experience, lead to the conclusion, that *the town sewerage water should be collected, and raised to the required altitude in as concentrated a condition as possible; but that it should be distributed and applied to the land, in such a state of dilution with water, as may be required by the season of the year, the state of the weather, and the quantity of moisture in the soil.* This may be easily accomplished, and almost without expense, by a pipe from the water-works, discharging into the downward arm of the sewage stand-pipe, at the command of the person in charge of the station. By these means, the sewerage water may be applied with advantage at all times. In dry weather, and upon thirsty soils, a weak solution would be used;

and in the winter season,—in wet weather, on uncropped land,—or with gross-feeding plants, as strong a solution as might be requisite, to produce the greatest possible fertility.

Having said this much of the company's operations, I feel bound to add that the failure of a sewer manure company in the Metropolis, as a commercial speculation, was predicted by Mr. Smith, of Deanston, and other competent agriculturalists, who withdrew from it. A disproportionately large outlay of capital and machinery was made from a wrong sewer, that is to say, from a sewer which in fact was an old watercourse, and chiefly adapted to the removal of storm water; and the supply of manure from this was carried to a wrong district, or one of the least suitable districts, namely, to a district already supplied at the cheapest rate with powerful manure: of that district only a small proportion received the company's supply. The whole of the available capital was expended before the pipes could reach the ordinary farming district, where there appeared to be a demand for it. Nevertheless, the fertilising power of the extremely diluted manure, when applied to the land, already highly charged with manure, was extraordinary. On this land, where town manure had been applied at an expense of 20*l.* per acre, and labour in working the land to about the same extravagant amount, an augmentation of nearly one third of the ordinary large crops was obtained. The range of the distribution by the jet was visible in the extra growth of the vegetation, although much of this success was no doubt attributable to the water itself, irrespective of the matter in solution.

Every sanitary reformer must have regretted that the company has not been more successful; but when its operations are pointed to as a reason why works for the application of the sewerage of towns should not be undertaken, it becomes necessary to indicate the causes of its success being partial only. The errors committed are in matters of detail; the principle—that town sewerage water is a valuable fertiliser—is fully confirmed, even by the company's operations.

In Table No. 1. (page 135.) I have shown the results of my investigations in Scotland.

In Table No. 2. (page 136.) I have converted the Scotch acres into English, so that the whole may be measured by the same standard.

TABLE No. 1. showing COST, &c. of the Application of SEWERAGE WATERS and LIQUID MANURES AT PLACES visited in SCOTLAND.

| Name of Place. | No. of Acres, Scotch. | Mode of application. | Cost of works, and apparatus. | Annual interest, &c., at $7\frac{1}{2}$ per cent. | Annual working expenses. | Total annual charges per acre. | Observations. |
|---|---|---|---|---|---|---|---|
| EDINBURGH. | | | | | | | |
| Craigentinny Meadows: | | | £ s. d. | £ s. d. | £ s. d. | £ s. d. | |
| High Level - - | 50 | Steam engine, pumps, and open gutters and panes - | 2,000 0 0 | 150 0 0 | 117 12 0 | 5 7 0 | Average rental, 20*l.* per acre. |
| Sea Meadows - - | 30 | Gravitation, open gutters and panes - - - - | 700 0 0 | 52 10 0 | 19 17 6 | 2 8 3 | Worthless 25 years ago, now worth 660*l.* per acre. |
| Old Meadows - | 180 | Ditto - - - | 2,700 0 0 | 202 10 0 | 119 5 0 | 1 15 9 | Maximum rental, 31*l.* per acre. |
| GLASGOW. | | | | | | | |
| Mr. Harvey's farm - | 400 | Steam engine, pumps, underground iron main pipes, and iron distributing pipes | 1,450 0 0 | 108 15 0 | 240 10 0 | 0 17 6 | 10 feet thick of grass cut from an acre in six months. |
| AYRSHIRE. | | | | | | | |
| Myer Mill farm - - | 400 | Steam engine, pumps, underground iron mains, gutta percha hose, and jet pipe - | 1,586 0 0 | 118 19 0 | 162 10 0 | 0 14 0 | 70 tons of grass cut from an acre in six months. |
| Canning Park farm - | 40 | Ditto - - - | 210 0 0 | 15 15 0 | 11 0 0 | 0 13 $4\frac{1}{2}$ | $14\frac{1}{4}$ feet thick of grass cut in seven months. |
| Leg or Dunduff farm - | 40 | Gravitation, underground iron mains, gutta percha hose, and jet pipe - - | 191 0 0 | 14 6 6 | 3 10 0 | 0 8 11 | 12 stacks per annum previously; 80 stacks last year. |

TABLE No. 2. showing COST, &c. of the Application of SEWERAGE WATERS and LIQUID MANURES.

| Name of Place. | No. of English acres. | Mode of application. | Cost of works, and apparatus. | Annual interest, &c. at 7½ per cent. | Annual working expenses. | Total annual charges per English acre. | Observations. |
|---|---|---|---|---|---|---|---|
| EDINBURGH. | | | £ s. d. | £ s. d. | £ s. d. | £ s. d. | |
| Craigentinny Meadows: High Level | 63 | Steam engine, pumps, and open gutters and panes | 2,000 0 0 | 150 0 0 | 117 12 0 | 4 4 11 | Average rental, upwards of 16*l.* per English acre. |
| Sea Meadows | 38 | Gravitation, open gutters and panes | 700 0 0 | 52 10 0 | 19 17 6 | 1 18 1 | Worthless 25 years ago, now worth about 520*l.* per English acre. |
| Old Meadows | 228 | Gravitation, open gutters and panes | 2,700 0 0 | 202 10 0 | 119 5 0 | 1 8 2½ | Maximum rental, 25*l.* per English acre. |
| NOTTINGHAMSHIRE. The Duke of Portland. Clipstone Meadows | 300 | Catch-meadow, gravitation and open gutters | 36,000 0 0 | 2,700 0 0 | 150 0 0 | 9 10 0 | Previously worth from 3*s.* to 5*s.* per acre per annum, now worth upwards of 12*l.* |
| WILTSHIRE. Wiley Meadows | 150 | Bed-work of ridge and furrow, gravitation and open gutters | 3,000 0 0 | 225 0 0 | 52 10 0 | 1 17 0 | Four heavy crops of grass per annum. |
| DEVONSHIRE. The Duke of Bedford. Tavistock Meadows | 90 | Bed-work and catch-meadow, gravitation and open gutters | 1,183 0 0 | 88 14 6 | 67 10 0 | 1 14 8½ | Land more than quadrupled in value after only four years irrigation. |
| BERKSHIRE. Philip Pusey, Esq., M.P. Pusey Meadows | 100 | Catch-meadow, gravitation and open gutters | 445 0 0 | 33 7 6 | 37 18 4 | 0 14 3 | Land not previously worth more than 5*s.* per acre, is now yielding six heavy crops of grass per ann. |
| GLASGOW. Mr. Harvey's farm | 508 | Steam engine, pumps, underground iron main pipes, and iron distributing pipes | 1,450 0 0 | 108 15 0 | 240 10 0 | 0 13 9 | 10 feet thick of grass cut from an acre in six months. |
| AYRSHIRE. Myre Mill farm | 508 | Steam engine, pumps, underground iron mains, gutta percha hose, and jet pipe | 1,586 0 0 | 118 19 0 | 162 10 0 | 0 11 1 | 70 tons of grass cut from an acre in six months. |
| Canning Park farm | 50 | Ditto | 210 0 0 | 15 15 0 | 11 0 0 | 0 10 8½ | 14½ feet thick of grass cut in seven months. |
| Leg or Dunduff farm | 50 | Gravitation, underground iron mains, gutta percha hose, and jet pipe | 191 0 0 | 14 6 6 | 3 10 0 | 0 7 1½ | 12 stacks per annum previously; 80 stacks last year. |
| STAFFORDSHIRE. The Duke of Sutherland. Hanchurch farm, near Trentham | 83 | Steam engine, pumps, underground iron mains, gutta percha hose, and jet pipe | 520 13 4 | 39 1 0 | 18 6 0 | 0 13 9¾ | Tanks constructed sufficient for 300 acres. |
| LANCASHIRE. Halewood farm | 120 | Ditto - - Ditto | 521 12 0 | 39 2 5 | 19 15 2 | 0 9 9¼ | One dressing of liquid, equal to 25 to 30 tons of farm-yard manure per acre. |
| CHESHIRE. Liscard farm | 150 | Ditto - - Ditto | 672 1 10 | 50 8 0 | 17 11 0 | 0 9 8¾ | A fourth crop of grass being weighed was found equal to 10 tons per acre. It was the lightest crop cut off the same land. |
| GLAMORGANSHIRE. Porth Kerry farm | 50 | Gravitation, underground iron mains, gutta percha hose, and jet pipe | 300 0 0 | 22 10 0 | 10 0 0 | 0 13 0 | Tanks constructed sufficient for 300 acres. Between 9 and 10 feet of grass cut. |

It has been stated that the objects of the catch-water meadow and the application of liquid manure are quite different. Plain water applied judiciously is undoubtedly a powerful fertiliser, but the primary object of catch and bed work, in many instances, is the submersion of the soil. This cannot for a moment be supposed to be the natural condition of grass, which is neither a subaqueous nor an amphibious production. Practically, more is produced by Mr. Pusey with his small streams, capable at times of only *damping the soil*, than by the enormous quantities of water poured over the meadows of Wiltshire.

Another practical fact is, that the open gutter works at Edinburgh, Mansfield, and Tavistock are for the application of town sewage manure; and that in nearly every instance of catch-meadows or bed-irrigation advantage is properly taken of all the liquid and liquified manure capable of being turned into the gutters. Great good is stated to result from the practice of feeding cattle upon the same meadows until the crops are eaten down, and then turning over the stream, so as to liquify the droppings of solid manure, and produce another crop.

On the other hand the experience acquired under the distribution of liquid manure by pipes, leads invariably to a greater dilution with water; and eminent cultivators have testified that, in the absence of available liquid manure, it would be highly remunerative to distribute plain water by the hose and jet.

Starting therefore from the opposite points of "plain water," and the strongest solution of "liquid manure," the advocates of both have arrived at about the same point of *productive dilution;* but each attributes much of his great success to his particular mode of application.

Irrespective of other and more strictly sanitary considerations therefore, the economy of the various modes of application becomes properly a matter of investigation, when the object of your Honourable Board is to advise the Local Boards acting under the Public Health Act throughout the country.

The comparative expense of irrigation by open gutters, and by pipes and hose, has been considered, and the facts stated are undoubtedly in favour of the latter system, on a financial view of the question. On sanitary grounds there can scarcely be two opinions as to which is the most desirable for adoption. There is one further consideration, however, which has only been briefly alluded to, namely, the extent of land taken up by the gutters and carriers, and, with one or two exceptions, totally lost for producing purposes, on comparison with the application by pipes. The average area of panes in bedwork is half an acre or less; in catchwork probably somewhat more, and the average width of the gutters, large and small, about two feet. This gives about 133 square yards, or one thirty-seventh part of an acre as the average, equal to one acre of producing surface out of every 37 acres, lost and wasted by the open gutter system. This is, of course, a general average statement, which may be in excess in particular instances, and will be too little in others.

Much is now being said of Mr. Mechi's establishment at Tiptree, and of his balance sheet, which shows a loss upon last year's farming of 650*l*. A recent visit to the farm induces me to offer one or two remarks on what has been done there, and what may be done.

Mr. Mechi could scarcely have settled himself in a more discouraging locality; much of the district around is an uncultivated heath, and the soil upon a part of the farm full of flints and stones, with large conglomerates of peroxide of iron. Other parts of the land were strong loamy clay.

By thorough drainage, subsoiling, and the extensive use of manures, he has already increased the value of the land threefold within a short time. His practice has been to keep a larger live stock than his sterile land would support, and to purchase a great quantity of food for conversion into manure. The custom of Essex does not admit of this appearing to his credit, and hence the apparent deficiency.

I should exceed my duty to your Honourable Board by any description of Mr. Mechi's improvements; but, with the farm in its present state, I have no hesitation in saying that the use of liquid manure will at once transfer the balance to the opposite side of the sheet, so as to show a large surplus.

I took an account of the calves, bullocks, cows, horses, pigs, and sheep, and find them equal, as to liquid and soluble manure, to 87 bullocks. From what is done elsewhere I am able to state the question in two ways:—

By the application of the manure in a liquid condition, by means of pipes and hose, the present live stock at Tiptree is capable of giving the greatest fertility to two thirds of the farm, without the purchase of any manure or food.

Under the operation of liquid manure, applied by pipes and hose, the farm at Tiptree is capable of supporting live stock equal to 120 bullocks, or about half as many more as at present.*

Mr. Mechi is fully aware of the value of liquid manure, and intends to lay down iron pipes for its distribution over his farm. He has a small tank in his garden, and has used the liquid from the closet with the greatest success in the cultivation of all kinds of culinary vegetables and fruits, especially for strawberries. A paddock in front of the hall has also been dressed with it by means of the cart with much advantage.

* The most recent instance that has come under my notice of the *proper* use of liquid manure is that of Jno. W. Wilmot, Esq., who has by this means kept 10 beasts, 5 horses, 50 sheep, and 6 pigs on 16 statute acres of land,—summer and winter.—*W. L.*

In this report I have confined myself strictly to the special investigations with which your Honourable Board intrusted me.

Every succeeding instance adds new proof to the vast agricultural importance of the question, and the cases of Edinburgh, Mansfield, Tavistock, and the Metropolitan Sewage Manure Company show peculiarly the great practical results from the use of town sewerage waters, even when the arrangements for its application are in various respects imperfect and objectionable.

Your Honourable Board are already informed of the instances which I brought before your notice, in my former report, of the use of sewage manure in Ashby-de-la-Zouch, where 100*l.* per annum was named as compensation for the withdrawal of it from only 40 acres of land;—of Mileham, where the land under irrigation is valued at 5*l.* to 6*l.* per acre, against adjoining land letting at 11*s.* 6*d.*;—of Newcastle-under-Lyme, where heavy crops of grass were being cut in the month of October; and of many other towns, to which I need not again advert, where the great value of sewage manure had been practically tested.

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In obedience to your direction, I have considered the most efficient and most economical arrangement of the distributary apparatus for sewage manures, and have prepared several diagrams and estimates to illustrate the subject.

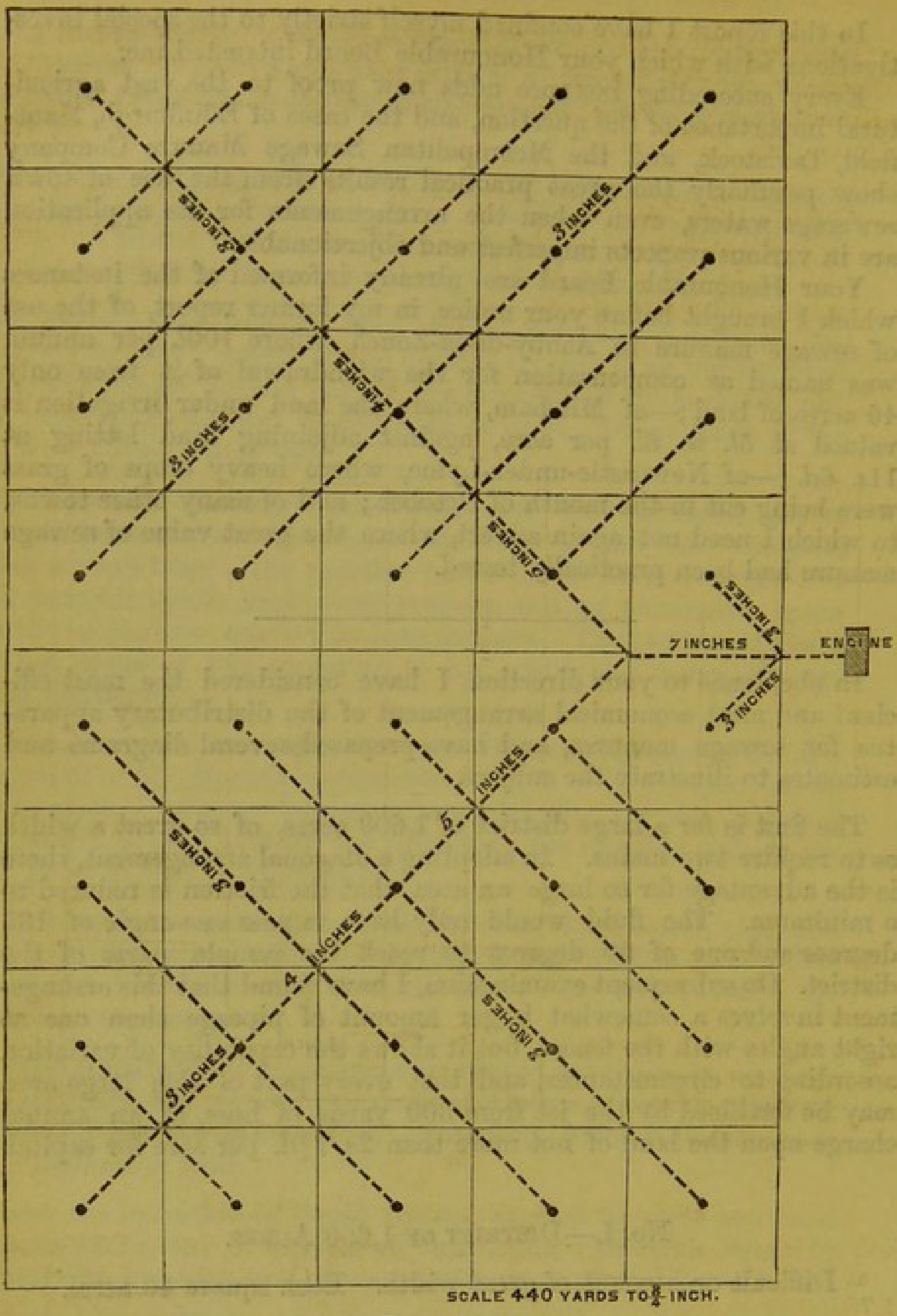
The first is for a large district of 1,600 acres, of so great a width as to require two mains. In adopting a diagonal arrangement, there is the advantage for so large an area that the friction is reduced to a minimum. The fluid would only have to pass one angle of 135 degrees and one of 90 degrees to reach the remote parts of the district. On subsequent examination, I have found that this arrangement involves a somewhat larger amount of pipeage than one at right angles with the fences, but it shows the capability of variation according to circumstances, and that every part of this large area may be fertilised by the jet from 300 yards of hose, at an annual charge upon the land of not more than 2*s.* 7¾*d.* per acre for capital.

### No. I.—District of 1,600 Acres.

Difficult on account of great width. Each square 40 acres.

To be fertilized with sewage manure, conveyed in cast-iron pipes, with hydrants and hose and jet. The most distant parts to be reached by 300 yards of hose.

[*See diagram on following page.*]




## Estimate for Distribution complete.

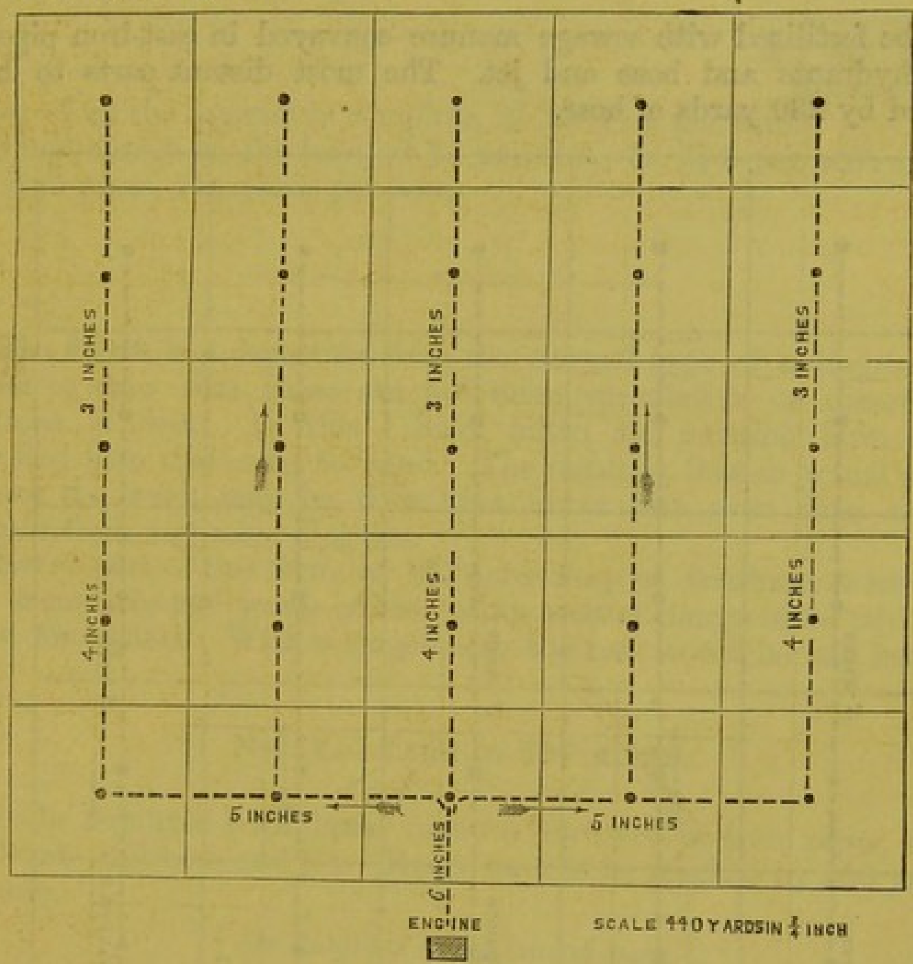
| | | | | £ | s. | d. |
|---|---|---|---|---|---|---|
| 600 yards of 7-inch cast-iron pipe, and jointing and laying, at 7*s.* 2*d.* | | | | 215 | 0 | 0 |
| 1,866 yards of 5-inch | ditto | ditto | at 4*s.* | 373 | 4 | 0 |
| 1,244 yards of 4-inch | ditto | ditto | at 3*s.* | 186 | 12 | 0 |
| 16,794 yards of 3-inch | ditto | ditto | at 2*s.* 4*d.* | 1,959 | 6 | 0 |
| 40 hydrants, at 20*s.* | | | | 40 | 0 | 0 |
| 3 lengths of hose, 300 yards each, per yard 1*s.* 4*d.* | | | | 60 | 0 | 0 |
| 3 discharge pipes and spreaders, at 20*s.* | | | | 3 | 0 | 0 |
| | | | | £2,837 | 2 | 0 |

Cost of all the apparatus complete, 1*l.* 15*s.* $5\frac{1}{2}$*d.* per acre.
Annual charge on land, at $7\frac{1}{2}$ per cent., equal to 2*s.* $7\frac{3}{4}$*d.* per acre.
Iron pipes, $12\frac{3}{4}$ yards per acre.

The next is for a district of 1,000 acres, in which the arrangement is more simple, and the cost less. The length of the hose would be the same, and the annual charge, as interest on capital at 7½ per cent. only 2*s.* 6½*d.*, per acre.

No. II.—District of 1,000 Acres.—Each square 40 acres.

To be fertilized with sewage manure conveyed in cast-iron pipes with hydrants and hose and jet. The most distant parts to be reached by 300 yards of hose.




Estimate for Distribution complete.

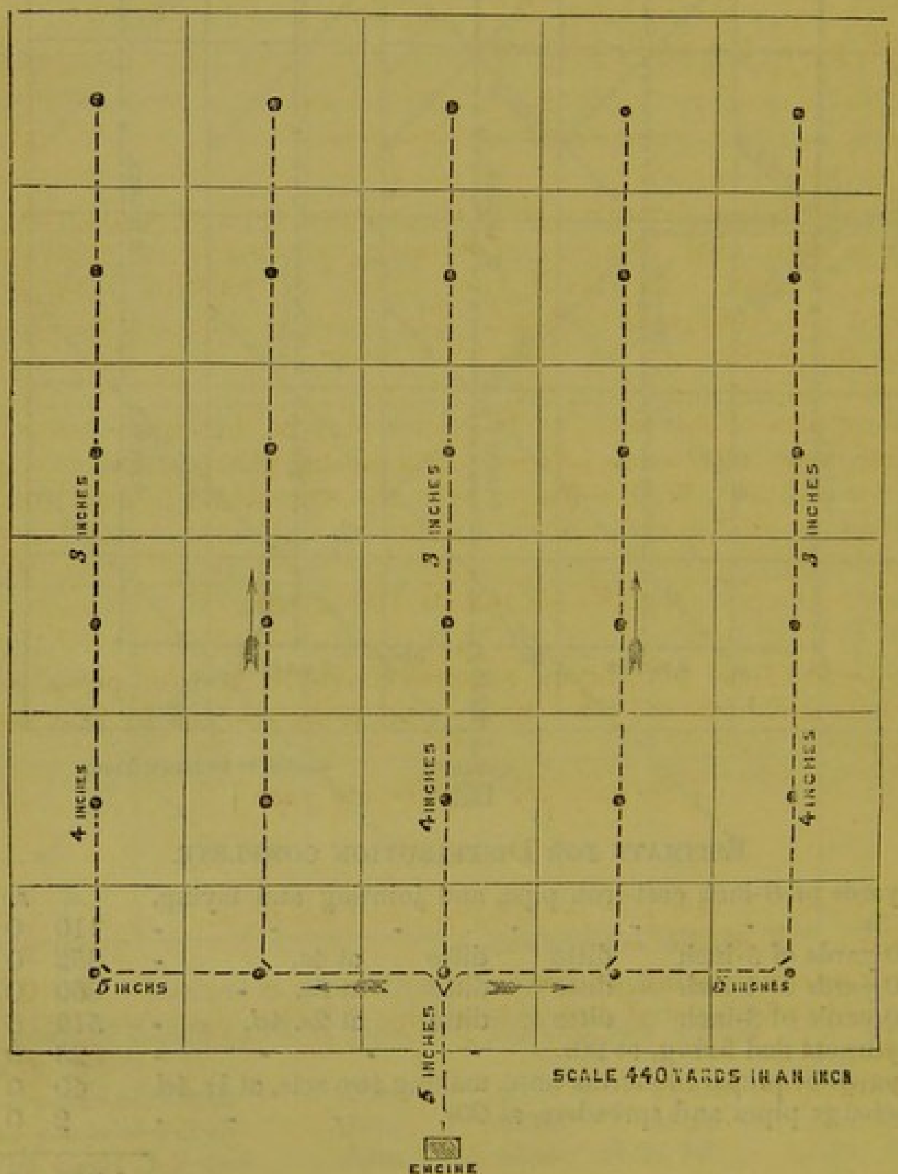
| | £ | s. | d. |
|---|---|---|---|
| 440 yards of 6-inch cast-iron pipe, and jointing and laying, at 5*s.* | 110 | 0 | 0 |
| 1,760 yards of 5-inch ditto ditto at 4*s.* | 352 | 0 | 0 |
| 4,400 yards of 4-inch ditto ditto at 3*s.* | 660 | 0 | 0 |
| 4,400 yards of 3-inch ditto ditto at 2*s.* 4*d.* | 513 | 6 | 8 |
| 25 hydrants and fixing, at 20*s.* | 25 | 0 | 0 |
| 600 yards of prepared canvas hose, making two sets, at 1*s.* 4*d.* | 40 | 0 | 0 |
| 2 discharge pipes and spreaders, at 20*s.* | 2 | 0 | 0 |
| | £1,702 | 6 | 8 |

Cost of all the apparatus complete, 1*l.* 14*s.* 0½*d.* per acre.
Annual charge on land at 7½ per cent., equal to 2*s.* 6½*d.* per acre.
Iron pipes, 11 yards per acre.

The third is a similar arrangement for a district or large farm, of 675 acres. I have given this as an illustration of the fact that the shortening of the hose, which is removable to any part the district or farm, increases the length of the permanent iron pipeage, and consequently increases the cost of the whole system. In this instance the hose is reduced from 300 to 230 yards, and the annual charge on the land is increased from 2*s.* 6½*d.* to 3*s.* 2½*d.* per acre.

No. III.—District of 675 Acres.—Each square 22½ acres.

To be fertilized with sewage manure conveyed in cast-iron pipes, with hydrants and hose and jet. The most distant parts to be reached by 230 yards of hose.



ESTIMATE FOR DISTRIBUTION COMPLETE.

| | £ | s. | d. |
|---|---|---|---|
| 1,650 yards of 5-inch cast-iron pipe, and jointing and laying, at 4*s.* | 330 | 0 | 0 |
| 3,300 yards of 4-inch ditto ditto at 3*s.* | 495 | 0 | 0 |
| 4,950 yards of 3-inch ditto ditto at 2*s.* 4*d.* | 577 | 10 | 0 |
| 30 hydrants, at 20*s.* | 30 | 0 | 0 |
| 230 yards of hose, at 1*s.* 4*d.* | 15 | 6 | 8 |
| Discharge pipe and spreader | 1 | 0 | 0 |
| | £1,448 | 16 | 8 |

Cost of all the apparatus complete, 2*l.* 2*s.* 11*d.* per acre.
Annual charge on the land, at 7½ per cent., 3*s.* 2¼*d.* per acre.
Iron pipes, 14⅗ yards per acre.

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The fourth is a departure from the normal type of a diagram, in order to show that these are not mere speculative or theoretical notions of cost. In this I have taken an existing farm from the first plan that came to hand. The result is, that in actual experience the work may be done at a lower rate even than would appear from any mere diagram.

Every part of this farm of 107 acres may be fertilised with the jet from *only 200 yards of hose*, at an annual charge of 2*s.* 9½*d.* per acre, for capital. With a longer hose the cost would be still less.

No. IV.—FARM OF 107 ACRES.

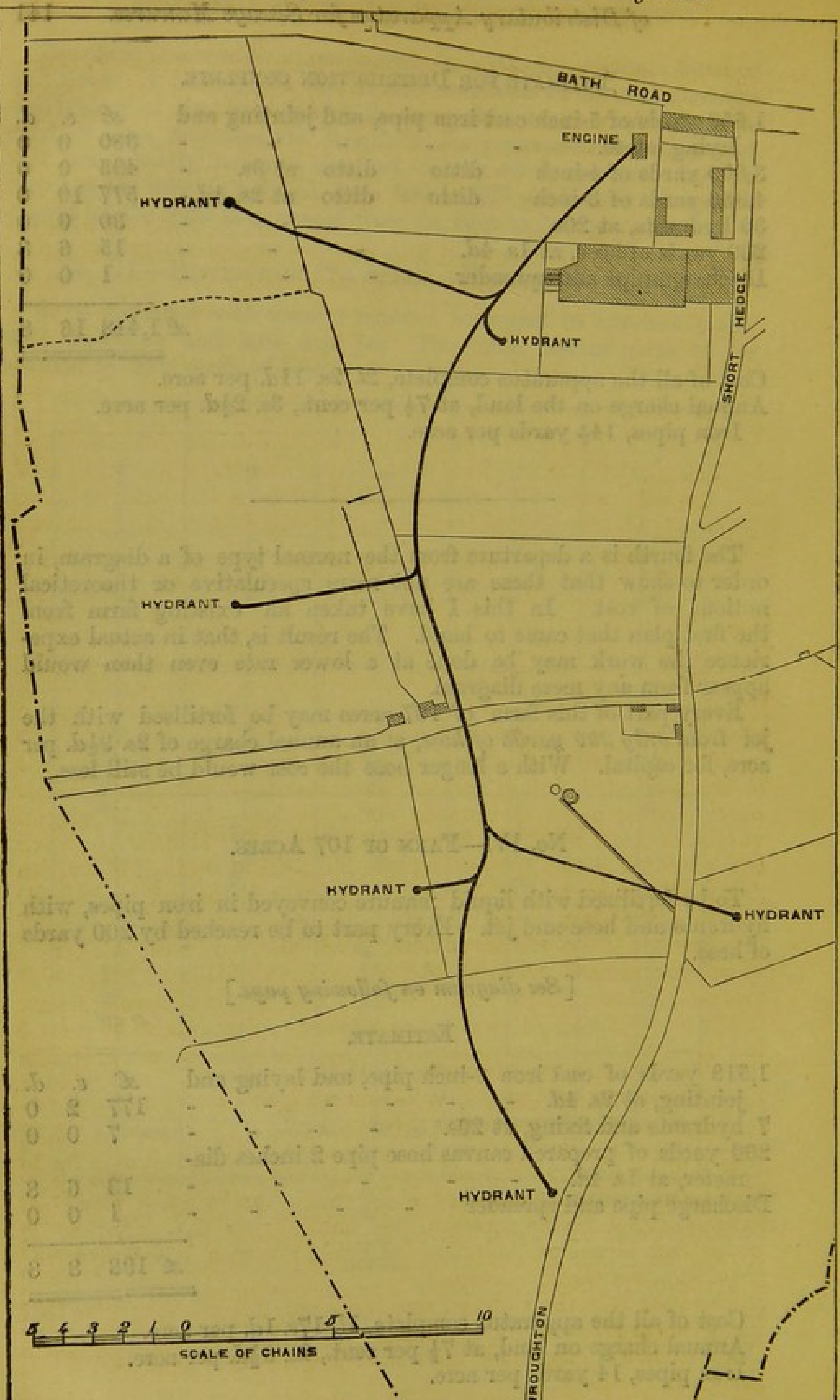
To be fertilized with liquid manure conveyed in iron pipes, with hydrants and hose and jet. Every part to be reached by 200 yards of hose.

[*See diagram on following page.*]

ESTIMATE.

| | £ | s. | d. |
|---|---|---|---|
| 1,518 yards of cast iron 3-inch pipe, and laying and jointing, at 2*s.* 4*d.* | 177 | 2 | 0 |
| 7 hydrants and fixing, at 20*s.* | 7 | 0 | 0 |
| 200 yards of prepared canvas hose pipe 2 inches diameter, at 1*s.* 4*d.* | 13 | 6 | 8 |
| Discharge pipe and spreader | 1 | 0 | 0 |
| | £ 198 | 8 | 8 |

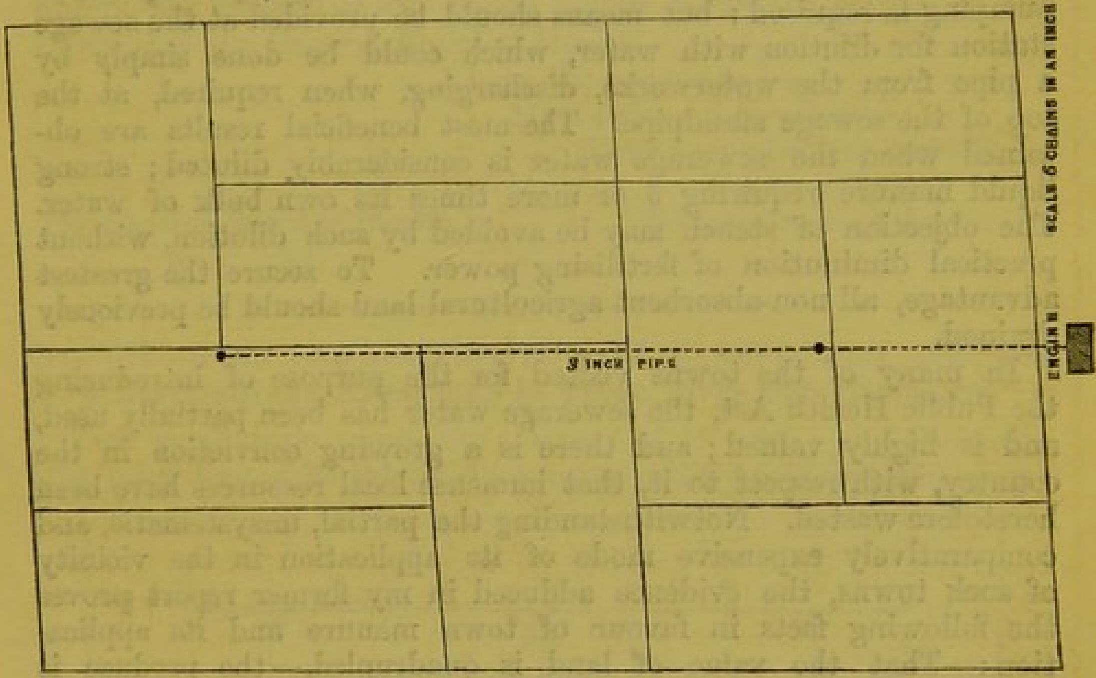
Cost of all the apparatus complete, 1*l.* 17*s.* 1*d.* per acre.
Annual charge on land, at 7½ per cent., 2*s.* 9½*d.* per acre.
Iron pipes, 14 yards per acre.


BATH ROAD
ENGINE
HYDRANT
HYDRANT
SHORT HEDGE
HYDRANT
HYDRANT
HYDRANT
HYDRANT
5 4 3 2 1 0 5 10
SCALE OF CHAINS
FROM WROUGHTON

No. V. is merely to show that the economy of distribution is not dependent upon the taking in of a large area. It is for a small farm of only 40 acres, and the annual charge upon the land for capital 2*s.* 7*d.* per acre.

### No. V.—Farm of 40 Acres.

To be fertilized with liquid or sewage manure conveyed in cast-iron pipes, with hydrants and hose and jet. The most distant parts to be reached by the jet from 200 yards of hose.




### Estimate for Distribution complete.

| | £ | s. | d. |
|---|---|---|---|
| 450 yards of 3-inch cast-iron pipe, and laying and jointing, at 2*s.* 4*d.* - - - - | 52 | 10 | 0 |
| 2 hydrants, at 20*s.* - - - - - | 2 | 0 | 0 |
| 200 yards of prepared canvas hose, at 1*s.* 4*d.* - | 13 | 6 | 8 |
| Discharge pipe and spreader, at 20*s.* - - | 1 | 0 | 0 |
| | £68 | 16 | 8 |

Cost of apparatus complete, 1*l.* 14*s.* 5*d.* per acre.
Annual charge on land, at 7½ per cent., 2*s.* 7*d.* per acre.
Iron pipes, 11¼ yards per acre.

It will be observed that all these estimates are for cast-iron pipes. Having met with two instances in which earthenware pipes had entirely failed under pressure, and those being the only cases in which such pipes had been used for liquid manures, I have not ventured to adopt them.

The fault is in the manufacture, and I am not without hope that earthenware pipes may yet be made to stand. In that case all the above estimates might be reduced to a little more than two thirds the amounts stated.

As the result of my experience, I beg to lay before your Honourable Board the following suggestions and conclusions:—The most ECONOMICAL and EFFICIENT mode of improving the land by the use of town manure, and the only mode consistent with sanitary principles, is by systematic house drainage for its *collection*, cheaply constructed pipes for its *carriage* and *distribution*, and hose and jet pipe for its *application*.

The fertilising town sewage should (except in the case of roads of large traffic) be kept separate from the rain-fall, especially where pumping is required; but means should be provided at the sewage station for dilution with water, which could be done simply by a pipe from the waterworks, discharging, when required, at the top of the sewage standpipe. The most beneficial results are obtained when the sewerage water is considerably diluted; strong liquid manure requiring 5 or more times its own bulk of water. The objection of stench may be avoided by such dilution, without practical diminution of fertilising power. To secure the greatest advantage, all non-absorbent agricultural land should be previously drained.

In many of the towns visited for the purpose of introducing the Public Health Act, the sewerage water has been partially used, and is highly valued; and there is a growing conviction in the country, with respect to it, that immense local resources have been heretofore wasted. Notwithstanding the partial, unsystematic, and comparatively expensive mode of its application in the vicinity of such towns, the evidence adduced in my former report proves the following facts in favour of town manure and its application:—That the value of land is quadrupled,—the produce is largely increased,—and no other manure is equal to it. Land manured with it will support half as much more stock as highly cultivated land on which solid manure is used. It is better by one third than farm-yard manure; and it costs, compared with solid, little more than one fourth, to produce a crop of equal value.

All the later investigations, made specially with reference to this report, not only confirm the facts and conclusions previously stated, but add many new considerations, which must render any further avoidable waste of sewerage water or liquid manure a wilful and perverse sacrifice of food,—of agricultural prosperity,—and of health.

Irrespective of its enormous pecuniary value, the investigation of which has been only one object of this report, the expeditious removal of all organic refuse from towns is so essential to health, that every facility should be afforded, by the Legislature, the General Board of Health, and the Local Boards, for the most systematic and efficient application of the sewage waters to the land. To this end, more extensive legal powers are necessary to enable the Local Boards to extend the arrangements and works for such systematic distribution and application, *beyond the boundaries of the districts constituted for the general purposes of the Public Health Act*. Such powers should be subject to the sanction of the General Board, after special inquiry, as to the boundaries within which the sewerage water is to be applied, and the plans for its application. The Board should also be able to require the works to be executed according to the plans so approved, and should be a Court of Appeal in cases of dispute between the local authorities and persons interested. All the arrangements and cost, including station, plant, mains, and service pipes, should be carried out under the system of distributed charges.

Where arrangements shall *not* be simultaneously made by any Local Board for draining the town, and distributing the sewerage waters, the outfalls of the public sewers should be subject to the approval of the General Board of Health.

I have the honour to be,
My Lords and Gentlemen,
Your very obedient servant,
WILLIAM LEE,
*Superintending Inspector.*

*The General Board of Health,*
*&c. &c.*

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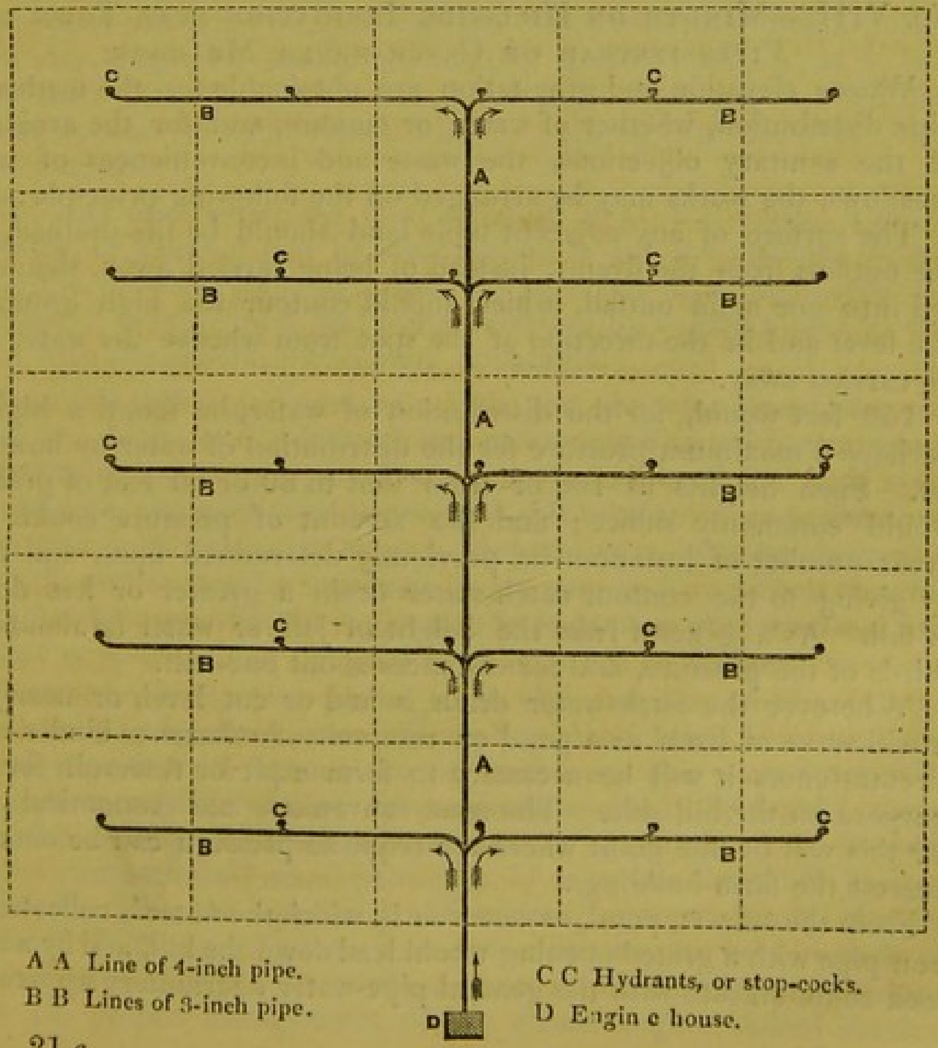
No. VII.—PLAN AND ESTIMATE BY T. W. RAMMELL, ESQ., C.E., FOR A DISTRIBUTARY APPARATUS BY FIXED PIPES AND HYDRANTS.

Each subdivision represents a square of 10 acres; and the entire area, consisting of 25 subdivisions, consequently contains 250 acres.




A A Line of 4-inch pipe.
B B Lines of 3-inch pipe.
C C Hydrants, or stop-cocks.
D Engine house.

ESTIMATE No. 1.—(*Cast-Iron Pipeage.*)

| Lin. yds. | | | £ | s. | d. |
|---|---|---|---|---|---|
| 1,100 | of 4 inch cast-iron pipe - - - | 2s. 4d. | 128 | 6 | 8 |
| 4,400 | of 3 inch ditto - - | 1s. 8d. | 366 | 13 | 4 |
| 5,500 | Laying and jointing - - - | 8d. | 183 | 6 | 8 |
| 25 | Hydrants and fixing - - - | 20s. | 25 | 0 | 0 |
| | Cost per acre £2 16. 3. | £ | 703 | 6 | 8 |

ESTIMATE No. 2.—(*Glazed Stoneware Pipeage, with Cast-Iron Collars.*)

| Lin. yds. | | | £ | s. | d. |
|---|---|---|---|---|---|
| 1,100 | of 4 inch stoneware pipes and collars | 1s. 6d. | 82 | 10 | 0 |
| 4,400 | of 3 inch ditto - - | 1s. 1d. | 288 | 6 | 8 |
| 5,500 | Laying and jointing - - - | 6d. | 137 | 10 | 0 |
| 25 | Hydrants and fixing - - | 20s. | 25 | 0 | 0 |
| | Cost per acre £1 18. 8. | £ | 483 | 6 | 8 |

No. VIII.—MINUTE ON HILL-SIDE IRRIGATION NEAR TOWN WITH PIPES INSTEAD OF CATCH-WATER MEADOWS.

Where elevation and gravitation are obtainable for the method of pipe distribution, whether of water or manure, and for the avoidance of the sanitary objections, the waste and inconveniences of water meadows, the works may be arranged on the following principle:—

The surface of any adjacent table land should be tile-drained, and the outfalls from the drains, instead of being carried away, should be led into one main outfall, which should contour the high ground at the level and in the direction of the spot from whence the water may be carried away.

150 feet would, for the distribution of water, be found a high or perhaps a maximum pressure for the distribution of water by hose and jet. Such heights as 100 or from that to 80 or 60 feet of pressure would commonly suffice; and the amount of pressure could in a great number of instances be previously determined upon and fixed by giving to the contour catch-water drain a greater or less degree of fall. As a general rule, the height of jets of water is about two thirds of the pressure, and for distances about one-half.

Wherever the catch-water drain is laid or cut level, or nearly so, it will serve of itself as a pond or reservoir of storage. Under other circumstances it will be necessary to form a pit or reservoir for that purpose on the hill side. The most convenient and economical place for this will be the point where the requisite pressure can be obtained nearest the farm buildings.

From the culvert, pond, or reservoir in which the water is collected, an iron pipe with a grated opening would lead down the hill, and by a stop-cock communicate with the general pipe-water distributary apparatus.

In the cases of moors, rocky or sterile uplands, of course collection by pipe drains would be unnecessary, and a contour ditch or catch-water culvert round the hill or headland would suffice for the collection of the same, and, as above stated, in many instances, for storage.

It will be obvious also, that any brook stream may be similarly contoured to the necessary altitude along the hill sides.

In the ordinary and more simple cases where the manure is at hand, it may be lifted to the pond, and mixed in a bay formed for the purpose; and from thence be distributed, as in the examples, described in the Appendix to the Report, where the liquified manure has been lifted to the high-level tanks. Vide the instance of Mr. Henry Thomson, and in that of Mr. Harvey. (Appendices p. 105 and 133.)

Nearly to the same level, the liquified manure may be distributed over the hill side by hose, or may be conveyed by a sufficient length of hose across vallies to opposite hill sides, and similarly applied. Mr. Thomson used the hose alone for distribution under 80 feet of pressure. He had 800 yards of hose, which alone served for the distribution of liquefied manure over more than 90 acres of land, and had no fixed pipeage whatsoever, for distribution. With this great length of hose, under only 80 feet of pressure, the jet from a discharging orifice five eighths of an inch diameter was 45 feet in length. The same apparatus, worked as he describes especially with lengths of hose with lateral apertures, would serve for the distribution of plain water from any poud or open culvert. The collecting pond, puddled with clay, might be usually provided, of greater capacity, at a lower cost than that which he incurred for a bricked and vaulted tank. There appears to be no reason why his working expenses need usually be exceeded.

In other cases where the farm steading is at a distance from the hill-side, or where it may be inconvenient to lift the manure, the pipe from the hill-side pond or head may pass into a wrought-iron tank capable of being closed, and communicating by a loop pipe and stop-cock with the general distributary apparatus.

Into this tank liquid manure may be put, the tank closed, the wtaer from the high level admitted, the communication with the general distributary apparatus opened, when the contents of the tank will be mixed with the high-level water, and will be cleared and distributed with it at such a rate or in such proportions as may be deemed expedient, and as may be regulated by the stop-cocks. When the clearance has been effected the tank may be re-opened, and receive another charge of manure, and the process be repeated *ad libitum.*

In towns where steam power is the cheapest for continuous application, the hydraulic engines referred to are coming into use, as the cheapest and most convenient for work requiring only intermittent or sudden applications, as for working cranes. Hydraulic engines are also coming into use for continuous applications, in the cases where comparatively small power, as of one, two, or three horses, is required. For the application of hydraulic power (as on the principle of the Bramah press), it is only necessary to turn a cock, and the power is instantly exerted; and it may be as instantly stopped. For the proper management of the steam engine skilled service is required, but the hydraulic engines may be comparatively safely worked by the ordinary labourers on the farm steading.

Where heads of water are got at such heights as 150 feet, the hydraulic pressure obtained by the closed pipes may be advantageously used for the work of the farm-steading, by hydraulic machines of the description noticed in the Report on the Supply of Water, p. 262, note 1 and 2.

The various important and economical services performed upon farms by steam engines arestatedin Appendix No. VI. In the cases now under consideration the hydraulic pressure of water would supersede the use of steam, and with still greater economy.

Another and scarcely collateral service to which such heads of water may be applied, is the supply of the house and farm buildings for food and other domestic purposes; for cleansing and washing by the jet the cattle steadings and premises; for perfecting the drainage of the whole of the buildings, and conveying the same into a tank, from whence it may again be discharged, and applied by its own gravitation to other lands at a still lower level.

Where the solid manure for liquefaction is put into the upland pond, the water supply for the farm-buildings must of course be taken from the contour catchwater drain before the stream enters the pond. But where the wrought-iron tank already described is adopted, one pipe and stream of water will suffice for all purposes.

In such cases also, the wrought-iron tank would receive all the drainage and sewage of the buildings, as well as the solid manure of the farm.

The improved value of the land supposed to be under-drained would amply repay the outlay, for the same reasons which prove land drainage generally to be highly remunerative. It would therefore be unfair to charge such drainage to the irrigation account, merely because the water has not been allowed to run to waste, as drainage water generally does, but has been turned to further use.

The following, according to Mr. Lee, may be taken as a general example of the cost of apparatus for the fertilization of 90 acres. The solid manure being put into an upland pond for liquefaction, and the iron pipe laid to obtain a pressure of 70 feet, with an average fall of 1 in 12; the distribution to be by flexible hose, and the land accessible to the jet from 400 yards of hose. The pond is supposed to be made in an average position, and to contain a head of 640 cubic yards of earthwork, at 1*s*. per yard. The estimate would, Mr. Lee states, be as follows, including all the distributary apparatus complete:—

| | £ | *s.* | *d.* |
|---|---|---|---|
| Pond or contour catchwater drain, as the case might be | 32 | 0 | 0 |
| Iron pipe 3 inches diameter, and laying and jointing 280 yards, at 2*s*. 4*d*. - - - - | 32 | 13 | 4 |
| 400 yards of prepared hose at 1*s*. 4*d*. - - | 26 | 13 | 4 |
| Grate, stopcock, and discharge pipe - - | 2 | 10 | 0 |
| | £93 | 16 | 8 |

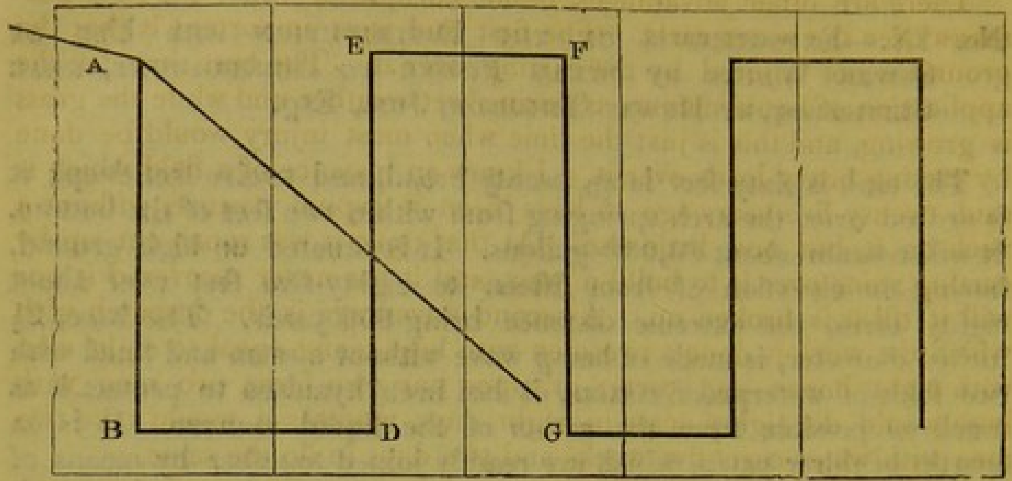
The whole outlay for these important objects being only a fraction more than 1*l*. sterling per acre.

No. IX.—EXPERIMENTS ON THE DISTRIBUTION AND USE OF SEWER WATER BY STEAM POWER TO AGRICULTURE, NEAR CLITHEROE, BY HENRY THOMSON, JUN., ESQ.

The tank is sixty feet long, twenty broad, and twelve feet deep; it is arched over, the arch springing from within two feet of the bottom. It will contain about 80,000 gallons. It is situated on high ground, having an elevation of from fifteen to eighty-five feet over about eighty acres, the extreme distance being 800 yards. The hose, $2\frac{1}{2}$ inches diameter, is made of hemp wove without a seam and lined with two folds of waterproof cotton; it has been kyanised to protect it as much as possible from the action of the liquid manure. It is in lengths of thirty yards, which are readily joined together by means of screw couplings with which the ends of each length are furnished. For the direction of the jet there is a mouthpiece five feet long and of the same diameter as the hose where it is joined on to it, and tapering off to the orifice, which is five-eighths of an inch diameter. I have tried various sizes of orifice and found this to be the best for extent of jet and quantity of liquor delivered, taken together. At a low pressure a larger orifice is better, because the quantity is increased while the length of jet is not materially shortened. Under high pressure a smaller orifice gives a longer jet, but the quantity delivered is less. The hose when in use requires two men: one to direct the jet, the other to assist him in moving the hose, putting on additional lengths, &c. The length of the jet is a very material point in this system. The following results, confirmed by repeated experiments, will show that it is fully adequate to the object in view. The fall is taken from the top of the water in the tank. The diameter of hose and orifice as stated before.

| Length of Hose Yards. | Fall in Feet. | Length of Jet in Yards. | Gallons per Minute. | Gallons per Hour. |
|---|---|---|---|---|
| 50 | 15 | $7\frac{1}{2}$ | $21\frac{1}{2}$ | 1290 |
| ,, | 24 | 12 | $33\frac{1}{2}$ | 2010 |
| 140 | 20 | 9 | 25 | 1500 |
| ,, | 32 | 15 | 40 | 2400 |

These experiments were made when I had only 140 yards of hose, and I have not repeated them with longer lengths, but I do not find that the jet increases much beyond 15 yards. It was about the same with 800 yards of hose and 80 feet of fall. Now there is very little of the land where there is less than 25 feet of fall, to the larger portion of it there is above 50. In the calculations which are to follow, it will be quite fair to take the jet at 15 yards, and the quantity at 2,010 gallons per hour. In the application of the jet to grass land, the only way I have tried it yet, the method is as follows. Suppose the field to be a square, the side of which measures, say 200 yards—




It is marked off by putting down a few sticks into stretches of 40 yards wide. The man with the jet starts at A and goes on to B, watering the whole breadth of the stretch before him and adding fresh lengths of hose as he proceeds. From B he goes to D, and then returns up the other stretch D E, but he does not require additional lengths, the other man moving the hose for him as he advances, so that he will get nearly to G before he requires additional lengths. At that point the hose will lie in the direction A G; and in this manner he proceeds over the whole field. Adding or taking off a length of hose was at first attended with some trouble, it being necessary to put down the valve at the tank and sometimes to empty the hose before it could be done, on account of the pressure. This is obviated by a simple contrivance—two pieces of wood and two screws thus,

between which the hose is placed, and on tightening the screws is effectually closed. The next consideration is the cost of the application. We have already stated the quantity delivered per hour to be 2,000 gallons, and this I shall assume as sufficient for an acre, which gives 10 acres per day; the labourers are paid 2*s.* per day each, which makes the cost of the application 5*d.* per acre. The hose, at 1*s.* 2*d.* per yard, and 2*d.* per yard for kyanising and fitting up, cost 53*l.*

The per-centage to be charged on this amount for interest of capital and for wear and tear is at present a matter of speculation, but I have reason to suppose it would be covered by 5 per cent., on the capital and 10 per cent. for wear and tear, together 15 per cent., amounting on 53*l.* to 7*l.* 19*s.* to be charged on 80 acres, being 2*s.* per acre. I may here observe that had the tank been more favourably situated, had it been the centre of a circle instead of the apex of a triangle, the same length of hose would have sufficed for 415 acres, and then the per-centage would only amount to 4½*d.* per acre. As it is, however, the cost is 2*s.* per acre and 6*d.* for the labour, making 2*s.* 6*d.* I have, for the sake of comparison, made a recent trial with water carts. The result was that two men with two horses making in all fifty-six journeys, covered in two days five acres, the distance from the tank being 600 yards. Five shillings per day in this country is a low charge for a man and horse, and rating it at this it gives 20*s.* for the five acres, or 4*s.* per acre.

There are other advantages, beside cheapness, which the hose possesses over the water carts. The first and most important is that the ground is not injured by the carting over it. The best time for the application of liquid manure is during wet weather and while the grass is growing, and this is just the time when most injury would be done by carting heavy loads over it. I know an instance of a field which is said twenty-five years ago to have been a capital pasture, without a ruck on it, but now little else. At that time it was much cut up by carting stone over it to build a weir, and it has never recovered it nor will it till it is broken up. A second advantage is the despatch with which the work is done: two men with hose being equal to eight men with eight horses and carts; or, upon our own farm, two men with hose would do eighty acres in eight days, whereas it would take two men with water carts five weeks and two days to do the same.

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No. X.—Sewage Irrigation. Trial of the Application of Sewer Manure from a single House,* communicated by Cuthbert W. Johnson, Esq.

The word "irrigation" too naturally induces the cultivator to remember only the meadow lands lying by the banks of copious streams; or, if he extends his views to the far more valuable system of sewage irrigation, he as naturally thinks of those favoured meads adjoining populous places—towns whose sewage is available in copious supplies. This, however, is taking a very limited view of the value of sewage irrigation, even on a small plot of ground to a farm. There are very many situations where the farmhouse is situated at such an elevation as to admit of its sewage being carried by its own gravity on to desirable lands adapted for the formation of watered plots of grass; and although the plots which are thus watered must be of limited extent, if they have to rely upon the house sewage *only*, yet where there is an available spring of water to dilute the sewage, or the steam engine can be employed, in that case plots of grass may be readily watered to an extent worthy of most farmers attention; for not only is one rood of such a mead fully equal in produce to three of ordinary pasture land, but it furnishes grass for the purpose of soiling, not only early in the spring, but late in the autumn—periods when it is not procurable from any other source.

As I observed on another occasion (*The Cottage Gardener*, edited by C. W. Johnson, vol. v. p. 39), the advantage of applying house sewage to grass has long been known to be very considerable. For the purpose of testing the various little points of detail which might arise when carried on on a small scale by small landholders, I laid down the turf on a plot of grass in my garden, near Croydon, in February and March 1850. This was only 16 yards long and 13 yards broad. The bed, therefore, contains only about 208 square yards, and is surrounded by a raised border of turf about two inches high, to prevent the escape of the irrigating sewage; and for a similar purpose the bed is divided by two turfed ridges of about the same size into three compartments. These ridges would have been repeated crosswise, so as to divide the bed into nine compartments (to suit the size of our beds to the bulk of our sewage), had we not wished to

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* Containing a family of 5 persons.

avoid impeding the action of the scythe, the whole produce being intended for the soiling of a pony. Soon after the bed was formed, earthenware pipes of about two inches bore were laid down, extending from a tank constructed on some higher ground than the grass plot, the contents of which, whenever the tank is sufficiently filled, is allowed (by the lifting of a plug) to flow on to the grass—the orifice of the pipe from whence the sewage issues being about eight or nine inches above the level of the turf. From this pipe the sewage is distributed, by means of an open wooden trough, to any part of the plot that is just cleared. Our practice has been to cut sufficient grass for two days consumption, and then immediately the grass is removed to direct on to the cleared space all the sewage which has accumulated since the last cutting, occasionally adding to its bulk by allowing some pump water to flow for a minute or two from the sink through the house-pipe drain into the tank. By this plan the collateral advantage has arisen, that the sewer pipe, tank, and delivery-pipe, as well as the house sewage itself, by being so constantly cleansed or removed, has not time to undergo putrefaction. The plan, therefore, is carried out (generally the first thing in the morning) without any of the inmates or visitors to the house being aware that such a manuring is systematically going on. The result, in fact, shows that the noxious effluvia from sewers arises, not as a necessary result of the matter conveyed in them, but from their ill construction, and the barbarous practice of allowing the long accumulating contents of overflowing cesspools and choked drains to flow into them.

The general result of this little experiment has been such as to induce me to confidently and warmly recommend the repetition of the plan to such of my readers who are so situated that the contents of their house-tanks can be directed by its own gravity on to a conveniently placed grass-plot. The herbage produced by this mode is not only exceedingly luxuriant, but the pony and some goats we notice decidedly prefer it to either lucern or meadow grass, produced without irrigation; and the same remark is made by one of my neighbours, who has a field irrigated with the water of the river Wandle, which contains occasionally a notable portion of the drainage of the town of Croydon.

It is, perhaps, of little use (as our turf was only laid in March) to report one season's produce of grass; still as we have kept an account of it, it may be cheering to the reader to have the account. The grass was not ready to cut the first time until May 25th, since the turf had to establish itself, and to contend with dry weather. The weight and the days of cutting were as follows:—

| | lbs. |
|---|---|
| May 25 | 28 |
| „ 27 | 40 |
| „ 30 | 42 |
| June 1 | 50 |
| „ 3 | 60 |
| „ 8 | 65 |
| „ 10 | 50 |
| „ 12 | 50 |
| „ 15 | 50 |
| Total | 543 |

The ground was then irrigated, as I before described, only once It began to grow again *immediately*, and kept on in spite of a very dry season, which *parched up all the surrounding* grass lands. By July 27th it was ready to cut again—the produce being evidently better than before. The days of cutting, and the weight of this second crop, were then—

| | lbs. |
|---|---|
| July 27 - - - - - | 75 |
| „ 30 - - - - - - | 65 |
| Aug. 1 - - - - - - | 55 |
| „ 3 - - - - - | 40 |
| „ 5 - - - - - - | 60 |
| „ 7 - - - - - - | 50 |
| „ 8 - - - - - | 40 |
| „ 10 - - - - - | 75 |
| Total - - - | 460 |

The same plan was a third time carried on of cutting and irrigating; the same dry weather still attended us, and the same growth of grass took place. On the 1st of October the cutting of our third crop of grass was commenced. The produce was as follows:—

| | lbs. |
|---|---|
| October 1 - - - - - | 70 |
| „ 5 - - - - - | 50 |
| „ 7 - - - - - - - | 50 |
| „ 9 - - - - - - | 50 |
| „ 11 - - - - - | 50 |
| „ 14 - - - - - | 45 |
| „ 16 - - - - - | 45 |
| „ 18 - - - - - | 45 |
| Total - - - | 400 |

The same immediate irrigation was applied to the land, and the same rapid shooting of the grass for the fourth time took place. The reader will remark that we thus secured three crops, and lost the time (in February and March) sufficient for the growth of a fourth; but, omitting that from our calculations, we have mown 1,295lbs. of grass off 208 square yards of land since the turf was first laid in March, or at the rate of 13¼ tons per acre.

The produce of the grass from this plot, in 1851, showed clearly that the land had increased in fertility by this system of irrigation. The first cutting was as follows:—

| | | | lbs. |
|---|---|---|---|
| May 23 | - - | Grass cut | - - 70 |
| „ 26 | - - | „ | - - 80 |
| „ 29 | - - | „ | - - 70 |
| „ 31 | - - | „ | - - 80 |
| June 3 | - - | „ | - - 80 |
| „ 5 | - - | „ | - - 30 |
| „ 7 | - - | „ | - - 0 |
| „ 9 | - - | „ | - - 60 |
| „ 11 | - - | „ | - - 100 |
| „ 14 | - - | „ | - - 60 |
| „ 16 | - - | „ | - - 60 |
| | | Total | - 750 |

or 325 lbs. more than the first cutting in 1850.

The second crop yielded the following weight of grass:—

| | | lbs. |
|---|---|---|
| July | 24 | 100 |
| " | 28 | 100 |
| " | 31 | 90 |
| Aug. | 2 & 4 | 80 |
| " | 5 | 80 |
| " | 19 | 70 |
| | Total | 520 |

or 60 lbs. more than the second cutting in 1850. The third crop is now (September 1) growing rapidly. If we allow another 520 lbs. for the third crop, we shall have this year mown 1,790 lbs. of grass from the 208 square yards, or at the rate of more than 18¼ tons of grass per acre.

The produce would be far greater if we had a greater bulk of sewage to bestow upon it. This is indicated by the superior luxuriance of the grass growing around the troughs, from which some of the sewage occasionally overflows in its way to other portions of the grass plot, and to land devoted to other crops.*

CUTHBERT W. JOHNSON.

1st September 1851.

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No. XI.—EXTRACT FROM A LETTER, DATED OCTOBER 11th, 1851, FROM JOHN ROE, ESQ., C.E., GIVING AN ACCOUNT OF SOME TRIALS BY HIM OF THE APPLICATION OF LIQUID MANURE FROM A SINGLE HOUSE.†

In reply to your inquiry, respecting the result of my last experiment on the application of sewage water to meadow land, I beg to state that the quantity of land experimented on was a quarter of an acre.

Nature of the soil { Vegetable mould, varying from 9 to 18 inches in depth. Subsoil, a stiff clay.

Drains 20 feet asunder, at an average depth of 2 feet.

Sixty gallons of foul water from a house with water-closets and from stable each day on an average for 26 weeks, diluted with six times that quantity of pure water.

The watering applied immediately after each cutting of grass, put on as the cutting proceeded.

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* *The inoffensiveness of well-regulated sewage.*—I have found, by the experience of about three years, that house sewage drained through impermeable pipes into a water-tight tank may be even stored for four or five days without becoming offensive, when, indeed, in the summer months (owing to our cutting the grass, and irrigating the cleared space almost daily) the sewer tank is so regularly and completely emptied, at least once in every 48 hours, that upon removing the lid of the tank there is no more, or perhaps not so much, odour perceptible than from a London water butt. The house sewage indeed retained in an impermeable receiver for even a few days differs very strangely indeed in its degree of fluidity and other qualities from the noxious contents of an ordinary cesspool from which the more fluid portion of sewage is constantly straining. From these and other observations I am led to the conclusion, that the town sewage conveyed on to the land, not from overflowing cesspools, but direct from the houses, through impermeable pipes, will not possess any properties offensive to the adjoining inhabitants.

† The family consists of 3 persons, and 1 pony is kept.

Five crops of grass cut in 26 weeks; kept one working horse in excellent condition for that period without hay or corn.

The water passed through a tank in which the stable dung was placed.

The water was pumped up by hand, and distributed by the use of small wooden spouts or troughs.

The experiment was made within 200 feet of a row of second-rate houses, and close to the garden walls of the same; no one felt the slightest effluvia arise from the irrigation.

The first crop one year was began cutting in April; another year on the 2d of May; weighed at the rate of 9 tons per acre (green).

The money matter to me stood as follows:—

| | £ | s. | d. |
|---|---|---|---|
| Man's time pumping water, and attending troughs, cutting grass, and carrying it to stable - - - - - | 2 | 8 | 0 |
| Rent of land (5*l.* per acre) - - - | 1 | 5 | 0 |
| | 3 | 13 | 0 |
| 26 weeks keep of horse at 8*s.* - | 10 | 8 | 0 |
| Cost to deduct - - - | 3 | 13 | 0 |
| Profit on a quarter of an acre per annum - | 6 | 15 | 0 |
| | | | 4 |
| Or, per acre - - - - - | 27 | 0 | 0 |

The first year's saving more than paid for the pump and troughs, and draining the land.

The grass from this particular plot had previously been sold to a cowkeeper at 8*l.* per acre per annum.

I have just began the same course on meadow land, having from 3 to 6 inches depth of vegetable mould, and a gravelly subsoil.

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## No. XII.—Instructions on the Use of Liquid Manures, drawn up by Professor De Candolle, and approved of by the Committee of Agriculture of the Society of Arts at Geneva.*

### GENERAL UTILITY OF LIQUID MANURES.

All countries in which liquid manures are collected with care have acknowledged their utility, and travellers are struck with the general beauty of the meadows and other crops where these manures are used. Flanders has had in this respect a reputation of long standing. In those parts of England where these processes have been introduced a remarkable increase of production has been observed; and the luxuriance of the meadows in German Switzerland, and particularly in the cantons of Zurich, Argovie, and Berne, attest these truths in the strongest manner.

* I was at considerable trouble to obtain this paper, which was scarce on the Continent, and has not, that I am aware, been translated or appeared in English before.—E. C.

We shall not be surprised at the results which experience has given in this respect if we can reflect,—1st. that manures begin to serve as food for plants only when by successive operations they are almost entirely dissolved in water; 2d. that animal liquids, such as urine, the contents of drains from stables, and house sewers, contain a large quantity of nutritive substances and stimulating principles.

### ON VARIOUS METHODS OF USING LIQUID MANURES.

Two methods of using liquid manures are to be distinguished: either they are distributed on lands already covered with vegetation for the purpose of immediately increasing the growth of the crop, or they are used on fallow land for the purpose of storing up in it a certain quantity of nutritive matter ready to be absorbed by the crop that is to follow. This difference of object requires a similar difference in the nature of the liquids to be employed and in the method of using them. When it is intended to spread it on living vegetation care must be taken, first, that the manure is not so strong as to burn the crop, nor so diluted as to reduce the benefit merely to that arising from irrigation with so much water; secondly, the manure should be distributed at a proper time relatively to the age of the plants, to the season, and to states of the atmosphere. On the other hand, when the object is to spread liquid manure on fallow land as a store of nourishment, the strength of acridity of the manure need not be dreaded; neither is there any fear that the time may not be suitable. The first method requires more care and attention, but gives larger immediate results; the second is more certain, easier, and more generally applicable.

### ON THE MODE OF COLLECTING LIQUID MANURES.

The liquid manures used in agriculture are, first, drainings from stables and cow-houses; second, urine from dwelling-houses; third, the greasy water from sinks and from manufactures in which animal or vegetable substances are used.

The drainings from stables are obtained in two ways, and the properties of the manures differ widely according to the mode of their extraction and fermentation.

1st. The name of "lizier" (in German, Gülle) is given to the liquid manure when it is received immediately from the stable into vessels or boxes under ground, where it is allowed to undergo a mucous or slimy fermentation, during which process it ought not to be stirred. It is this "lizier," not less than that which drains from the dunghill, and more charged with mucilaginous matter, which ought especially to be used on meadow land.

The method of collecting this manure recommended by the agriculturists of Zurich, is as follows:—The floor on which the animals stand is made of planks, and inclined about four inches from the head to the feet of the cattle, and is proportioned to their size, so that the excrement may fall into a channel which runs the whole length of the stable or cow-house. The depth of this channel is fifteen inches, and its width ten inches. It should be so placed as to receive, when desired, a stream of water from a cistern. It communicates with five vessels or boxes; a door or lid, which is lifted up, serves to empty the channel into the vessel. These boxes or vessels are covered by a flooring a little below the level of that on which the cattle stand. It is important that the vessels should be covered, in order to facilitate fermentation. They are made of masonry, well pargetted, and the bottom of clay firmly beaten together so as to prevent infiltration. They usually make five vessels, in order that the liquid may remain undisturbed during fermentation, which lasts about four weeks. Their size is made in proportion to the number of cattle, so that one vessel may be filled in a week. The "lizier" is emptied from the vessels by portable pumps of about nine-inch bore. Every morning, when the man enters the stable, he finds the channel partly filled with the water which he had let in over-night, and partly with the excrement. He mixes the water with the manure that is in it, carefully crushing the more compact parts, so as to form of the whole an evenly-mixed and flowing liquid; for it is on the perfection with which this part of the process is done that the good quality of the "lizier" mostly depends. It ought to be neither too thick, for then it ferments too slowly, nor too thin, as then it will not be sufficiently nutritive. When the mixture is complete, the channel is emptied into the vessel by the trap-door, and the man again lets water into the channel. In the course of the day, every time he comes into the stable, he throws into the channel the dung that may have fallen underneath the cattle, and the channel may be emptied as soon as the liquid it contains is sufficiently thick. The proportions of the liquid should be, if the cattle are fed with grass and hay, three-fourths of water to one-fourth excrement; if they are fed with grain, and being fattened, four-fifths of water to one-fifth of excrement.

2d. The name of manure water (in German, Jauche) is given to the liquid which flows from the dunghill. This liquid is of quite a different nature from the former; all the mucilaginous substances of the dung have been gradually destroyed by the long fermentation of the manure, and little is left in the liquid that flows from it but salts, which are often very acrid, and large quantities of carbonaceous matter (*des matières carboniques*). It may be considered, therefore, that it is dangerous to apply this manure water directly to growing plants, as it would burn by its acridity. But it is very useful when put on land before the crop is planted. To collect this water, the dung-heap is placed on a spot well paved and cemented, and having a slight inclination, so that all the liquid may drain into a hollow made at one corner. Water may be brought to the dung-heap by a pipe placed at the opposite corner. By means of the pump mentioned before, they can at will either water the dung-heap with the liquid in the hollow, or throw it on the heaps of earth, or any other substances that are intended for compost.

Even when, from the position of the locality, the whole of the method of preparing "lizier" which has been described above cannot be carried out, yet the great advantages of liquid manure should not be entirely renounced. It is sufficient that the stable is so placed as to allow all the liquids from it to drain into a covered tub or hollow, whence it may be taken out and distributed upon the meadows in winter, and in summer upon the compost beds. The liquid may also be allowed to run into pools, and used for watering lawns and gardens.

The liquid which in many localities can be drained from privies may be used for the same purpose as the above-mentioned manure. Lastly, the greasy water from sinks and wash-houses may be collected either into the vessel of the "lizier," or into the pool containing "manure water," and increase the quantity with advantage.

### ON THE METHOD OF USING LIQUID MANURES FOR WATERING LIVING VEGETATION.

The "lizier" ought never to be spread upon the meadows when the grass has sprouted, but always when it is about to spring. Thus, at the end of winter they may be watered with "lizier" very advantageously, and during summer the meadow may be watered immediately after the grass has been cut. On those fields which are mown several times in the year to furnish green food for the cattle, and where consequently only a small part is mown at once, especial care should be taken to distribute the "lizier" on the part which has just been cut; it is from this continued care that the meadows in German Switzerland are always in that luxuriant condition which is so much admired by travellers. Using "lizier" in summer requires greater care in the preparation of it, for if it be too strong there is much risk of the vegetation being injured by it; the danger is much less in winter. The acridity of the "lizier" may be diminished by diluting it with the water from the pools before mentioned. It ought to be remarked also, that when the weather is dry the liquid manure ought to be diluted with a larger quantity of water than is usually mixed with it, and on the contrary, when the weather is rainy and the soil is filled with moisture, a stronger "lizier" may be used with advantage.

### ON THE METHOD OF USING LIQUID MANURES FOR IMPROVING FALLOW LANDS.

There are two ways of using liquid manure for improving the soil: either, first, by watering the land itself which is to receive the crop, or secondly, by watering with the liquid manure the heaps of earth and other matters destined to be carried afterwards upon the land. The first method is simple and practicable, care being only required to spread the manure upon land which has already been prepared by the plough, in order that it may infiltrate quickly, and not remain long upon the surface, as the action of the air destroys a large portion of the manure. On this account it is better to distribute the liquid a short time only before the land is to be planted.

The second method of improving lands by liquid manure is with compost. It is formed of alternate layers of earth and rubbish and sweepings, and any kind of animal or vegetable matter capable of putrefaction. This heap is watered from time to time with the liquid that drains from the dunghill or from dwelling-houses; care must be taken that the heap is made rather hollow at the top, so that nothing may be lost that has been thrown on; the whole heap is well mixed together twice a year, in order that every part may be equally impregnated and amalgamated. These compost beds ought to be placed in a shady spot, so as to prevent them being dried. It is well to have two heaps; one in progress, and which serves to receive all the rubbish that can be collected; the other completed, and only receiving the liquid manure. On large farms the number may be increased with advantage; and then it is useful to vary their contents, in order to prepare a soil of different qualities, and applicable to different crops and lands. Where there is more liquid manure than is required for the compost beds of rubbish, simple earth may be usefully saturated with the manure. For this purpose a heap of earth is made in the form of a truncated sugar-loaf, the top slightly depressed in the shape of a cup, and from time to time manure water, or "lizier," or the drainage from dwelling-houses, is poured into this hollow. Some farmers put a wheelbarrow full of sand morning and evening into the channel which receives the urine of the cows, and afterwards use this sand, saturated with "lizier," for improving and manuring stiff lands, *terre compacte*. In this respect, compost formed of dead leaves, mixed with a little earth, and frequently watered with "manure water," with "lizier" or greasy water, cannot be too highly recommended. The leaves contain a large quantity of silicious earth, and the constant use of this compost is a certain means of improving in length of time clayey soils.

The following are the rules for the application of water to plants laid down by De Candolle, which should also be considered in the distribution of liquid manures:—

A. *The quality of the water used.*

That it should be well aërated; the presence of atmospheric air is good, but of carbonic acid gas much better. The next qualities desirable are, that it should contain fertilising matters; the water should be as little muddy as possible; the temperature of the water is of importance, especially for hothouse plants: the water used in hothouses is allowed to stand for some time before it is employed, in order that it may have the temperature of the place; it is well that other water employed should stand for a time in the sun.

B. *The times of the application:*

In the winter-time there should be little irrigation, because the plants are then dormant, and water is then superabundant. In spring-time water is usually abundant. In summer it is wanting; and at that time the water should be given in the evening.

C. *The quantity of the water to be applied, which should be varied according—*

1. To the object of the culture: when for leaves, more water should be given than when for flowers; less water should be given when for fruits or grains.

2. The depths of the roots; the application should be more frequent to the plants which the roots are superficial; less frequent to deeper roots.

3. The structure of the foliage; those which evaporate much, such as plants with large leaves, more frequently than perennial, or plants with thick leaves.

4. The consistence of the stalks and of the roots serves to guide the application. Roots with fleshy fibres, such as the (protea?) do not thrive if too abundantly watered, at the same time they are injured by dryness. Tuberculous or bulbous plants, or plants with fleshy leaves,

can bear a long-continued dryness, and therefore infrequent yet abundant waterings suit them well.

5. In regard to the stage of vegetation, it is important to bear in mind that young germinating plants require light and frequent waterings; those that are in the height of growth abundant waterings; and when the fruit or seed is being matured the waterings should be infrequent. Those that have been transplanted require abundant watering.

6. The nature of the soil, according to which these rules must be modified. The lighter the soil the more frequent and plentiful must be the waterings. If it is a compact and clayey soil less watering will be required.

7. The state of the atmosphere. It will be readily conceived that the watering must be more frequent when the temperature is high, the sky clear, and the air dry, and during drought.

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## No. XIII.—The Flemish Method of collecting and applying Town Manures. By Boussingault.

From the interesting inquiries upon urine made by M. Lecann, it appears that a man passes nearly half an ounce of azote with his urine in the course of twenty-four hours. A quantity of urine taken from a public urine-pail of Paris yielded 7 per 1,000 of azote. The dry extract of the same urine yielded nearly 17 per cent.

Human soil as commonly obtained consists of a mixture of feculent matters and urine. It may be applied immediately to the ground as it comes from the privy. In some parts of Tuscany it is mixed with three times its bulk of water, and so applied to the surface. I have myself seen nightsoil as it was obtained, and without preparation, spread upon a field of wheat without any ill effect, so that the Tuscan preparation may be regarded as a simple means of spreading a limited quantity of manure over a given extent of ground.

It is in French Flanders, however, that human soil is collected with especial care; it ought to be so collected everywhere. The reservoir for its preservation ought to be one of the essential articles in every farming establishment, as it is in Flanders, where there is always a cistern or cesspool in masonry, with an arch turned over it, for the purpose of collecting this invaluable manure. The bottom is cemented and paved. Two openings are left, one in the middle of the turned arch for the introduction of the material, the other, smaller and made on the north side, is for the admission of the air which is requisite for the fermentation.

The Flemish reservoir may be of the dimensions of about 35 cubical yards. Whenever the necessary operations of the farm will permit, the carts are sent off to the neighbouring town to purchase nightsoil, which is then discharged into the reservoir, where it usually remains for several months before being carried out upon the land.

The favourite Flemish manure is applied in the liquid state (mixed in water) before or after the seed is in the ground, or to transplanted crops after they have been dibbled in. Its action is prompt and energetic. The sowing completed, and the land dressed up with all the pains which the Flemish farmer appears to take a pleasure in bestowing upon it, a charge of the manure is carried out at night in tubs or barrels. At the side or corner of the field there is a vat that will hold from 50 to 60 gallons, into which the load is discharged, and from which a workman, armed with a scoop at the end of a handle a dozen feet in length or more, proceeds to lade it out all around him. The vat emptied in one place is removed further on, and the same process is repeated until the whole field is watered.

The purchase, the carriage, and the application of this Flemish manure cannot be otherwise than costly, we therefore see it given particularly to crops which, when luxuriant and successful, are of the highest market value—such as flax, rape, and tobacco.

The wheat stubble is ploughed down at the end of the autumn, and about 1,000 or 1,100 gallons of the liquid manure per acre are distributed; the oats are sown in the spring.

For beet, the dose of Flemish manure is carried the length of from 1,300 to 1,400 gallons per acre.

The price of Flemish manure at Lisle is 2½*d.* for a measure containing 22 gallons. In Flanders it is held that this quantity, which will weigh very nearly 2 cwt., is equal to about 5 cwt. of farm-yard dung.

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## No. XIV.—Experience in Germany on Liquid Manures, as stated by Sprengel.

When the *gülle* is applied as a top-dressing we must take care that in pumping it into the barrel in which it is carried into the field no agitation takes place, otherwise the decomposed particles, consisting of vegetable fibre, will lie on the leaves of the young plant and produce an injurious incrustation.

In summer it should be applied only in wet weather, otherwise the plants, when the soil is dry, will receive too concentrated a nutriment, and consequently become rather worse than better. We might, indeed, obviate the evil by a greater dilution of the *gülle* with water; but the labour of carting it out of the field would then become too much increased.

On account of the labour of carriage, the *gülle*, generally speaking, can only be applied to fields and meadows which lie near the homestead, unless you proceed with it as they do in the Black Forest, where the *gülle* pits are made in the fields and meadows, or close to them. The most indispensable requisite in the preparation of *gülle*, as we may easily suppose, is a sufficient supply of water; and that water is best adapted for the purpose which holds a large quantity of saline particles in solution, for then the soil obtains additional substances which afford nourishment to plants.—(*Sprengel's Work on Animal Manures.*)

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No. XV.—Paper showing the amount of certain elements contained in the food of man, and requisite for the growth of plants; also the amount of such elements, according to analysis by Dr. R. Angus Smith, contained in the river Medlock, a stream which serves as the main sewer for about one third of the borough of Manchester, and is one of those which receives vast quantities of dye-house refuse.

It must be evident that the species of manure proposed to be conveyed to the land will be far more valuable than guano or any other kind which can be supplied, inasmuch as the refuse of a town has necessarily all those elements contained in the food of the inhabitants except those which may escape in the form of gas, and those which are inevitably wasted. As, however, the area from which the inhabitants derive their food will exceed many times that to which the irrigation can be extended, it follows that the food of plants,—the elements which human food contains,—must be supplied to the irrigated districts in far greater abundance than it is removed; since not only is all that is taken from such land (except that which is supplied by the air) returned to it, but much which is brought, in the form of food, from distant places is also added. It follows, therefore, that the fertility of such land will be constantly and rapidly increased; which circumstance accounts for the high value which land irrigated with sewer water rapidly attains.

The following tables show the quantity of the elements of plants contained in the food annually consumed by a hundred adult persons, as ascertained by actual observation. The 44,400 lbs. of farinaceous food are taken as about equal to 93 quarters of wheat, which would grow on about 20 acres of good land:—

Quantities of the elements of food contained in the provisions consumed by one hundred adult persons.

| —— | 44,400 lbs. of farinaceous food.* | 26,000 lbs. of Potatoes and Vegetables, 4 lbs. per week each. | 36,500 pints of Beer, at 15 gallons to the bushel. 300 bushels of Malt, one pint per day each. | 13,000 lbs. of Meat, or 11,143 lbs. deducting 1-7th for fat, 2¼ lbs. per week each. | 4,333 lbs. of Bone. | 4,600 lbs. of Cheese, 2 oz. per day each. | Total Quantities. |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Potass and Soda - | 368 | 193 | 103 | 70 | 13 | 80 | 827 |
| Lime and Magnesia - | 177 | 20 | 58 | 10 | 2,889 | 4 | 3,158 |
| Phosphoric Acid - | 486 | 13 | 85 | 60 | 1,039 | 30 | 1,713 |
| Silica - - | 21 | 3 | 142 | - - | - - | - - | 166 |
| Metallic Oxides - | 5 | fraction | - - | fraction | - - | - - | 6 |
| Nitrogen - - | 1,021 | 94 | 242 | 580 | 75 | 200 | 2,3[illegible] |
| Sulphur and Chlorine - | - - | 23 | 4 | 4 | 2 | 54 | 87 |

* This is the proportion of farinaceous food consumed at the Hanwell Asylum for Lunatic inmates; it is somewhat greater than the average consumption. Allowing the loss of weight in grinding to be equal to the gain in cooking, 44,400 lbs. of such food is equivalent to about 93 quarters of wheat, which would grow on less than 20 acres of good land.

QUANTITIES of the ELEMENTS of FOOD REMOVED from 100 ACRES of SOIL by the usual four-course system: and the quantities which would be supplied by the excretions of one hundred adult persons.

| —— | 25 acres of Wheat, five quarters per acre. | 25 acres of Barley, five quarters per acre. | From the land in flesh of Animals. | 40 Lambs at 90 lbs. each. | Four Calves. | Four young Cows. | Two young Horses. | Carried away from 50 acres of Wheat and Barley, and 50 acres of green crops. | Excretions of 100 adults contain — |
|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Potass and Soda - | 470 | 395 | 10 | 8 | 2 | 4 | 2 | 780 | 827 |
| Lime and Magnesia - | 350 | 225 | 144 | 250 | 27 | 45 | 22 | 948 | 3,158 |
| Phosphoric Acid - | 680 | 430 | 145 | 210 | 21 | 42 | 21 | 1,549 | 1,713 |
| Silica - - | 30 | 420 | - - | - - | - | - | - | 450 | 166 |
| Metallic Oxides - | 4 | 4 | - - | - | - | - | - | 8 | 6 |
| Sulphur and Chlorine - | - - | - - | 5 | 12 | 1 | 2 | 1 | 21 | 87 |
| Nitrogen - - | 1,360 | 1,030 | 113 | 128 | 15 | 23 | 12 | 2,681 | 2,312 |

By these tables it is evident that if all the excrementitious matter of a given population were returned to the soil, it would maintain in fertility more than as many acres as there are inhabitants, if those elements only which are shown to be deficient were added,—viz., silica and nitrogen; the former of which would be supplied by the disintegration of the soil, the latter by the ammonia contained in rain. The refuse, however, of such a town as Manchester contains enormous quantities of valuable matter not included in the above tables; for instance, large quantities of alkali contained in soap; manure of horses, cattle, pigs, and other animals; and refuse from manufactories. The quantity of such matter varies exceedingly according to the changes in manufacturing activity.

On October 2d, 1845, the river Medlock, according to the analysis of Dr. R. Angus Smith, brought down the following substances: and there is no reason for supposing that they were on that day in unusual quantity.

| | Per diem. | Per annum. |
|---|---|---|
| Potass - - - | 178 cwt. | 3,200 tons. |
| Soda - - - - | 257 ,, | 4,640 ,, |
| Lime - - - | 940 ,, | 16,900 ,, |
| Magnesia - - - | 9 ,, | 160 ,, |
| Phosphoric acid - - | 71 ,, | 1,280 ,, |
| Silica (in solution) - - | 266 ,, | 4,800 ,, |
| Alumina (do.) - - | 18 ,, | 320 ,, |
| Oxide of iron - - - | 124 ,, | 2,240 ,, |

| | Per diem. | Per annum. |
|---|---|---|
| Sulphuric acid - - | 444 cwt. | 8,000 tons. |
| Chlorine - - - | 151 „ | 2,720 „ |
| Organic matter, 1,355 cwt., containing 6 per cent. of nitrogen, or - - - | 80 „ | 1,440 „ |
| Insoluble matter, chiefly silica, alumina, and iron - - | 1,866 „ | 33,600 „ |

It will be noticed that five of the most valuable substances for agricultural purposes, viz., potass, soda, silica, phosphoric and sulphuric acids, are here contained in great abundance which now run to waste. The Irwell probably brings down twice as much as the Medlock of all these substances, all of which will be saved and usefully employed by the adoption of the Company's plan.

It may perhaps be not quite correct to conclude that the quantities of these substances brought down are always as great as on the day of examination, but if they be, the annual quantity of each, in tons, would be as is stated in the last column of the table. The matter contained in the water of the Irwell has not been ascertained, but it probably much exceeds that of the Medlock. Large quantities of materials valuable in agricultural, besides night soil, &c., are not included in the calculation, as, in consequence of deficient drainage, they do not at present find their way into the rivers. When the drainage is complete the quantity of phosphoric acid, nitrogen, and the alkalis will be largely increased. The phosphoric acid at present brought down by the Medlock alone is sufficient to supply 95,000 acres of ordinary wheat crops, 184,000 acres of clover, 258,000 acres of potatoes, or 280,000 acres of oats. The silica in solution in the waters of the Medlock would supply 50,000 acres of wheat, and the other elements would respectively supply still larger extent of cultivation. It may be said that it will be difficult, if not impossible, to convey by irrigation the sewer waters of the town to any such extent of country, and that is very true. But there is no reason why the food of plants may not be profitably applied to the soil in quantity far exceeding that required for ordinary crops. This has indeed been done at Edinburgh and elsewhere, and the limit of profitable application does not appear to have been yet reached, even though the productiveness of the land has been increased many times and the rent raised from an average of 3*l.* to an average of 30*l.* per acre, and this too by a much less perfect application of the refuse water than that now proposed.

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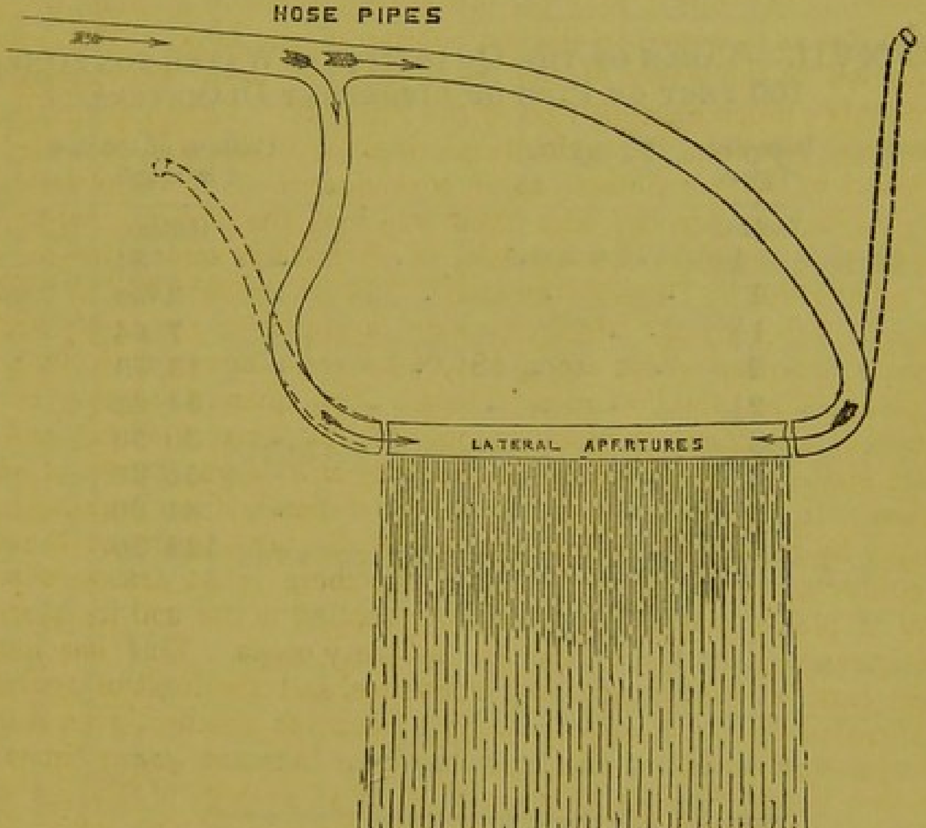
No. XVI.—Extract from a Report by Mr. Donaldson, Surveyor, on the Application of Manure by a Hose with Lateral Openings.

The annexed diagram shows roughly the way in which I attached the hose pipes for conveying the liquid to that with the lateral apertures. All that is necessary in the operation of applying the liquid, is for the labourers to move the hose-pipes gradually across or over the ground, or where it is not level; up the ground, beginning at the bottom of the field.

Where the sewage is supplied through pipes laid down in the ground, with stand-pipes, the two ends of the hose, with lateral apertures, may advantageously be supplied from two of these stand-pipes, as shown by the dotted lines in the diagram, the length of the service-pipes being just sufficient to reach from one stand-pipe to another.'




The hose used for the transit of sewage was $4\frac{1}{2}$ inches diameter, the branches from it, used with jets, was $2\frac{1}{2}$ inches, the length of main trunk for transit varied with circumstances, the least 25 yards, the greatest 450; the greatest elevation at which it was discharged was 30 feet above the barge deck. The size of hose, with lateral apertures, was 3 inches in diameter. I had calculated the proper size of the apertures very nicely, beginning at $\frac{3}{16}$ of an inch, and increasing in size up to $\frac{7}{16}$, or nearly half an inch in 100 feet of hose; but I found some difficulty in graduating them so nicely in practice, and so adopted two sizes of aperture, of which the smallest was a quarter of an inch in diameter. The length of delivery-hose, with lateral apertures, used was 25 yards; and we could not effect an equal distribution by supplying sewage at one end of it only, not having force enough, but on applying it at both ends, effected it very satisfactorily.

The length of the shedding-hose must be proportionate to the force or pressure at command, and the size of the lateral apertures proportionate to their distance apart; and a variation of their distance apart will effect the same thing as a variation in their size.

NOTE.—Gutta percha tubing is highly convenient for the ready adjustment of the lateral apertures, to the requirements of various pressures; the holes, if found too long, may be closed by heat.

## No. XVII.—Table of the Quantity of Water contained in 100 feet of Pipe of different Diameters.

| Diameter of pipe. | Contents of 100 feet in length. |
|---|---|
| Inches. | Gallons. |
| ½ | ·84 |
| 1 | 3·39 |
| 1½ | 7·64 |
| 2 | 13·58 |
| 2½ | 21·22 |
| 3 | 30·56 |
| 4 | 54·33 |
| 5 | 84·90 |
| 6 | 122·26 |

# No. XVIII.—Table of Experiments on the Friction through Hose Pipes,

## *Made at the Request of E. Chadwick, Esq., by P. H. Holland, Esq., Manchester.*

### EXPERIMENTS with Pumps and Canvas Hose at the Manure Yard, Hulme, October 28th, 1847.

High-pressure Engine, eight-horse power; Two Pumps of nine inches diameter, each 1 ft. 6 in. stroke; Ground almost level, but with one or two falls of about 3 feet. In experiments 18 to 20 hose had one long bend.

| Description. | Minutes worked. | No. of strokes of pumps. | No. of gallons delivered. | Length of large hose in feet. | Diameter of hose. | Area of hose. | Length of small hose in feet. | Diameter of hose. | Area of hose. | Velocity in feet per second through Large hose. | Velocity in feet per second through Small hose. | Discharge in gallons pr second. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | min. sec. | | | | Inches. | Sq. in. | | Inches. | Sq. in. | | | | |
| 1. Hose had a sharp bend | 1 5 | 11 | 37 | 60 | 4½ | 15·9 | | | | 0·83 | | 0·57 | |
| 2. Hose kept straight | 50 | 11 | 37 | 60 | 4½ | 15·9 | | | | 1·0 | | 0·74 | |
| 3. Velocity increased | 20 | 10 | 37 | 60 | 4½ | 15·9 | | | | 2·7 | | 1·85 | |
| 4. Ditto | 15 | 10 | 37 | 60 | 4½ | 15·9 | | | | 3·63 | | 2·47 | |
| 5. Double length of hose | 55 | 11 | 37 | 120 | 4½ | 15 9 | | | | 1·0 | | 0·67 | |
| 6. Ditto ditto | 15 | 10 | 37 | 120 | 4½ | 15·9 | | | | 3·63 | | 2·47 | |
| 7. Two small hose jet pipes, with flat spreaders | 1 0 | 11 | 37 | 120 | 4½ | 15·9 | | | | 0·91 | | ·62 | |
| 8. Ditto ditto | 20 | 10 | 37 | 120 | 4½ | 15·9 | | | | 2·7 | | 1·85 | |
| 9. Ditto ditto | 16 | 11 | 37 | 120 | 4½ | 15·9 | | | | 3·38 | | 2·3 | |
| 10. Three lengths of hose | 55 | 11 | 37 | 180 | 4½ | 15·9 | | | | 1·0 | | 0·67 | |
| 11. Ditto | 17 | 11 | 37 | 180 | 4½ | 15·9 | | | | 3·2 | | 2·2 | |
| 12. Three lengths of large | 1 15 | 12 | 37 | 180 | 4½ | 15·9 | 60, 60 | 2¼, 2¼ | 3·9, 3·9 | 0·72 | 1·40 | 0·49 | |
| 13. Hose as before, with two lengths of small hose | 25 | 14 | 37 | 180 | 4½ | 15·9 | 60, 60 | 2¼, 2¼ | 3·9, 3·9 | 2·0 | 4·0 | 1·4 | |
| 14. Same arrangement as above, with two flat spreaders | 20 | 14 | 37 | 180 | 4½ | 15·9 | 60, 60 | 2¼, 2¼ | 3·9, 3·9 | 2·7 | 5·4 | 1·85 | |
| 15. Without the jets | 1 10 | 12 | 37 | 180 | 4½ | 15·9 | 120, 120 | 2¼, 2¼ | 3·9, 3·9 | 0·7 | 1·4 | 0·51 | |
| 16. Ditto | 17 | 11 | 37 | 180 | 4½ | 15·9 | 120, 120 | 2¼, 2¼ | 3·9, 3·9 | 3·2 | 6·4 | 2·2 | |
| 17. With jets as before | 22 | 11 | 37 | 180 | 4½ | 15·9 | 120, 120 | 2¼, 2¼ | 3·9, 3·9 | 2·5 | 5·0 | 1·7 | |
| 18. Without jets | 40 | 13 | 37 | 180 | 4½ | 15·9 | 300, 300 | 2¼, 2¼ | 3·9, 3·9 | 1·3 | 2·6 | 0·92 | |
| 19. Ditto | 25½ | 12 | 37 | 180 | 4½ | 15·9 | 300, 300 | 2¼, 2¼ | 3·9, 3·9 | 2·2 | 4·4 | 1·5 | |
| 20. With flat jets on | 1 25 | 13 | 37 | 180 | 4½ | 15·9 | 300, 300 | 2¼, 2¼ | 3·9, 3·9 | 0·83 | 1·66 | 0·57 | |
| | 35 | 13 | 37 | 180 | 4½ | 15·9 | 300, 300 | 2¼, 2¼ | 3·9, 3·9 | 1·6 | 3·2 | 1·10 | Hose much distressed with the action of pumps. Larger air vessel required. |

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# GENERAL BOARD OF HEALTH.

# MINUTES

OF

# INFORMATION

COLLECTED IN RESPECT TO THE

# DRAINAGE OF THE LAND FORMING THE SITES OF TOWNS,

TO

# ROAD DRAINAGE,

AND THE

# FACILITATION OF THE DRAINAGE OF SUBURBAN LANDS.

**Ordered to be printed for the use of Local Boards of Health and their Surveyors, engaged in the Administration of the Public Health Act.**

JANUARY 1852.

Presented to both Houses of Parliament by Command of Her Majesty.

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1852.

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## APPENDIX.



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A 2

# GENERAL BOARD OF HEALTH.

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Minutes of Information collected in respect to the Drainage of Land forming the Sites of Towns, to Road Drainage, and the Facilitation of the Drainage of Suburban Land.

Town drainage is two-fold—foul-water drainage and simple-water drainage. The first comprehends sewerage as the term is now commonly used; that is, the removal from within dwellings or from their immediate neighbourhood of all solid refuse which can be carried off by water. The second—simple-water drainage—is the removal from the sites and suburbs of towns of superfluous water, causing dampness, whether such water be derived from land springs or rain-fall.

So generally is the latter or simple-water drainage neglected, that it appears from the late sanitary investigations that in town districts which are called drained, the foundations of the houses are very generally damp from the retentiveness, or the water-bearing power, of the soil in which they are built. Water rising from a damp foundation by absorption renders the floors and the walls damp, in proportion to the absorbent nature of the materials of which they are constructed. When experienced medical officers see rows of houses springing up on a foundation of deep retentive clay, inefficiently drained, they foretel the certain appearance among the inhabitants of catarrh, rheumatism, scrofula, and other diseases, the consequence of an excess of damp, which break out more extensively and in severer forms in the cottages of the poor who have scanty means of purchasing the larger quantities of fuel, and of obtaining the other appliances by which the rich partly counteract the effects of dampness. Excess of moisture is often rendered visible in the shape of mist or fog, particularly towards evening. An intelligent medical officer took a member of the Sanitary Commission to an elevated spot from which his district could be seen. It being in the evening level white mists could be distinguished over a large portion of the district. "These mists," said the officer, "exactly mark out and cover the seats of disease for which my attendance is required. Beyond these mists I have rarely any cases to attend but midwifery cases and accidents." Efficient drainage causes the removal, or at least a great diminution of such mists and a proportionate abatement of the diseases generated or aggravated by dampness.

After houses built in the manner described have been inhabited for some time, and especially if crowded, fevers of a typhoid type are added to the preceding list of diseases, in consequence of emanations from privies and cesspools. The poisonous gases, the product of decomposing animal and vegetable matter, are mixed with the watery vapours arising from the excessive damp, (such vapours being now recognized as the common vehicle for the diffusion of the more subtle noxious gases,) and both are inhaled night and day by the residents of these unwholesome houses. A further consequence of the constant inhalation of these noxious gases, which have an extremely depressing effect, is inducing the habitual use of fermented liquors, ardent spirits, or other stimulants by which a temporary relief from the feeling of oppression is obtained.

The system of drainage for houses, streets, yards, and covered spaces in towns which is now found to be the most economical as well as the most efficient for its main purposes, —the removal of matters injurious to the public health,— consists principally of tubular and impermeable drain pipes. The arrangements hitherto in general use for the purpose consisted of spongy brick drains, or drains of other material, which let in the land springs or the surplus moisture of the site, and when these brick drains were of proper inclinations they slowly carried it away, notwithstanding the obstacles created by their defective form, material, and construction; but too frequently on account of their permeability they let out and saturated the site with the foul water, which it is most important they should keep in and remove from it. Whilst these common brick drains thus let out much of the soluble portions of the cesspool matter, which saturates the foundations of houses, and ascends the absorbent brick walls, they detain, as sponges or as filters, much of the solid portions of the refuse matter. This accumulates in the drains and sewers, the gaseous products from its putrefaction escape through the permeable brick itself, and still more copiously through openings into houses, and through gully shoots into the streets, and pollute the atmosphere. *Vide Minutes of Information on House Drainage.*

As the apparatus for an improved system of house drainage must be impermeable, that all foul matter may be certainly removed—which it is most important should be removed quickly and completely and without any escapes whatsoever, either liquid or aerial,—the plain surplus land water, whether from upland springs or from the rain-fall in garden ground or in the space uncovered by houses or by the paving of yards or streets, will remain to be specially provided for, and it is deemed will be most economically carried off by arrangements of permeable pipes, on the same principle as those used for the drainage of land under cultivation.

It has been supposed by those who have not had sufficient practical acquaintance with the improved system of town drainage, that the rain water from the roofs of houses as well as from the roads should be separated from the refuse removed by the house drains, and carried away by other drains, but it is found that water from the roofs brings down soot and dirt, and that this water and the surface water from streets and roads of much traffic is often more foul even than common-sewer water, and is valuable as a manure; and unless there be a very large proportion of such water, its separation from the sewage would involve the expense of double sets of drains, and injuriously complicate the arrangements.

Besides the space occupied by houses,—the jurisdiction of a Local Board of Health will often be defined by a natural drainage area, comprehending the line of water shed, dividing a hill top or a ridge, and bounded by a brook or river beneath dividing a valley. Generally the covered portion of the land occupied by a town itself forms only a small portion of the area under the jurisdiction of a Local Board, the greater proportion being occupied by tillage or grazing land, the perfect drainage of which is, on the sanitary grounds hereunder stated, of importance proportionate to its proximity to the town, and on agricultural grounds the importance is proportionate to the greater value for culture of land near a market.

The complete drainage of the agricultural portion of the natural drainage area in which a town is situate is of special importance to fit it for the reception of the town manures, especially if they are to be applied in the liquid form by way of sewage irrigation, and also for the better drainage of the public roads and footpaths within the area, by which their usefulness and durability will be alike increased.

Suburban lands requiring drainage may be divided into two classes;—garden, villa, and house lands in and immediately adjoining the town; and market garden, tillage, grazing land, and commons in its vicinity.

As a question of economy or pecuniary policy it is important that provision should be made for the removal of all stagnant water and superfluous moisture from land otherwise suitable for building upon or in the neighbourhood of dwellings. It frequently happens that the richer portions of a community choose their places of residence at a distance from the town with which they are connected by business or otherwise, because of the difficulty of finding pleasant and healthful places of residence in the vicinity. There are two chief causes of this difficulty: one, the prevalence of smoke, which so far as it arises from steam furnaces is preventible; the other, dampness of the soil, which by draining can be avoided without adopting the ordinary expedient of choosing for a place of residence a soil naturally dry. It is evidently of great social importance that everything which tends to drive the more opulent, who are also generally the more educated and refined, classes to distant places of residence should be removed; and it is also evidently of economical importance that a locality should not lose the contributions of its more opulent members towards the local taxes and subscriptions. It is clear, also, that whatever renders a place better suited for the residence of the wealthy must enhance the value of the property, and that the expenditure for effecting such a change may prove a very profitable investment.

The sanitary interests also of the locality urgently demand attention to the drainage of its suburban land; for excess of moisture most powerfully influences the local climate both as to dryness and temperature, as shewn in the report of the Metropolitan Sanitary Commissioners under the following heads:—

1. Excess of moisture, even on lands not evidently wet, is a cause of fogs and damps.

2. Dampness serves as the medium of conveyance for any decomposing matter that may be evolved, and adds to the injurious effects of such matter in the air:—in other words, the excess of moisture may be said to increase or aggravate atmospheric impurity.

3. The evaporation of the surplus moisture lowers temperature, produces chills, and creates or aggravates the sudden and injurious changes or fluctuations of temperature,

by which health is injured.* *Vide Sanitary Report*, 1842, pp. 80, 92; *Second and Third Metropolitan Sanitary Reports; and postea*, pp. 66-69.

Where there is a large accumulation of surplus moisture, having animal or vegetable matter in suspension or solution, the injury to the public health is so direct and considerable as to amount to a nuisance requiring authoritative intervention. The evils thus arising, which are found in the greatest intensity in low-lying town districts, in valleys near rivers, or on sites below high-water mark, have been exemplified in the General Sanitary Report and also in the Second Report of the Metropolitan Sanitary Commissioners. The inhabitants of drier districts are often afflicted with marsh diseases from the ill-drained lowlands; thus, after the prevalence of easterly winds over the Essex and Kent marshes, cases of marsh fever and ague are found scattered throughout the whole extent of the metropolis.

* Every one must have remarked on passing from a district with a retentive soil to one of an open porous nature,—respectively characterised as cold and warm soils,—that often whilst the air on the retentive soil is cold and raw, that on the drier soil is comparatively warm and genial The same effect which is here caused naturally may be produced artificially by providing for the perfect escape of superfluous water by drainage, so as to leave less to cool down the air by evaporation. The reason of this difference is two-fold. In the first place, much heat is saved, as much heat being required for the vaporisation of water as would elevate the temperature of more than three million times its bulk of air one degree. It follows, therefore, that for every inch in depth of water carried off by drains which must otherwise evaporate, as much heat is saved per acre as would elevate eleven thousand million cubic feet of air one degree in temperature. But that is not all. Not only is the temperature of the air reduced, but its dew point is raised, by water being evaporated which might be drained off; consequently the want of drainage renders the air both colder and more liable to the formation of dew and mists, and its dampness affects comfort even more than its temperature. It is easy then to understand how local climate is so much affected by surplus moisture, and so remarkably improved by drainage. A farmer being asked the affect on temperature of some new drainage works, replied that all he knew was, that before the drainage he could never go out at night without a great coat, and that now he could, so that he considered it made the difference of a great coat to him. Mr. William Tilley, head gardener to the Duke of Portland, stated to Mr. Lee, Superintendent Inspector of the Board, that the local climate was improving, that in consequence of the drainage of part only of the district there had been a rise of one degree in the temperature of the whole district on the average of ten years. As the evaporation is greatest in the summer, the rise of temperature is greatest at that season. Dr. Madden has observed a difference of 6½ degrees in the summer temperature of drained and undrained land, and of course there would be a corresponding difference in the temperature and dampness of the air. It appears, therefore, that an effect similar to that of removal to a more genial climate may be produced by draining, which is itself a profitable employment of capital, both to the owners and occupiers of the soil.

The following are the chief agricultural advantages of land drainage to individual occupiers or owners:—

1st. By removing that excess of moisture, which prevents the permeation of the soil by air, and obstructs the free assimilation of nourishing matter by the plants.

2nd. By facilitating the absorption of manure by the soil, and so diminishing its loss by surface evaporation, and by being washed away during heavy rains.

3d. By preventing the lowering of the temperature and the chilling of the vegetation, diminishing the effect of solar warmth not on the surface merely, but at the depth occupied by the roots of plants.

4th. By removing obstructions to the free working of the land, arising from the surface being at certain times from excess of moisture too soft to be worked upon, and liable to be poached by cattle.

5th. By preventing injuries to cattle or other stock, corresponding to the effects produced on human beings by marsh miasma, chills, and colds, inducing a general low state of health, and in extreme cases the rot or typhus.

6th. By diminishing damp at the foundations of houses, cattle sheds, and farm steadings, which causes their decay and dilapidation as well as discomfort and disease to inmates and cattle.

All these evils lower the productiveness and diminish the money value of land, as well as the comfort of suburban occupations.

Every Local Board of Health is by its surveyor charged with the duty of providing and maintaining in good action the watercourses which serve as the main *outfalls* for the drainage of land as well as houses, of the entire district both town and suburbs. Whatever amount of money a private individual, be he owner or occupier, may spend for relief by drainage, or however skilfully drainage works within his own premises may be constructed, the money and the labour will be thrown away unless the natural outfall be kept clear, or unless an appropriate artificial outfall be provided and kept open.

A duty of the Local Board, to be performed by its surveyor, in respect to suburban land drainage, therefore, is providing, adjusting, and maintaining outfalls to facilitate and complete the drainage works of private individuals within the jurisdiction, and as contributors to the rate and to the payments for the services of the officers of the Local Board, such persons are entitled to as much aid as may be given by those officers consistently with other more general demands upon their time.

The first service which the Local Board may render to private occupiers or owners is to extend to them the benefit of the general survey, to a copy of which, with the levels of his land and premises, each owner or occupier should be entitled upon payment of the expense of the tracing. He might also, at a fixed scale of moderate charges, be accommodated by the filling in of any additional particulars in the survey which he may desire for any purpose of his own.

On any ratepayer applying to the Local Board signifying his wish to drain his premises, the surveyor should examine the plot, and determine respecting it the points that lie within the jurisdiction of the Board; namely, the depth, the size, and the direction of the outfall; and the surveyor should also see that the proposed drainage is not likely to clog the outfalls or the sewers with silt. Beyond the determination of these conditions, the Local Board has nothing to do with the modes of land drainage adopted. The owner or the occupier may drain wide or close, across or down slopes, with tile tubes or with tiles and soles, or with stones, as he may think fit. As an accommodation, however, the surveyor might be permitted (under such arrangements as the Local Board may sanction, to avoid the risk of his public duties being neglected, and at such rate of charge as they may fix,) to give any advice or assistance that may be needed. Before the drains are filled in, he should be required to see that they are of a proper fall or inclination so as to give an effectual discharge to the water.

As curators of the general system of drainage, as guardians of the public convenience and health so far as they are affected by these works, and also for the protection of the ratepayers against useless and fraudulent works,—the Local Board may beneficially exercise, by its officers, a certain degree of care as to the adaptation of private drains to the main outfalls and to the general system of the drainage under their jurisdiction. It has been determined as a principle in respect to private house drainage, that no house-drains of such a size, inclination, or description as to accumulate, deposit, and give off emanations calculated to pollute the air and injure the public health shall be admitted into the public sewers; and on the like principle, the Local Board should protect their general system of drainage from the admission of any land drainage likely to injure it by bringing into the mains detritus, mud, or soil; and the surveyor to the Board should take care that the drainage water is discharged in such a manner as not to impede the general flow, nor increase unnecessarily the expense attendant on the working of the mains. This principle of administration laid down by the Sanitary Commissioners will, in its practical application, be protective of private, even more largely than of public, interests.

It will be convenient first to describe generally the construction of the outfalls, the main or public drainage works of the area, and of the road drainage, for which the Local Board, through their surveyor, will be directly responsible; —next, the private land drainage, which these public arrangements and the general survey will facilitate. In the Appendix will be found authentic practical information, furnished by the Inspectors under the Inclosure Commissioners, gentlemen who have had very extensive experience in the superintendence of land drainage works throughout the country.

*Suburban watercourses and town ditches.*

In consequence of the report of the Metropolitan Sanitary Commissioners the practice of draining by covered tubular drains, instead of open ditches, has been extensively adopted. Experience has shown that drains of this kind will be of great advantage to the lands that they adjoin; but the chief reasons for the change of system, as set forth in the Second Report of the Sanitary Commissioners, namely, that covered tubular drains, if properly laid down, carry water away more rapidly and are less expensive for the drainage of roads than open ditches, are equally strong for the abolition of field ditches, and the substitution for them also of covered drains. The sanitary advantages consist in the diminution of stagnant water surface and the prevention of unwholesome evaporation. These points are thus illustrated in the report referred to: —

" The field and road ditches existing everywhere over the suburbs have been a subject of special investigation by the Commission. We have received regarding them such reports as the following, which is drawn up by Mr. George Donaldson, Assistant Surveyor to the Court of Sewers, who was requested by us to examine various portions of the suburban lands.

" ' The marsh land east of Greenwich is divided into fields by ditches filled with water let in from the river by small sluices under the care of the wall-reeve. These ditches are on an average nine or ten feet in width and about three feet deep of water. They answer the purpose of fences, as well as watering places for cattle, and serve in some degree for drainage.

" 'Some of the workmen upon the marsh attending to cattle, &c., stated that in some states of the weather, where the ditches are not kept well scoured, they smell very much, or, in their own words, 'stink terribly,' when the water is low. The smell arises from the rotten weeds about the sides of the ditch. They stated, that at this season there is little or no smell from the ditches, but to me it was quite perceptible at the time I was speaking to them, although they seemed unconscious of it.

" 'These ditches are a bad substitute for fences. Neat hedges would take much less land and they would give shelter, which is much wanted. For the purpose of providing water for cattle not one fourth of these ditches are necessary. The drainage could be much better effected in a different manner.'

" Similar accounts are given in respect to portions of other suburban districts.

" It must be recollected also, that the occupiers of the new suburban dwellings have often no other means of drainage than the common ditches, and that these ditches frequently perform the office of sewers as well as of land-drains and watering-places for cattle.

" From examinations which we have directed to be made we find that in subservience to the larger drainage arrangements, and with proper outfalls, the road-drainage by open ditches may be superseded by means of tubular tile-drains put in at proper depths and inclinations, which the officers of the Commissioners of Sewers, who will have charge of the General Survey, may, with the aid of that survey, determine accurately.

" The objections to the present road-drainage by ditches of the common forms and sizes are analogous to those we have made to the common forms and sizes of sewers; namely, their unsuitableness to small runs of water; wide bottoms intended to be flat, but so irregularly shaped as to impede effectually the current of all but very large floods of water with considerable flows.

" If the road-drainage were placed in its proper subordination as part of a system of drainage, the ditches, which are usually only about two feet deep, might be filled up, and the roads drained into pipe-drains of from four to five inches in diameter and upwards, according to the length of the road and its position in serving as an outfall for the land-drainage.

" We are assured by persons engaged in carrying out agricultural improvement by land-drainage, that the roadside ditches commonly form the most serious obstructions to their work. Covered tubular drains, such as we propose as substitutes for the open ditch, would of themselves effect extensive land-drainage; and in some suburban lands, closely intersected with byways and public footpaths which should be deep-drained, would sometimes supersede the necessity of any other drainage.

"Mr. Smith of Deanston long since abolished all open ditches in his own farm and the roads adjoining with great advantage. Mr. Josiah Parkes concurs with other practical witnesses in our view, that the drainage of the roads by covered drains would greatly benefit the adjacent land. The extent of this drainage by the covered drains would, of course, be dependent on the depth of the road-drain and the permeability of the adjacent land. On a very stiff clay soil a road-drain might not act more than from twelve to fifteen feet on either side of it. But in freer soils several practical witnesses agree in stating that a single drain would frequently drain from one to two chains. Mr. Parkes mentions an instance of one drain, from five to seven feet deep, which drains a field of about twenty acres. The road-drains would commonly serve as excellent outfalls for the drainage of the land; and Mr. Parkes and other land surveyors think it would be of great advantage to the farmers if they had the right of carrying drains into them.

"Mr. Parkes attests the fact (in which other experienced drainers examined by us concur), that a proper covered drain of the same depth as an open ditch will drain a greater breadth of land than the ditch can effect. The sides of the ditch become dried and plastered and covered with vegetation, and even while they are free from vegetation, their absorptive power is inferior to the covered drain. A mile of double road-drains would drain from fifteen to twenty acres of the adjacent land; and the increased value to the land itself would, considering the common rates of charge for land-drainage, be worth the expense. A piece of land surrounded by roads, as often happens in the suburbs of towns, might be completely drained by the road-drains.

"On a mile of road, having ditches on both sides, the extent of evaporating surface of stagnant moisture with decomposing vegetable and animal matter would be from three quarters to an acre per mile; that is, three quarters of an acre in extent could be gained as dry road or as cultivable land.*

* The abolition of ditches at the road-side is the removal of a frequent cause of overturns and other accidents.

"The Wall-reeve of Poplar Marsh states to us, that the area of open ditches or sewers within the open part of his district of 520 acres is twenty-one acres, or in the proportion of one acre of water to twenty-five acres of land. He states that he is of opinion that the whole of the twenty-one acres of open ditches and sewers might be made available for grazing and other purposes, if pipes were laid and the ditches covered in.

"If stagnant and open ditches were abolished and suitable hedges substituted in their stead in places where agricultural improvement is backward, as it generally is in the marshy districts, the good that would be seen to arise from the drainage of the land situated near the road-drains would, with proper facilities, tend to the voluntary extension of general land-drainage, for which the new and extended surveys that have been proposed would be of very great importance.

"Mr. Stewart, a land surveyor and land agent, who has been extensively occupied in the draining of land, and has been recently engaged in the drainage of some lands between Greenwich and Woolwich, states, that the lands in the suburbs of the Metropolis are all very full of water and excessively in want of drainage.

"Being asked—

"How far do you believe the suburban lands may be improved for vegetable production or for the health of stock, not to speak of the health of the population, by suburban land-drainage?—I can give an idea of the improvement as respects the value of land. About five years ago I cut only one drain through the river bank and took in about twenty acres. The land has been recently let to a gardener at double the former letting. Generally speaking, by proper drainage, the low and wet lands may certainly be advanced in value from twenty-five to fifty per cent.

"The Commissioners have been led to inquire as to the practicability of superseding the road-drainage by open ditches, and substituting drainage by covered tubular tile-drains. Do you concur in the eligibility and the practicability of the proposed substitution?—I do indeed, most fully; there is no doubt of its answering perfectly, by proportioning the pipes to the quantity of water which they will have to carry; but I do not think that it will be requisite to have very large pipes in any one case for the purpose.

"What do you expect would be the effect of such drainage, independently of other land drainage, in the districts with which you are acquainted?—I do not think the other drainage would be complete without it. If you are about to drain the land in any district it would be inconsistent to leave the ditches as they generally are, say about two feet deep.

"On the low-lying lands you would drain very deeply, would you not?—Yes, where there is the means of sufficient outfall; in some of those lands I have found it necessary to drain as deep as from six to eight feet.

"To what depths have you been accustomed to drain agricultural land?—I never sink the drains of the outside of fields less than four feet, if I can get an outfall to that depth. I often go double and sometimes three times that depth.

"How long have you practised this deep draining?—All my life, where I have had the power.

"Then to allow the ditches to remain along with such land-drainage would only be leaving stagnant surface moisture?—Nothing more.

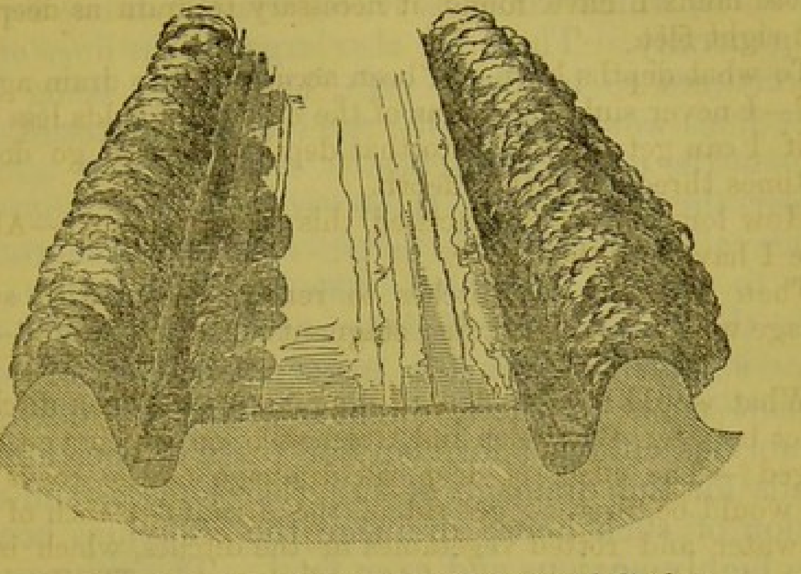
"What would be the effect of stopping up the open ditches in the district between Woolwich and Greenwich, on which you have been engaged?—The effect of deep tile-drainage of the roads in those parts would be, first, to get rid of the dreadful stench of the stagnant water and rotted vegetables in the ditches, which is at times enough to make any man sick, and does so. The health of the population would therefore be greatly improved by it. In the next place, the roads would be easier kept in repair because they would become more solid. At the height at which the water stands in these ditches, very often within a foot of the surface of the adjoining land (sometimes higher), it keeps the road soft and the land adjoining much wetter than it ought to be, often a quag.

"Where the fields are small and the roads very near, would not the deep tile-drainage of the roads very often suffice for the land-drainage?—Very often it would, provided the sub-soil is composed of gravel, sand, or matter pervious to water. I have now in hand some land where one roadside drain, if it were laid deep enough, would drain the whole field, the sub-soil being shingly gravel.

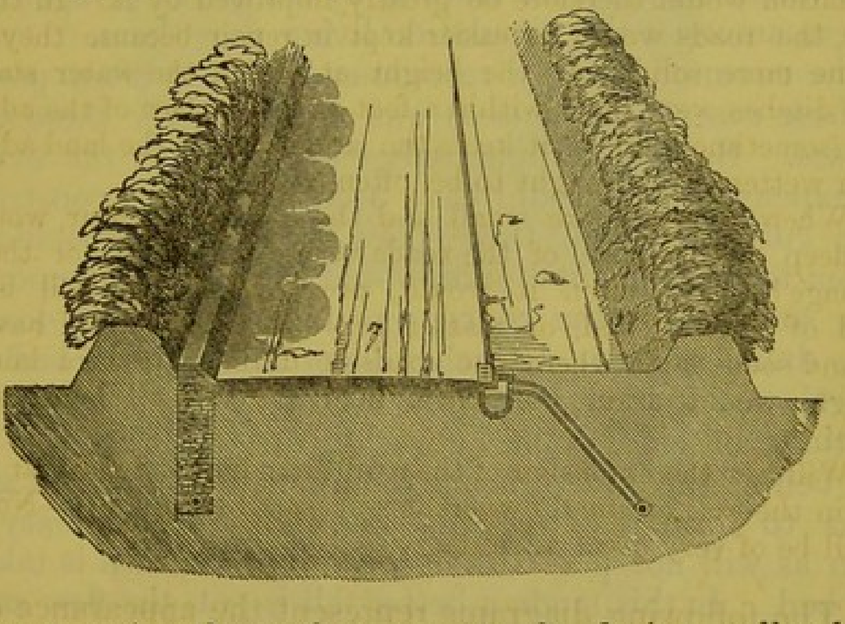
"Will not the extension of the road-drainage be of peculiar advantage in the case of small ownerships or small occupiers?—No doubt it will be of very great advantage.

"The following diagrams represent the appearance of the ditches along with hedges, which sometimes have ditches on both sides. The lower diagram gives the view of the position of the tubular drains. The road-water may be discharged either through a layer of broken stones or permeable gravel, to stop any silt, as at A, or through a small earthern vessel as at B, (into which silt would fall and be arrested, and which could be cleaned out conveniently by hand, from time to time,) and enter the drain below by a drain-pipe acting as a gully-shoot. In general the space occupied by the ditch may be advantageously added to the road, as at B. In other cases where there is a sufficient width of road it might be given to the land."

Section of road, with open ditches.



Section of road, as proposed, with covered ditches.



For conveying the surface water to the drains, gully-shoots placed at intervals with gutters running along the sides of the road, and entering the gullies, are to be preferred to gravel drains such as that figured in the cut at A. It has been estimated by experienced surveyors that with two-inch tubular drains the subsoil drainage of a road may be effected at 36*l.* 5*s.* per mile, and with three-inch drains at 42*l.* 17*s.* per mile. To take the surface water, the size, and, consequently, the cost, would be increased. But by this means the roads would be maintained dry and in good condition, and the adjoining fields would be drained to a considerable distance without any other drainage works, as well as provided with mains to receive the outfalls of the field drains.

The above descriptions refer to the cases of road drainage by ditches, which would serve as branch drains for the district generally. There are also larger main lines of natural watercourses to be dealt with, and which being lower or valley lines would generally receive, as tributaries, the pipe drains of the common ditches.

Near the Metropolis there are, besides the common ditches above described, large open watercourses which serve to carry away flood waters. When there are no floods, the water in the shallow streams or threads of water moves sluggishly over the uneven bottoms, or lodges in stagnant pools in these ditches, giving off offensive and insalubrious effluvia; for many of these ditches are used as outfalls for the drainage of suburban houses, and with the addition of such house drainage the effluvium becomes at times highly noxious and even fatal. The courses of these open watercourses were marked by excessive ravages of the cholera amongst the population living near them.

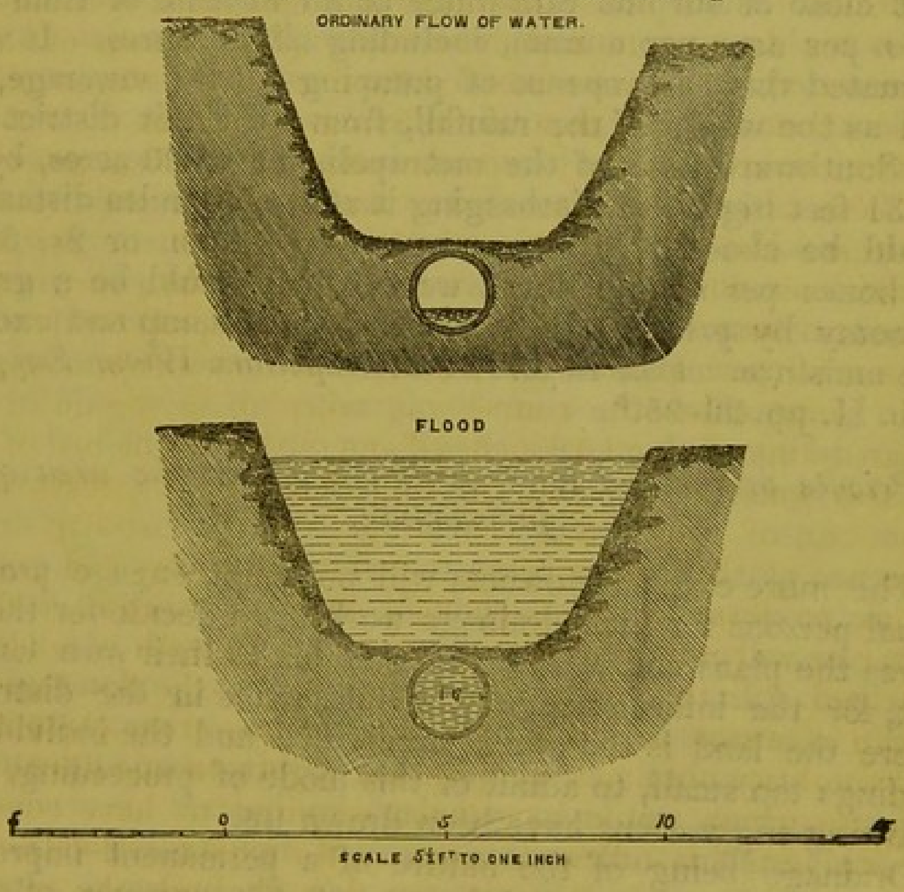
The common remedy recommended (and often practised in these cases near houses) was arching over these watercourses. But this would only have masked the evil, and the expense which would have been incurred by constructing large culverts in all these lines, which would seldom be chosen for permanent works, would have been enormous.

In some cases the course was taken of laying down tubular drains of about 18 inches diameter below the bed of the natural watercourse, and (leaving openings at intervals for junctions of side drains) covering over the tubular drain. The bed of the stream being re-formed with clay and gravel, so as to form a better channel, such extraordinary flood water as will not pass through the pipe beneath is taken on that bed. In this mode a better fall is got, the flow and the sweep of water is accelerated, and comparative cleanliness and salubrity obtained, at from one eighth to one fourth the expense which would have been required to have covered the culverts of sufficient capacity for extreme floods. So great is the acceleration of the flow through the pipe in the watercourses that it is only on comparatively rare occasions, perhaps not more than two or three times a year, that there is any overflow above them, and the surfaces usually present the appearance of a dry and clean narrow road The cost of this work was from 2*s.* 6*d.* to 4*s.* 2*d.* per foot of run complete; to have arched over such a stream would have cost about 12*s.* per foot of run. In some cases the foul water of open streams may be diverted into neighbouring sewers, when no further expense need be incurred except for re-forming the bed of the brook for the conveyance of flood-water.

In all cases of drainage by natural streams important opportunities will occur to a competent local surveyor for diminishing the friction and accelerating the discharge of surface water, by straightening and thereby shortening the watercourses, as well as by concentrating the flow by the construction of properly formed channels.

The following is a cross section of the species of draining described as executed under the direction of Mr. John Grant, one of the surveyors to the Metropolitan Commission of Sewers.

Transverse Sections of Stream, showing




A similar plan has been followed in the treatment of some old sewers with flat bottoms, in which the ordinary shallow streams are spread out, and by being so spread out friction is increased, the flow retarded, and accumulations of deposit occasioned. The expense of periodically cleansing these sewers by flushing was in some cases as much as 56*l*. per mile per annum. At the bottom of some of such sewers pipes of 16 and 18 inches diameter were put; and with the same quantity of water, with the same inclinations, such an acceleration of flow is obtained—in one instance where it was measured the acceleration of velocity was at times three, four, and fivefold, (*vide Report on Water Supply of the Metropolis*, p. 186,)—that the formation of any deposit is prevented, and the channels kept entirely clear of the foul accumulations; and it was proved that the expense of these works was nearly paid for by the saving in expense of cleansing by flushing.

Where a district is situate below high-water mark, or where there is no sufficient outfall, it should be known that the expense of providing for the quick and complete discharge of the sewerage as well as the rain-water is inconsiderable. Extensive fen districts are, by steam-power, kept clear of surplus rain-water at an expense of from 2*s.* to 5*s.* per acre per annum, including all expenses. It was estimated that the expense of pumping out the sewerage, as well as the whole of the rainfall, from a difficult district on the Southwark side of the metropolis, of 4,000 acres, by a lift 31 feet high, and discharging it at twelve miles distance, would be about 2*l.* 15*s.* per acre per annum, or 2*s.* 8¾*d.* per house per annum, for a work which would be a great economy by preventing dilapidation from damp and excessive moisture. *Vide Report on Metropolitan Water Supply, App.* II. pp. 22–25.*

*Private or general land drainage within the area of jurisdiction.*

The more extensive owners will no doubt engage professional persons for their drainage works, and decide for themselves the plans and adaptations suitable to their own lands. But, for the information of the ratepayers in the districts where the land is too much subdivided and the individual holdings too small, to admit of this mode of proceeding, the following suggestions have been drawn up.

Drainage being of the nature of a permanent improvement should be executed by, or at the expense of, the owner; but it being at the same time an additional work of convenience and value not agreed upon or contemplated at the time the land was taken, it will justify an additional rent for the new outlay.

* It will scarcely ever be necessary to provide an artificial outfall by pumping for all the sewage of the most unfavourably situated district, and in very few cases will it have to be lifted so high or carried so far off as is here assumed.

Many owners and occupiers are well aware of the defectiveness of their land in respect of drainage, but do not know how to apply the remedy. In a large proportion of cases the holdings are so small and subdivided that occupiers or owners cannot separately undertake the work at any reasonable charges, or with probability of success. It is therefore requisite for the surveyor not merely to make known the facilities that may be offered for the execution of works of private land-drainage, but also to explain the principles that determine those facilities, and to furnish detailed instructions to the ratepayers for their practical application. The public interests, for the reasons stated, are indeed so closely coincident with those of private owners in facilitating all works of land-drainage, that this class of works forms an exception to ordinary cases, and it is one where the Local Board may with propriety allow their surveyor to receive extra remuneration for extra service in the preparation of plans, or in otherwise aiding in the execution of the smaller land-drainage works, beyond the main outfalls which he will have in charge, as a matter of direct public duty.

The system of road-drainage by tubular drains, proposed by the Metropolitan Sanitary Commissioners, instead of the present open ditches, will offer most important facilities for private land-drainage of every description.

And first as to the principle of *thorough drainage.*

All the older drainage was chiefly *surface* drainage by ridge and furrow. This, besides leaving the land surcharged with moisture, carried away the finer particles of earth, and along with these such of the manures and fertilizing matters as were removable from off the surface in suspension in water. On the occasion of sudden and heavy storms, the greater part of a top-dressing of manure on such lands is sometimes carried into the ditches and watercourses. The modern method, which Mr. Smith of Deanston so far systematized, instead of draining over the surface, does away with ridges and furrows, makes the surface (except where it is raised for the growth of the plant) a perfect plain, and the water drains downward through the table of land into underground channels. In thus filtering through the soil, the fine earthy powder of the mould, and the particles of manure, or loose animal or vegetable matter, are left upon it, and soluble manure is carried down into and absorbed by it, and thus retained for the sustenance of vegetation. This saving of manure and of fertile mould increases the productiveness of thoroughly drained land, apart from the permeability, increased temperature, and better condition of the soil which thorough-drainage brings about. The action of a soil made permeable to air and moisture is fully elucidated in an extract, given in the Appendix (No. IV.), from a lecture on the preparation of soils for the reception of seeds by Dr. Madden, of Penecuick, published in the Transactions of the Royal Agricultural Societies of England and Scotland.

When there happen to be two outfalls into the same main from the same description of land, the one from surface-drained land and the other from under or thorough-drained land, the water from the thorough-drained land (if the drains be properly laid so as to effect a perfect filtration) may be seen running perfectly pellucid, while the water from the surface-drained land will be thick and muddy from the solid particles which it contains. The surveyor, in the exercise of his authority, should admit no outfalls from surface-drained land into the main drains, lest they should become obstructed.

The following extracts from a Report on Drainage by Dr. Shier, the Editor of "Davy's Agricultural Chemistry," Agricultural Chemist to the colony of British Guiana, one of the ablest scientific agriculturists that this country has produced, express clearly and concisely the nature and advantages of land-drainage, and they may serve for the guidance of owners and occupiers desirous of draining their lands.

"The history of drainage in Britain may be briefly told. Till the time of Smith of Deanston draining was generally regarded as the means of freeing the land from springs, oozes, and underwater, and it was applied only to lands palpably wet, and producing rushes and other aquatic plants.

"Springs may be viewed as natural Artesian wells, and are to be explained on the same principles. Rain falling on hills and high land runs over the surface to all lower levels. If in its progress it passes over clay or impervious rock, it cannot sink; if it encounters a pervious layer, such as sand or gravel, it immediately sinks and flows in the interstices as in a pipe. When we examine the upper geological layers we find clay and sand, or gravel, interstratified, sometimes in numerous layers; hence, if each pervious layer at its out-crop receives rain-water, and if the clay layers are unbroken, we may have under a plain, or in a valley or basin, many layers containing water, capable, by the pressure of the water entering at higher levels, of rising to the surface of the ground through any natural fissure or artificial boring.

"The old method of draining springs was to form a drain or culvert of sufficient capacity to carry the water under ground to lower levels, thus preventing the water from bursting out on the surface of the land. When several springs occurred in the same field or vicinity, a main drain was laid along the lowest level with a leader to each eye.

"On this method Elkington, a most sagacious and successful drainer, introduced sundry improvements, the chief of which was the use of the auger, with which he bored through the bottoms of the drains, in suitable situations, and thereby laid dry many of the natural springs and oozes, and greatly restricted the extent of the works required.*

"Oozes, or outbursts of water, as they are termed, occur in immense numbers in all undulated and hilly countries. They are caused by various arrangements of the pervious and impervious layers, but most frequently by the out-crop, or coming to the surface of an impervious clay layer, on which rests a pervious stratum. The water conveyed in the pores or interstices of the latter being unable to descend runs over the surface of the clay, forming a marsh, or in some cases a line of springs or marshy spots. The rule followed in dealing with such cases was to cut off the water

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* The Board had in view this process for the collection of the springs from the sandy districts, commencing at Bagshot in Surrey. The rain falling on such sands, like that upon gritstone formations, having passed through natural filters of insoluble silicious matter, is of the highest order of purity. The witnesses, having in view Elkington's process, called it "*drainage*" water, a term often used as denoting the discharge of mere waste and fluid impurities; whereas the process is properly one of the collection of shallow springs, of far greater purity than common wells or the deeper springs, which usually contain much mineral matter. These shallow springs are of superior quality, where available, to the common supplies from rivers. In respect to the quantities derivable from such springs, it was frequently represented by Elkington as so great, that it ought to be turned to account for working mills. In addition to the superior purity of the water, one great advantage of the derivation from these springs for towns is, that the supply is less variable, and less storage room than for surface flood water is required. (*Vide the Board's Report on the Supply of Water to the Metropolis*, p. 83 *to* p. 113.) The new supply of water for the town of Rugby, under the Public Health Act, is obtained by permeable pipe drains, 9 inches in diameter, laid 14 feet in a bed of gravel, by which means a supply of water of less than one half the hardness of the river water is obtained pure from animal and vegetable matter, clear and cool, as if from perennial springs, and fit for drinking without any artificial filtration. The water is as good as if the enormous expense had been incurred of carrying it, while fresh drawn, from a multitude of pumps sunk to the same depth, while its coolness is preserved and its purity secured. In other instances, under the Public Health Act, the same means of supply are successfully resorted to.

as near its source as possible, by running a drain along the line of out-crop, that is to say, between the wet and the dry, or a little below the commencement of the marsh. The water so intercepted was at convenient intervals conveyed to lower levels.

The principle of Elkington's drainage is thus described in his own terms, as dependent—

"1st. Upon finding out the main spring or cause of the mischief, without which nothing effectual can be done. 2d. Upon taking the level of that spring, and ascertaining its subterraneous bearings; for, if the drain is cut a yard beyond the line of the spring, you can never reach the water that issues from it; and by ascertaining that line, by means of levelling, you can cut off the spring effectually, and consequently drain the land in the cheapest and most eligible manner. And, 3dly, by making use of the auger to reach or tap the spring, when the depth of the drain is not sufficient for that purpose.

"Although the process of thorough-drainage does in most cases suffice for the removal of under-water, as well as surface-water, it is proper to state that there are cases where the old and new methods require to be combined, some special spring or ooze requiring special drainage, or more specific treatment than is provided for in the frequent-drain system. It will sometimes happen, too, that water may rest in layers below the subsoil, out of reach of the frequent drains put in at the usual depth, but may yet, under certain circumstances, prove prejudicial to the soil. No skilful drainer, appreciating the merits of both systems, will have much difficulty in dealing with such special cases.

"In regard to the construction of drains, attention is called to the following points:—

"1st. The direction of the drains, namely, that they ought invariably to run down the steepest descent, and parallel to each other.

"In directing the drains directly down-hill, there is a manifest departure from the old and sound rule observed in cutting off oozes and outbursts of under-water; but the purpose is different, and it can easily be shown (especially by models or diagrams) that by observing this rule the water has the shortest way to percolate in getting into the drain, and that when once in the drain its delivery into the mains is effected at the most rapid rate; points, both of them, of the greatest importance. To many persons the results of experience are more satisfactory than reasoning from principles, and to such it must be satisfactory to learn, that although in the infancy of thorough-drainage it was stoutly argued by many that the frequent drains should be directed in an oblique direction, and consequently at a lower inclination than the 'right down-hill' direction gave, the practice is now universally in favour of the rule laid down by Smith.

"The parallelism of the frequent drains is only departed from when the nature of the surface or the direction of the boundary lines of fields renders it necessary. In Britain the irregular undulation of surface is the chief cause why thorough-drainage is not always well planned.

"The direction of the mains and sub-mains depends entirely on the nature of the ground and levels. When the surface is undulating, the rule is, to lay a main of sufficient size along the principal hollow, with sub-mains along all the secondary hollows, the small drains opening into these generally at right angles. Mains require also to be introduced whenever the length of the small drains becomes as great as would give them more water to deliver than they are capable of.

"2d. The frequency of the small drains. The distance at which the small drains are placed apart depends on several circumstances, such as the nature and texture of the soil, the depth at which the drains are to be put in, and whether it is surface-water alone they have to deliver."

In regard to the depth and frequency of drains, the following statements are made by Mr. Josiah Parkes:—

"I gave several instances of this practice (deep drainage) in Kent in the Report of last year, already alluded to, and it is rapidly extending. Mr. Hammond stated to you (Journal, vol. iv. p. 47.), that he drained 'stiff clays 2 feet deep, and 24 feet between the drains, at 3*l.* 4*s.* 3*d.* per acre,' and 'porous soils, 3 feet deep, 33½ feet asunder, at 2*l.* 5*s.* 2*d.* per acre.' I now find him continuing his drainage at 4 feet deep, wherever he can obtain the outfall, from a conviction, founded on the experience of a cautious progressive practice as to depth and distance, that depth consists with economy of outlay as well as with superior effect. He has found 4-feet drains to be efficient at 50 feet asunder, in soils of varied texture, not uniform clays, and executes them at a cost of about 2*l.* 5*s.* per acre, being 18*s.* 4*d.* for 871 pipes, and 1*l.* 6*s.* 6*d.* for 53 rods of digging.*

* The cost above given can only be taken as that of the particular case.

"Communications have been recently made to me, by several respectable Kentish farmers, of the satisfactory performance of drains deeply laid in the Weald clays, at distances ranging from 30 to 40 feet, but I have not had the opportunity of personally inspecting these drainages.*

"The following little table shows the actual and respective cost of the above three cases of under-drainage, calculated on the effects really produced, *i. e.*, on the masses of earth effectively relieved of their surplus water at an equal expense. I conceive this to be the true expression of the work done, as a mere statement of the cost or drainage per acre of surface conveys but an imperfect, indeed a very erroneous idea of the substantive and useful expenditure on any particular system. This will be apparent on reference to the two last columns of the table, which give the cost, in cubic yards and square yards, of soil drained for one penny at the above-mentioned prices, depths, and distances :—

| Depth of the Drains in feet. | Distances between the Drains in feet. | Mass of Soil drained per acre, in cubic yards. | Mass of Soil drained for 1*d*., in cubic yards. | Surface of Soil drained for 1*d*., in square yards. |
|---|---|---|---|---|
| 2 | 24 | 3,226½ | 4·1 | 6·27 |
| 3 | 33½ | 4,840 | 8·93 | 8·93 |
| 4 | 50 | 6,453 | 12·00 | 8·96 |

"I may observe, that Mr. Hammond, when draining tenacious clays, chooses the month of February for the work, when he lays his pipes (just covering them with clay to prevent crumbs from getting in), and leaves the trenches open through March, if it be drying weather, by which means he finds the cracking of the soil much accelerated, and the complete action of the drains advanced a full season. The process of cracking may, doubtless, be hastened both by a choice of the period of the year in which drains are made, and by such a management of the surface as to expose it to the full force of atmospheric evaporation."

On the same point, Mr. Smith of Deanston expressed himself thus :—

"Estimating the thorough-drainage of land by the cubic contents of the soil, reckoning from the level of the bottom of the drainage to the surface of the ground, can give no exposition of the agricultural effect; because it

* For illustrated diagram, *vide* p. 64.

has not yet been fully determined by experiment or in practice how far it is beneficial to the growth of plants to remove the *free* water from the lower regions of the subsoil. One set of experiments over a course of three years has been furnished by Mr. Hope, of Foreton Burn, in East Lothian, from which it appears that the results were in favour of moderate depths of drains; and the practice in the Fens of Lincolnshire shows that the most beneficial distance from the surface for the free water is about two feet. In dry seasons, when the water in the level ditches falls below two feet from the surface, the crops are found to suffer, and it is customary to dam up the water to that level.* Water will rise some inches in soil by capillary or molecular attraction; but in such cases the water never fills the fissures or interstices of the soil to such an extent as to exclude the atmospheric air, but merely attaches itself to the surface of the particles of soil and of the smaller cells and channels in the soil, where it remains available to the roots of plants, and without any of the bad effects resulting from stagnant *free* water. Until the great point can be fully and practically determined as to the proper distance for retaining a supply of water, the depth to which land should be drained cannot be pronounced. The rule when ascertained will probably be found to vary with the nature and condition of the soil. In removing water falling on the surface it has been found in practice, and which agrees with a great theory, that having the artificial channels at near distances, and not over deep, is most effective in the immediate and complete removal of the free surface water. Distances of from 18 to 24 feet, with depths of from 2 feet to 3 feet, have been found over extensive tracts and in soils of various texture to effect complete thorough-drainage for agricultural purposes."

In regard to this disputed part of the subject of drainage, Mr. Stephens, the author of "The Book of the Farm," and of an able "Manual of Practical Draining," lays it down as a principle that the drains should be, at the very least, so deep as to place them beyond the reach of subsoil ploughing, which may penetrate 16 inches below the ordinary furrow of 7 inches, or 23 inches below the surface; that is, allowing 3 inches in addition to the depth of the subsoil furrow, the top of the drain ought to be at a depth of not less

* J. A. Clarke, Esq., the author of an elaborate report upon the farming of Lincolnshire, questions the real expediency of this practice. *Vide* Journal of the Royal Agricultural Society, vol. 12, p. 326.

than 26 inches. How much deeper than this it should be depends on the nature of the soil; a porous soil with a rapid discharge does not require much more depth; but if the soil be tenacious and less permeable, a greater depth will be required to give discharging room to the water coming from each side of the drain. On these grounds Mr. Stephens gives the following table for three different kinds of subsoils.

| | Porous Subsoil. | Tilly Subsoil. | Clay Subsoil. |
|---|---|---|---|
| | Inches. | Inches. | Inches. |
| Ploughed surface - - - | 7 | 7 | 7 |
| Depth of subsoiling, &c. - - | 16 | 16 | 16 |
| Thickness of earth above the filling materials - - - | 3 | 3 | 3 |
| Height of tiles and soles, say - | 6 | 6 | 6 |
| Depth of discharging effect of subsoils | 1 | 10 | 18 |
| Hence the *minimum* depth of drains in porous subsoils is - - | 33 | — | — |
| " tilly " " - - | - - | 42 | — |
| " clay " " - - | - - | - - | 50 |

To return to the extracts from Dr. Shier:—

" 4th. The materials employed.—The best materials for the construction of the water-way of the frequent-drains are tubes, tiles and soles, water-worn pebbles from the sea-beach, harped gravel, or broken stones.

" A decided preference should be given to tubes over tiles and soles. They are cheaper, occupy less space in the kiln as well as during transport, and are much less liable to breakage. They are easier laid, effect as complete drainage, and are less liable to silting or sediment, or, indeed, to accidents of any kind."

The action of thorough-drainage is illustrated as follows:—

" That in thorough-drained land it is intended that every drop of rain should sink on the spot on which it falls, and pass through the fissures of the soil and subsoil till it enters the drain laterally or by the bottom.

" When the drains are constructed so as to effect this, it follows:

" 1st. That all the water is filtered before it enters, and, consequently, that no silting can occur.

" 2d. That no loss of finely-divided matter can occur.

" The finely-divided portion of the soil contains its most active and valuable parts. But land drained on the open-drain and round-bed system is constantly deprived of this finely-divided portion, by its being carried over the surface into the open drains and deposited there.

" 3. It is now obvious why the drains should not draw downwards, especially at first.

" II. That it is essential to the success of thorough-drainage, that whenever there is excess of water present in the soil, it should be constantly sinking.

" The accuracy of this principle might be inferred from the fact, that in all the cases that occur of soils naturally of high fertility, and to which man has had to do nothing but till them, there is uniformly found effective drainage. Direct experiments on the effect produced on soils of the same kind when treated with water, allowed in the one case to percolate through the soil, and in the other to stagnate on the soil, are in progress, and may lead to instructive conclusions.

" III. That the fissures and water-ways that occur in thorough-drained land are caused by the shrinking of the soil as it dries.

" IV. That after a series of years the subsoil of a thorough-drained field changes into the nature of soil as far down as the level of the water in the drains.

" Those who are not familiar with the reality of this change will be most effectually convinced of it by inspection. It will be found to occur in the most marked degree when, as very often happens in clay lands, the original inorganic constituents of the soil and subsoil are not widely dissimilar. This change is accounted for—

" 1st. By the ameliorating effect of air and water, as has already been described, producing healthy decomposition of the organic and inorganic constituents, and thereby eliminating substances which constitute the food of plants.

" 2d. By the washing out of deleterious ingredients.

" 3d. By the loosening of its texture.

" 4th. By the penetration of roots, and by their ultimate decay in the subsoil.

" 5th. By the penetration of earth-worms and insects.

" It is now obvious, that when the subsoil has been thus changed it becomes fit for being mixed with the soil, and of greatly improving it, by supplying such principles as in the course of cropping may have become deficient.

" There are cases, too, where, from the very dissimilarity of the texture of the soil and subsoil, great benefit may accrue from their admixture: thus, for instance, a sand layer, did such occur under the surface of stiff clay, would obviously improve the texture of the clay were it ploughed up and intermixed with the soil.

" V. That the increased fertility of thorough-drained land is in a great degree due to the increase of feeding surface, to which the roots of plants obtain access.

" Thus, were an undrained soil that could never before be tilled with advantage deeper than six or seven inches to become deepened by thorough-drainage and subsoiling to eighteen or twenty-four inches, it would not be wonderful although its crops were doubled.

The following is Dr. Shier's enumeration of the results of thorough-drainage:—

" Induction from a copious number of facts is always desirable in coming to important practical conclusions. Fortunately the process of thorough-drainage has been so extensively adopted in Britain that the advantages are known to nearly all. A brief enumeration of the leading advantages will suffice.

" 1st. When properly executed, it always proves remunerative.

" Many cases have occurred where heath or moorland, dear at a rent of 5*s*. per acre, has, when thorough-drained and sub-soiled, become worth 30*s*. or 2*l*.; and of clay land, dear at 7*s*. 6*d*. per acre, becoming worth 3*l*., or, in good localities, even 4*l*.

" That it is a remunerative improvement is, if possible, more strongly shown by the fact, that Scotch tenants on a nineteen years lease have been frequently known to thorough-drain their farms at their own expense when no aid could be obtained from their landlords.

" 2d. That by thorough-drainage and subsoiling the quality as well as the amount of the crops is improved.

" 3d. That clay lands which, in the raised-ridge form, could produce only wheat, beans, and clover, have, when thorough-drained and subsoiled, been found capable of producing root crops, such as turnips, beetroot, and potatoes; thus enabling the naked fallow to be dispensed with, and permitting the adoption of a much safer and more profitable system of farming, in which the rearing and feeding of stock are combined with the growth of valuable grain-crops.

" 4th. That thorough-drained fields stand wet and drought better than undrained fields naturally of the same sort of soil.

" That they should stand wet better from being drained was to be expected; but it is not, at first sight, so apparent that they should also stand drought. Those who in travelling through districts of England or Scotland into which thorough-drainage has recently been introduced, have felt an interest in marking the effects, know well how, during protracted droughts, the thorough-drained fields call attention to themselves by their superior verdure. It follows, from the principles already laid down, that it should be so. It need only be mentioned that thorough-drained soils have been greatly deepened, that they do not bake, and that it is merely of superfluous water that the drains free them.

" 5th. That thorough-drained fields are more easily tilled and are in a fit state for the operations of tillage a much greater number of days per annum.

" In variable climates this is a very great advantage. There is not merely 'a time to sow,' but a time for every other operation of the field ; and when the state of the soil forbids an operation till the proper time is past, the result is seldom favourable.

" 6th. That all manures produce a much greater effect on thorough-drained fields than on undrained ones."

Among the beneficial effects of drainage are reckoned the admission of air into the soil from below, or by an under-draught through the drains. Common air and water are the two substances most important for plants, and both require to be supplied to the roots in proper measure ; and it is considered to be a great advantage to supply air from beneath as well as from above. But the effects of different methods of land drainage, in this respect, have not yet been sufficiently observed for the enumeration of any practical conclusions in relation to them. It is now, however, a practice with florists to make several holes at the bottom of flower-pots instead of only one, expressly with the view of admitting a more abundant supply of air.

The object of drainage is not to deprive the land of moisture, but to adjust the quantity so as to produce the highest degree of fertility ; and although the very best systems are far from being perfect in this respect, yet, under every mode of drainage that has been tried when gross errors of construction have been avoided, the returns have always been found to be a very high remuneration for the outlay.

It is presumed, however, in regard to suburban land and villa occupations, that the chief thing sought is the immediate drying of the soil ; so that in their case closely-laid drains will be requisite to ensure a rapid discharge of surface water, particularly from the footpaths.

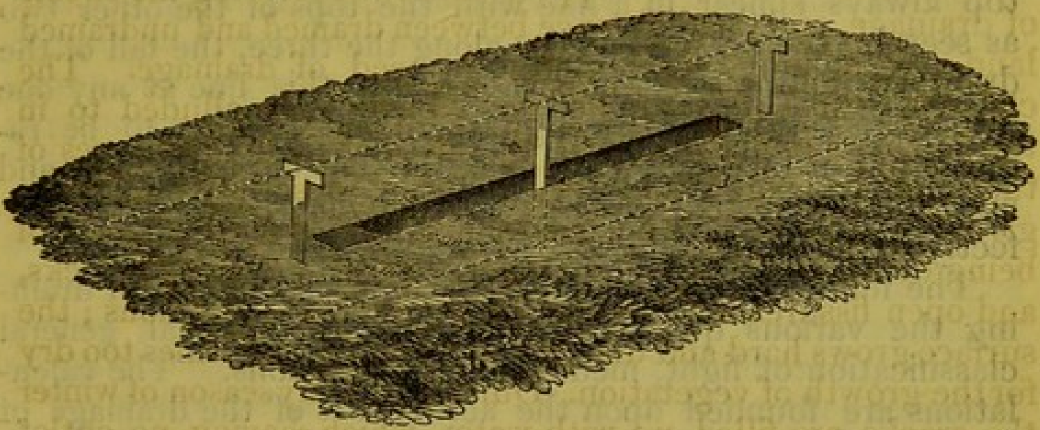
It should be kept in view that roads and footpaths cannot drain downwards by percolation, but over the surface. Once at the sides of the road, the water may either percolate into the drains or be received into them by gully-shoots properly trapped to prevent the ingress of sand or silt. The same remark applies to court-yards.

It is important, in reference to the suburban districts, to allude to the effect of drainage on the vigour and growth of trees. It has been determined by observations, that if the annual increase of trees on undrained land is 3 per cent., the increase on drained land will be 6 per cent.; and on land both drained and irrigated no less than 12 per cent., or four times the amount of the growth on the undrained land.

Those who have had no opportunities of observing the effects of drainage, and the difference between drained and undrained land, cannot judge when land is in need of drainage. The characteristics of ill-drained land have been alluded to in the previous explanations of the methods and advantages of thorough-drainage; and the following description may be given in addition. When undrained land is in the course of being dried up during the summer, the soil shrinks and cracks, and open fissures may be seen running in all directions; the surface grows hard and difficult to work, and becomes too dry for the growth of vegetation. During the rainy season of winter the cracks are filled up with water, which having no outlet remains in the soil and renders it soft and wet, and unfit for advantageous cultivation. In spring the crops are sickly, and there is a want of vigour in the plants generally; their colour is not the healthy hue; their parts are not fully developed, and they grow up and ripen very unequally. On ill-drained pasture lands the herbage is coarse, wiry, and of a sickly colour; the ground is hard and inelastic to the tread in summer, and in winter it sinks under the foot like a sponge. The more valuable species of herbage give way to a coarse bitter sort, which may, not unaptly, be termed the weeds of grass land. It has been remarked that grazing cattle prefer the best drained portions of the pasture ground.

The condition of the land and the extent of drainage that it may require can be best ascertained by proof pits or test-holes; that is, pits dug here and there in the soil from 5 to 7 feet deep, and wide enough for a man to work in them. The water flowing out from the sides of these pits will show at what levels it is accumulated, and how deep the drains must be to carry it off. Or, instead of pits, one or more deep cuts may be made in the proper direction from one end of a field to the other, and they will serve both as test-holes and beds for drains.*

One cause of the occasional failure of land-drains is their not having been made perfectly regular in inclination when they were first laid. If instead of a gradual and uniform fall there happen to be a slight rising in the bed of a drain, the descending water will be interrupted there till it accumulate so high as to be above the level of the rising, which will lead to a permanent stagnation or loss of fall for a certain length of the drain. Hence in laying the floor of the drains, means must be taken to make their descent to the outfall perfectly straight. This is accomplished by the use of what are called *boning-rods*, which may be described as follows:—



* It has been suggested that much useful information might be obtained from an examination of the nature and condition of lands throughout suburban districts, by means of trial-pits or test-holes, such as are made for examining the soil for land drainage. The information obtainable by this means consists of,—

1. A knowledge of the nature and capabilities of the land in each district.
2. Of the state of each district as to drainage, or the want of it.
3. The relative condition of adjacent districts, and how far the want of drainage in one district affects others.
4. How far a complete drainage of one district would affect others.
5. Whether the superfluous water in any particular locality arises from springs, or whether it be rain-water retained in the soil.
6. Whether water in any quantity likely to be useful could be collected by land drainage in any particular locality.
7. The most suitable localities for reservoirs for collecting such waters.
8. The qualities of the water found in the different localities.

In some particular spots it might for special purposes be desirable to make pits with the spade, to show the soil and subsoil; but generally an auger-bore of 3 inches to 6 inches diameter would be sufficient. And where water is found, a few small drain-pipes might be dropped into the bore to keep it open in case of any future examination of the quantity or quality of the water being desirable.

Where there are ditches filled with water, such test-holes would serve to show whether the adjoining fields were saturated to or near the level of that in such ditches. And in case of the removal of or substitution of tubular drains for ditches, the trial-pits would serve to indicate their effects upon the land.

Generally such information might be obtained as would form a record of the present state of suburban districts as to drainage, or the want of it, to which reference could in future be made, from time to time, as to the effect of any drainage executed. Together with the information so obtained should be annexed a precise account of the state of each locality, so as to form a ready book of reference on all matters relative to the state of land drainage.

Three staffs are made use of, two of them 2 feet long, and the third as much more than 2 feet as the drain is deep; that is, if the drain is 3 feet 6 inches deep, it must be 5 feet 6 inches long. The staffs are strips of wood, with cross pieces 9 inches long at the end that is to stand uppermost. The two shorter staffs are planted upright, one on the ground on a level with the field at the head of the drain, and the other at the lower end; and a person stands at one of them looking over its top, with his eye in a line with the other. A second man then takes the longest staff and holds it upright in the drain just touching the bottom, and walks along from one end of the drain to the other, keeping it in the upright position. If, while it is moved along, its top always appear in a line with the tops of the other two as seen by the person looking along the three, the fall of the drain is uniform; but if it rises above this line at any one place, the bottom is too high there and requires to be reduced; if it falls below the line, the bottom is too low and must be raised. In this way the fall may be rendered perfectly uniform.

The following are estimates of the probable cost of draining the various qualities of land under the usual general classification of light, medium, and heavy soils. The calculations are founded upon the actual cost of the drainage of lands of these qualities.* (See Table *A.*)

Subjoined also are extracts from published statements, by Mr. Smith of Deanston and Mr. Josiah Parkes, of the cost of drainage in various parts of the country. (See Tables *B.*, *C.*, *D.*)

Annexed is a diagram and statement of the comparative cost of draining a field of twenty acres on the two systems of Mr. Smith and Mr. Parkes. These estimates are rather " outside estimates," as is proper for small works. (See Tables *E.*, *F.*)

Private land-drains being liable to be opened or otherwise interfered with by the occupiers of the lands or their workmen, and to have the surface flood waters or contents of open ditches turned into them, traps or pits are necessary wherever such interference is allowed or practised; but with the drains properly constructed at first, and not afterwards injuriously interfered with, these sand traps or pits will not usually be required.

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* It is thought probable that the cost of land-drainage may be considerably reduced by the operation of a recently invented drain-plough, which is described by Mr. Pusey in the Journal of the Royal Agricultural Society, vol. 12, pp. 639-641. *Vide* Appendix, No. VIII. p. 119.

Annexed also is a drawing and statement of the cost of draining plots of land for villa residences and cottages. (See Tables *L.*, *N.*) The necessity of a very complete and rapid drainage from such premises occasions a higher average cost than in the drainage of agricultural or garden ground. In general, drains for the removal of springs, or the clearance of the sites of houses from surplus water, are required to be cut much deeper than for common-land drainage, usually deeper than the foundations of buildings.

That more attention should in general be given to the condition of the suburban villas is proved by the frequent complaints of the dampness of such habitations. The dampness of their undrained soil is often aggravated by the trees that are planted about them, which exclude the action of the sun, and engender the unwholesome closeness of overgrown and neglected spots. The mosses and lichens that overspread such localities are signs of an unhealthy vegetation and a tainted atmosphere.

It is also of great importance to provide by means of suitable hedges or otherwise a shelter from the cold winds of winter, which by sweeping over the naked surface of open ground produce an excessive degree of cold, which the shelter of good hedges would tend greatly to ameliorate.

To secure the salubrity of a suburban or country residence the drainage should be deep and close. In the case of the roots of trees entering the drains, it may be remarked that they do so in order to obtain nourishment; and it is thought that it would be often worth while to allow them this facility, even though additional drains should be required in consequence; but, if necessary, the entrance of roots may be prevented by the use of collars to the drains.

The high value of suburban land in general will enable it to bear a larger expenditure with a view to secure a more productive cultivation. The space of ground near Birkenhead, now called the park, was a short time ago, like much suburban land near the metropolis, a mere marsh, over which thick mists hung at nightfall. It was thoroughly drained by Sir Joseph Paxton, with drains varying in depth from seven feet to close surface drains. The mists and fogs created on this tract have, since the drains came into operation, disappeared. The expense of that work was 20*l.* per acre; and the land, which before the drainage was worth only 1*l.* per acre, is now worth, at the least, 4*l.* per acre for pasturage; so that the work pays 15 per cent. direct profit, besides effecting its main object,—the improvement of the neighbourhood in comfort and salubrity.

(*A.*)

## A TABLE OF THE COST OF LAND-DRAINAGE PER ACRE.

The differences in the quality of soils, that lead to differences in the depth and distance of the Drains, are also such as to affect the cost of digging the Drains. An increase of depth necessarily causes an increase of cost, from the mere circumstance of more earth having to be moved. But the same reason that causes Drains to be made closer, namely, the stiffness of the soil, renders them more difficult to dig, and hence increases the price of digging. This will explain how it happens, in the following Table, that the cost per rod is greater, not only as the depth increases, but as the distance of the Drains is less. Of two soils drained at the same depth, the expense of draining a rod will be least in that for which the Drains are farthest apart, which is where the soil is of the freest or least tenacious description.

| Description of Soils. | | Distance of Drains apart. | Depth of Drains. | Number of Yards of Drains per Acre. | Cost of cutting and filling per Chain. | Cost of cutting and filling per Acre. | Number of Drain Pipes of 12 Inches long required per Acre. | Cost of Drain Tiles per Acre, at 30*s.* per 1,000. | Total Cost per Acre. |
|---|---|---|---|---|---|---|---|---|---|
| | | Feet. | Ft. in. | | £ *s.* *d.* | £ *s.* *d.* | | £ *s.* *d.* | £ *s.* *d.* |
| Heavy Soils. | Compact tenacious gravelly Clay - - - | 15 | 2 6 | 968 | 0 1 8 | 3 13 4 | 2,905 | 4 7 2 | 8 0 6 |
| | Stiff adhesive Clay - | 16½ | 2 6 | 880 | 0 1 7 | 3 3 4 | 2,640 | 3 19 2 | 7 2 6 |
| | Friable Clay - - | 18 | 2 9 | 807 | 0 1 6 | 2 15 1½ | 2,420 | 3 12 7 | 6 7 8 |
| | Free soft Clay - - | 21 | 2 9 | 692 | 0 1 4 | 2 2 0 | 2,076 | 3 2 3 | 5 4 3 |
| Medium Soils. | Clayey Loam - - | 22 | 3 0 | 660 | 0 1 8 | 2 10 0 | 1,980 | 2 19 5 | 5 9 5 |
| | Marly Loam - - | 24 | 3 0 | 605 | 0 1 6 | 2 1 3 | 1,814 | 2 14 5½ | 4 15 8 |
| | Gravelly Loam - - | 27 | 3 3 | 538 | 0 2 4 | 2 17 2 | 1,613 | 2 8 4½ | 5 5 6½ |
| | Friable Loam - - | 30 | 3 3 | 484 | 0 2 0 | 2 4 0 | 1,452 | 2 3 6½ | 4 7 6½ |
| Light Soils. | Light gravelly Loam - | 33 | 3 6 | 440 | 0 2 10 | 2 16 8 | 1,320 | 1 19 7 | 4 16 3 |
| | Light marly Loam - | 36 | 3 9 | 403 | 0 2 8 | 2 9 4 | 1,209 | 1 16 3 | 4 5 7 |
| | Sandy Loam - - | 39 | 4 0 | 373 | 0 2 6 | 1 19 8 | 1,117 | 1 13 6 | 3 3 2 |
| | Soft light Loam - - | 42 | 4 0 | 346 | 0 2 4 | 1 16 9 | 1,037 | 1 11 1½ | 3 7 10½ |
| | Sandy Soil - - | 45 | 4 0 | 325 | 0 2 4 | 1 14 5 | 974 | 1 9 2½ | 3 3 7½ |
| | Light gravelly Sand - | 49½ | 4 3 | 293 | 0 3 4 | 2 5 0 | 880 | 1 7 4½ | 3 12 10 |
| | Deep do. do. - | 55 | 4 3 | 264 | 0 3 0 | 1 16 0 | 792 | 1 3 9 | 2 19 9 |
| | Coarse gravelly do. - | 60 | 4 6 | 242 | 0 4 0 | 2 4 0 | 726 | 1 1 9 | 3 5 9 |
| | Loose do. - - | 66 | 4 6 | 220 | 0 3 4 | 1 13 4 | 660 | 0 19 9½ | 2 13 1½ |

## (*B.*)

A Table showing the Cost per Acre of Draining on Hard Subsoils, with Tiles and Soles, extracted from Mr. Smith of Deanston's Pamphlet on Drainage.

| Subsoils to which the Distances are applicable. | Distance between the Drains. | Number of Rods per Acre. | Cost per Acre of Tiles at 14*s.* and Soles at 7*s.* per Thousand. | Cost of cutting and filling at 3½*d.* | Total Cost per Acre. |
|---|---|---|---|---|---|
| | Feet. | | £ *s.* *d.* | £ *s.* *d.* | £ *s.* *d.* |
| Clay - - - | 15 | 176 | 3 0 11½ | 2 11 4 | 5 12 3 |
| Sandy Clay - - - | 18 | 147 | 2 10 9¾ | 2 2 10½ | 4 13 8½ |
| Ditto - - | 21 | 126 | 2 3 6½ | 1 16 9 | 4 0 3½ |
| Free Stony Subsoil - | 24 | 110 | 1 18 1½ | 1 12 1 | 3 10 2½ |
| Ditto - - - | 27 | 98 | 1 13 10¼ | 1 8 7 | 3 2 5¼ |
| Porous - - - | 30 | 88 | 1 10 6 | 1 5 8 | 2 16 2 |
| Ditto - - - | 33 | 80 | 1 7 8½ | 1 3 4 | 2 11 0½ |
| Sand or Gravel - - | 36 | 74 | 1 5 4 | 1 1 7 | 2 6 11 |

## (*C.*)

Instances of the Cost of Draining cited by Mr. Josiah Parkes in the Sixth Volume of the "Journal of the Royal Agricultural Society," the Drain Pipes being assumed to cost Six Shillings per Thousand, being made upon the Estate.

| County. | Instances cited. | Depth of Drains. | Distances between Drains. | Cost of Labour per Acre. | Cost of Pipes per Acre. | Total Cost per Acre. | Character of the Soil. |
|---|---|---|---|---|---|---|---|
| | No. | Feet. | Feet. | £ *s.* *d.* | *s.* *d.* | £ *s.* *d.* | |
| Kent - | 1 | 3 | 33 | 1 0 0 | 7 11 | 1 7 11 | Uniform Clay. |
| Sussex - | 2 | 3 | 33 | 1 0 0 | 7 11 | 1 7 11 | Ditto. |
| Surrey - | 3 | 3 to 4 | 33 | 1 6 8 | 7 11 | 1 14 7 | Ditto. |
| Ditto - | 4 | 4½ to 4 | 40 | 1 2 0 | 6 6 | 1 8 6 | Ditto. |
| Ditto - | 5 | 4 | 50 | 1 6 6 | 5 3 | 1 11 9 | Clay, with some stones. |
| Kent - | 6 | 3 to 3½ | 49½ | 1 15 6 | 5 4 | 2 0 10 | Clay—Hard Gravelly Subsoil. |
| Ditto - | 7 | 4 | 49½ | 1 15 6 | 5 4 | 2 0 10 | Ditto. |
| Ditto - | 8 | 4 | 66 | 1 6 8 | 4 0 | 1 10 8 | Various—Clay, Gravel, Sand. |
| Ditto - | 9 | 3½ to 4 | 33 | 2 10 0 | 7 11 | 2 17 11 | Clay, Gravelly Subsoil. |

(*D.*)

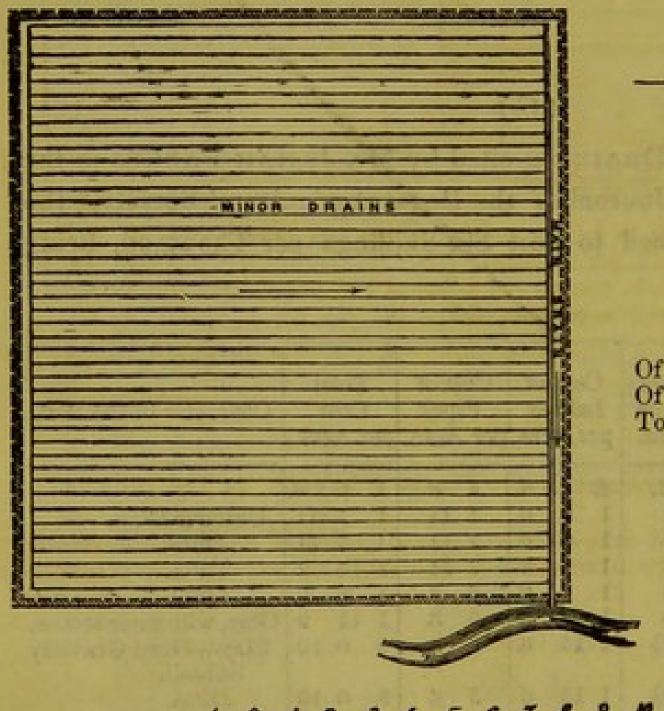
EXTRACTS from the "Gardener's Chronicle and Agricultural Gazette," 18th March 1848, of the COST of the DRAINAGE of LANDS in the County of NORTHAMPTON, by Mr. JOSIAH PARKES.

| FARMS. | Extent drained. | Depth of Drains in Feet. | Distance apart in Yards. | Cost of Labour, including Mr. Parkes' Commission of 5*s*. an acre. | Cost of Tiles. | Total Cost. | Cost per Acre. | Character of the Soils. |
|---|---|---|---|---|---|---|---|---|
| | A. R. P. | | | £ *s.* *d.* | £ *s.* *d.* | £ *s.* *d.* | £ *s.* *d.* | |
| A | 33 0 0 | 4 | 12 | 113 8 5 | 37 16 3 | 151 8 4 | 4 11 7 | Heavy Clay. |
| B | 61 0 31 | 4 | 12 | 152 11 0 | 77 12 8 | 230 3 8 | 3 15 5 | Various Clay. |
| C | 16 0 0 | 4 | 10 to 11 | 46 18 3 | 20 6 9 | 67 7 9 | 4 4 2 | Strong Clay. |
| D | 16 0 0 | 4 | 13 | 60 15 7 | 15 4 2 | 76 9 9 | 4 15 7 | Strong Land. |
| E | 20 0 0 | 4 | 10 | 68 16 8 | 25 2 6 | 93 19 2 | 4 13 11 | Weak Blue Clay. |
| F | 46 0 0 | 4 | 12 | 165 4 5 | 55 15 6 | 220 19 11 | 4 16 1 | Whitish Stubborn Clay. |
| G | 13 0 0 | 4 | 11 to 12 | 49 8 7 | 17 15 6 | 67 4 1 | 5 3 4 | Strong Clay and Gravel. |
| H | 12 0 0 | 4 | 12 | 36 12 7 | 14 3 9 | 50 16 4 | 4 4 8 | Whitish Clay. |

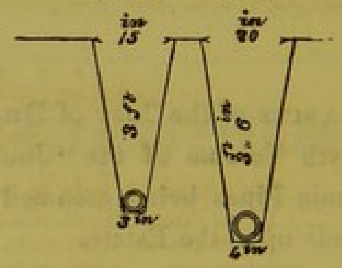
The Tiles were made upon the estate and drawn by the Tenants, who also pay to the Landlord 5 per cent. on the outlay.

(*E.*)

A Field of 20 acres, with the Drains 3 feet deep and 22 feet apart, upon Mr. Smith of Deanston's system.




Scale of chains.




| Sectional Area. | In. |
|---|---|
| Of minor drain - - | 324 |
| Of main drain - - | 504 |

To be removed in digging the drain.

| | £ | *s.* | *d.* |
|---|---|---|---|
| Main drain, 60 rods, at 8½*d.* per rod - - | 2 | 2 | 6 |
| Drain pipes, 990, at 40*s.* per thousand - - | 1 | 19 | 7½ |
| Minor drains, 2,261¼ rods, at 4½*d.* per rod - - | 42 | 8 | 0 |
| Drain pipes, 37,320, at 30*s.* per thousand - - | 55 | 19 | 7 |
| | £102 | 9 | 8½ |

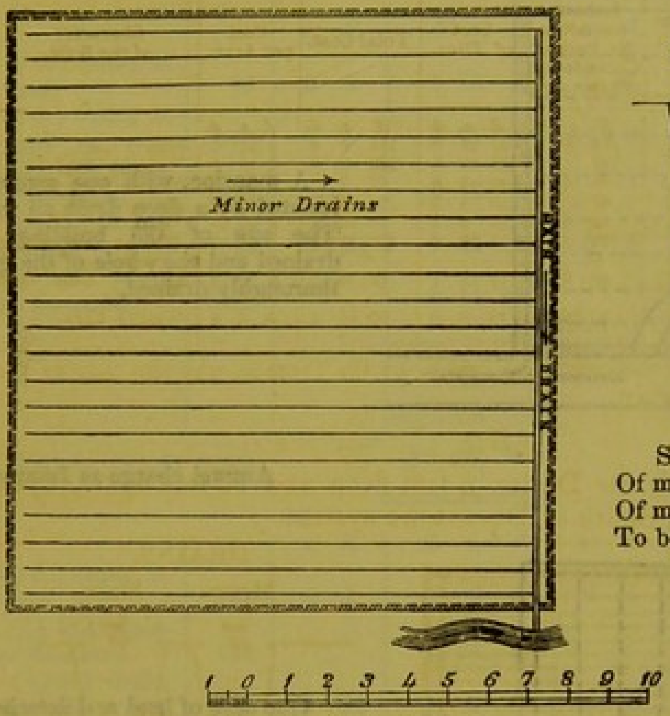
£5 2*s.* 6*d.* per acre.

Annual charge as Improvement Rate or Rent at 20 years, 7*s.* 7*d.* per acre.

The two fields are assumed to be alike in size and quality of soil, and the prices for cutting and filling the drains are in proportion to their depth and sectional area respectively.

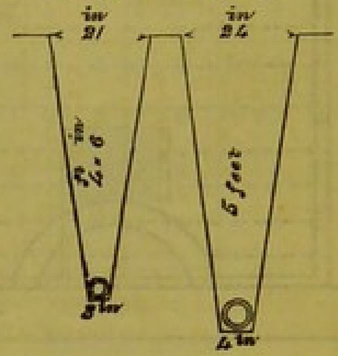
(*F.*)

A Field of 20 acres, with the Drains 45 feet apart, and 4½ feet deep, upon Mr. Josiah Parkes's system.




Scale of chains.

DRAINS.




| Sectional Area. | In. |
|---|---|
| Of minor drain - | - 648 |
| Of main drain - | - 840 |

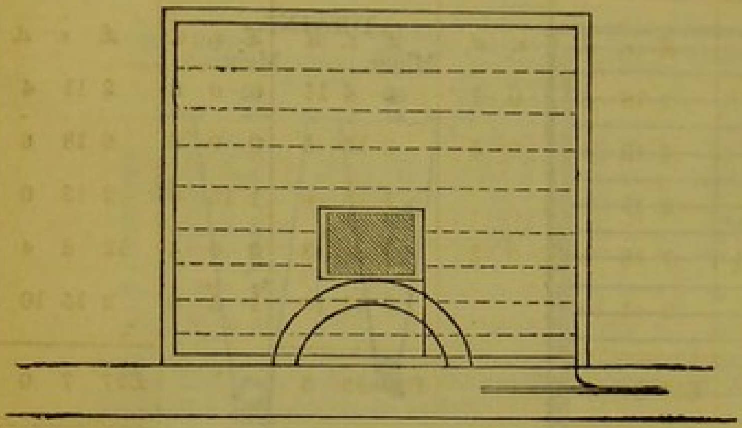
To be removed in digging the drains.

| | £ | s. | d. |
|---|---|---|---|
| Main drain, 60 rods, at 1*s.* 2*d.* per rod for cutting and filling - | 3 | 10 | 0 |
| Drain pipes, 990, at 40*s.* per thousand - - - | 1 | 19 | 7½ |
| Minor drains, 1,109 rods, cutting and filling at 10*d.* per rod - | 46 | 4 | 2 |
| Drain pipes, 18,300, at 30*s.* per thousand - - - | 27 | 9 | 0 |
| | £79 | 2 | 9½ |

£3 19 1½ per acre.

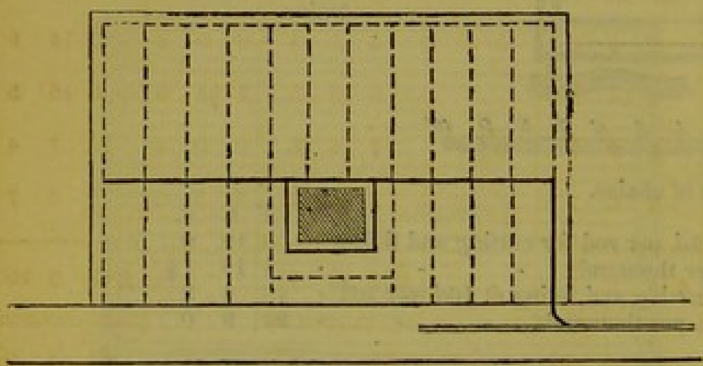
Annual charge as Improvement Rent or Charge at 20 years, 6*s.* 1¼*d.* per acre.

The two fields are assumed to be alike in size and quality of soil, and the prices for cutting and filling the drains are in proportion to their depth and sectional area respectively.



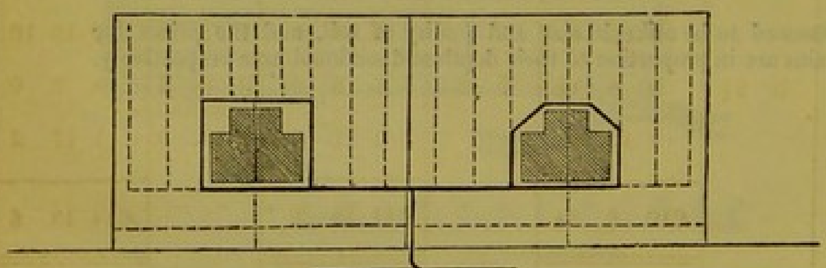
A mansion, with one acre of land isolated by a deep drain all round it. The site of the building deeply drained and the whole of the grounds thoroughly drained.

Annual charge as Improvement



One acre of land and detached villa residence. The site of the buildings deep-drained, and the rest of the ground thoroughly drained.

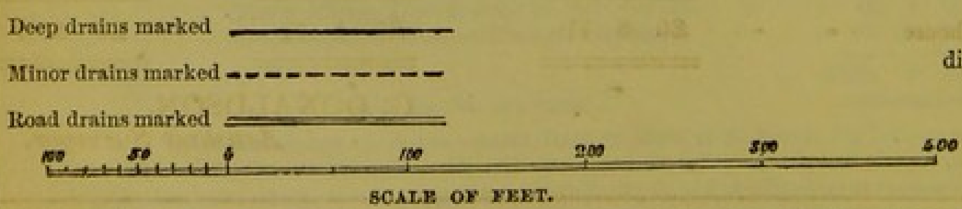
Annual charge as Improvement



One acre of ground, laid out for four semi-detached villa residences. The sites of the buildings deep-drained, and the grounds thoroughly drained.

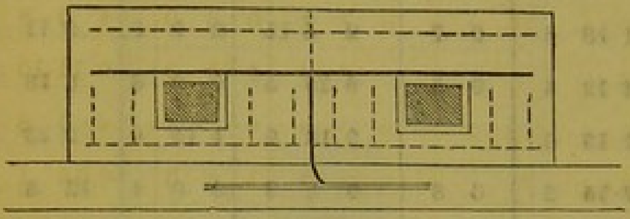
Annual charge as Improvement

ditto



| Labour and Materials. | Quantities. | Light Soils. Rate. | Light Soils. Amount. | Medium Soils. Rate. | Medium Soils. Amount. | Heavy Soils. Rate. | Heavy Soils. Amount. |
|---|---|---|---|---|---|---|---|
| | | *s. d.* | *£ s. d.* | *s. d.* | *£ s. d.* | *£ s. d.* | *£ s. d.* |
| Deep (6 ft.) drain, at per yard - - | 77 | 0 6 | 1 18 6 | 0 7 | 2 4 11 | 0 0 8 | 2 11 4 |
| „ (5 ft.) drain, at per yard - - | 277 | 0 4 | 4 12 4 | 0 5 | 5 15 5 | 0 0 6 | 6 18 6 |
| Drain (1¼ in.) pipes, at per thousand - | 1062 | | 2 13 0 | | 2 13 0 | 1 15 0 | 2 13 0 |
| Minor (3½ ft.) drains, at per yard - | 745 | 0 2½ | 7 15 2 | 0 3 | 9 6 3 | 0 0 4 | 12 8 4 |
| Drain (1 in.) pipes, at per thousand - | 2235 | | 2 15 10 | | 2 15 10 | 1 5 0 | 2 15 10 |
| | | | £19 14 10 | | £22 15 5 | | £27 7 0 |
| Rent or Rate, for twenty years | | - | £1 10 3 | | £1 14 8¼ | - - | £2 3 2½ |
| | | *s. d.* | *£ s. d.* | *s. d.* | *£ s. d.* | *£ s. d.* | *£ s. d.* |
| Deep (5 ft.) drain, at per yard - - | 147 | 0 4 | 2 9 0 | 0 5 | 3 1 3 | 0 0 6 | 3 14 6 |
| Drain (1¼ in.) pipes, at per thousand - | 441 | | 0 14 5 | | 0 15 5 | 1 15 0 | 0 15 5 |
| Minor (3½ ft.) drain, at per yard - | 622 | 0 2½ | 6 9 7 | 0 3 | 7 15 6 | 0 0 4 | 10 7 4 |
| Drain (1 in.) pipes, at per thousand - | 1866 | | 2 6 7 | | 2 6 7 | 1 5 0 | 2 6 7 |
| | | | £12 0 7 | | £13 18 9 | | £17 2 10 |
| Rent or Rate, for twenty years | | - | £0 18 3½ | | £1 1 4¾ | - - | £1 6 0¼ |
| | | *s. d.* | *£ s. d.* | *s. d.* | *£ s. d.* | *£ s. d.* | *£ s. d.* |
| Deep drain, at per yard - - | 151 | 0 4 | 2 10 4 | 0 5 | 3 2 11 | 0 0 6 | 3 15 6 |
| Drain (1¼ in.) pipes, at per thousand - | 453 | | 0 15 10 | | 0 15 10 | 1 15 0 | 0 15 10 |
| Minor drains, at per yard - - | 495 | 0 2½ | 5 3 1½ | 0 3 | 6 3 9 | 0 0 4 | 8 5 0 |
| Drain (1 in.) pipes, at per thousand - | 1485 | | 1 17 2 | | 1 17 2 | 1 5 0 | 1 17 2 |
| | | | £10 6 5½ | | £11 19 8 | | £14 13 6 |
| Rent or Rate, for twenty years | | - | £0 15 8½ | | £0 18 3 | - - | £1 2 4¼ |
| ditto per house - - | | - | £0 3 11 | | £0 4 6¾ | - - | £0 5 7 |

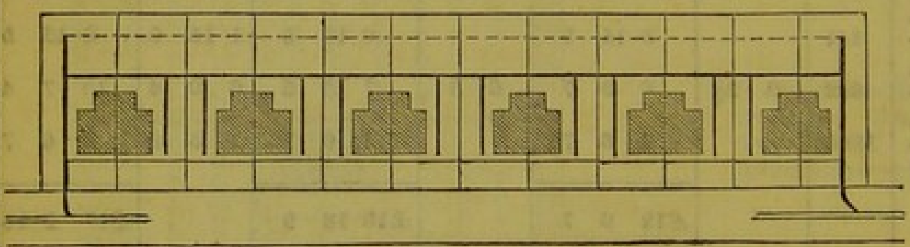
G. DONALDSON,
*Assistant Surveyor.*



Half an acre of land, laid out for two detached villa residences. The sites of the buildings deep-drained, and the grounds thoroughly drained.

Annual charge as Improvement

ditto



One acre of land, laid out for 12 semi-detached villa residences, and thoroughly drained.

Annual charge as Improvement

ditto

Deep drains marked ——————

Minor drains marked - - - - - - - - -

Road drains marked ═══════

100 200

SCALE OF FEET.

| Labour and Materials. | Quantities. | Light Soils. Rate. | Light Soils. Amount. | Medium Soils. Rate. | Medium Soils. Amount. | Heavy Soils. Rate. | Heavy Soils. Amount. |
|---|---|---|---|---|---|---|---|
| | | s. d. | £ s. d. | s. d. | £ s. d. | £ s. d. | £ s. d. |
| Deep drains, at per yard - - | 161 | 0 4 | 2 13 8 | 0 5 | 3 7 1 | 0 6 0 | 4 0 6 |
| Drain (1¼ in.) pipes, at per thousand - | 483 | | 0 16 10 | | 0 16 10 | 1 15 0 | 0 16 10 |
| Minor drains, at per yard - - | 242 | 0 2½ | 2 10 5 | 0 3 | 3 0 6 | 0 0 4 | 4 0 8 |
| Drain (1 in.) pipes, at per thousand - | 726 | | 0 18 1 | | 0 18 1 | 1 5 0 | 0 18 1 |
| | | | £6 19 0 | | £8 2 6 | | £9 16 1 |
| Rent or Rate, for twenty years | | - | £0 10 8 | | £0 12 3¼ | - - | £0 14 11½ |
| ditto per house - | | - | £0 5 4 | | £0 6 1½ | - - | £0 7 6¾ |

| Labour and Materials. | Quantities. | Light Soils. Rate. | Light Soils. Amount. | Medium Soils. Rate. | Medium Soils. Amount. | Heavy Soils. Rate. | Heavy Soils. Amount. |
|---|---|---|---|---|---|---|---|
| | | s. d. | £ s. d. | s. d. | £ s. d. | £ s. d. | £ s. d. |
| Deep drains, at per yard - - | 484 | 0 4 | 8 1 4 | 0 5 | 10 1 9 | 0 0 6 | 12 2 0 |
| Drain pipes, at per thousand - - | 1452 | | 2 10 9½ | | 2 10 9½ | 1 15 0 | 2 10 9½ |
| Minor drains, at per yard - - | 147 | 0 2½ | 1 10 7 | 0 3 | 1 16 9 | 0 0 4 | 2 9 0 |
| Drain pipes, at per thousand - - | 441 | | 0 11 0 | | 0 11 0 | 1 5 0 | 0 11 0 |
| | | | £12 13 9 | | £15 0 3½ | | £17 12 9½ |
| Rent or Rate, for twenty years | | - | £0 19 4¼ | | £1 2 10½ | - - | £1 6 11 |
| ditto per house - | | - | £0 1 7½ | | £0 1 11 | - - | £0 2 3 |

G. DONALDSON,
*Assistant Surveyor.*

The simple indented tube-tiles may be purchased in the country at a retail price of 15*s*. the thousand, and the double horse-shoe tiles at 40*s*. the thousand. Those who manufacture tiles themselves may obtain both kinds at a much lower cost. In the Appendix, p. 70, is given a table, showing the prime cost of making tubular drain-tiles, of various diameters, by the Ainslie tile-kiln and machine. The ordinary kilns require one half more coal. This table will furnish data which will enable those who have clay on their own lands to determine whether it will be better to manufacture or to purchase pipes.

To guard against the ingress of sand, mud, detritus, or other matters, from private land-drainage into the public mains, it is proposed that all private land-drainage shall pass through at least a chain (22 yards) of sub-main drain immediately before discharging into the mains ; the sub-mains to be such as shall be approved of by the Surveyor to the Local Board ; and that there be placed in each at a suitable point, not less than six yards from its junction with the main drain, a trap with a grating for intercepting any matters that might tend to choke or clog the mains.

Such traps should have a grating placed in the line of the drain pipes, with a recess for receiving the intercepted matter, the top or cover being moveable for the purpose of cleaning it out when necessary. All junctions of sub-main drains with the mains should be so constructed as to bring the line of the sub-main nearly parallel with the line of the main, so that at the point of junction the streams may flow together without collision ; and in every case of junction whatsoever the same mode of connexion should be observed.

Attached to the following scales of estimated charges for the work are statements of the rates for spreading the repayment over a term of years.*

The land to be drained is taken of three classes, light, medium, and heavy. The cost of draining per acre will be—

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* Appendix IX. contains tables for calculating the amount necessary for repaying any sum, with interest, by equal annual instalments in any period from one to thirty years at any rate of interest from $3\frac{1}{2}$ to 6 per cent.

| | £ s. d. | | £ s. d. | Tenant's annual Charge. s. d. | | s. d. |
|---|---|---|---|---|---|---|
| For Light Soils, from | 2 13 6 | to | 4 16 3 | 4 1 | to | 7 4 |
| For Medium Soils „ | 4 7 6 | „ | 5 10 0 | 6 $8\frac{1}{16}$ | „ | 8 $4\frac{3}{4}$ |
| For Heavy Soils „ | 5 5 0 | „ | 8 0 0 | 8 $0\frac{1}{16}$ | „ | 12 $2\frac{1}{4}$ |

For villa drainage the cost per acre will be from 10*l.* 6*s.* 6*d.* to 27*l.* 7*s.* according to circumstances.

The cost of drainage of a single villa will vary from 3*l.* 10*s.* to 27*l.*, according to the extent of ground and the drainage required.

A charge of 7*l.* 13*s.* 9*d.* per cent. upon the outlay would repay the cost, with interest at the rate of $4\frac{1}{2}$ per cent. in the course of twenty years.

The foregoing explanations and suggestions refer to the removal from the land of the surplus water arising from rainfalls and springs. But in the case of premises not supplied with water, the occupiers may be expected not only to reserve for their own use the rain falling on the roofs of their houses and offices, but to collect part of the drainage and spring water of the fields into appropriate tanks or receptacles. The only service that could be expected from the surveyor in regard to such tanks or reservoirs would be to attend to the connexion of the overflow pipes with the main outfalls.

In respect to the house-drainage or the removal of the refuse from the water-closets, kitchens, sculleries, stables, and offices, as well as the drainage from the farm steading, it is presumed that in the case of suburban dwellings occupied by parties engaged in land-tillage, the occupiers, instead of allowing it to run to waste, will carefully retain it in tanks provided for the purpose, with the view of applying it as manure to increase the productiveness of the land.

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In the Appendix will be found the answers, obtained by the Earl of Carlisle, from persons of the chief practical experience who have been consulted on land-drainage works throughout the country.

On the whole, the collection of practical information in the Appendix will be found to be the most authentic, full, and complete of any which is known to have been yet formed upon the subject; and looking to the importance of suburban land-drainage as a means of relief to the densely-populated districts, as subservient to the application of the refuse productively, as well as means for the diminution of damp and fogs, and nuisances injurious to the public health, it is to be hoped that this information will be widely circulated, to stimulate and guide private exertions for the extension of the practice of thorough drainage.

But whilst safe profitable results are now available for immediate practical application, still further improvements may, no doubt, be effected by skilful local surveyors who have studied the improved principles of drainage. The investigations of the works of town-drainage for the purpose of the sanitary improvement of the town population have elicited, on a large scale, some important results in respect to hydraulic arrangements which are applicable to land-drainage works on a small scale.

It was found that a large proportion of sewers were constructed with flat bottoms, which, when there was a small discharge, spread the water, increased the friction, retarded the flow, and accumulated deposit. It was ascertained that by the substitution of circular sewers of the same width, with the same inclination and the same run of water, the amount of deposit was reduced more than one-half. *Vide Sanitary Report*, 1842, p. 55.

By a better adaptation of the size of tubular drains to the water which they are required to convey, with the same quantities and inclinations, a velocity of discharge more than four times greater was in some important cases attained, and complete and rapid clearances effected, and heavy substances swept away which previously formed part of the accumulations of decomposing matter polluting the air of towns. (*Vide Exemplification, Report on the Water Supply of the Metropolis*, 1850, p. 185. *et seq.*) It was proved also that a great reduction of the sectional area of the system of drains was generally expedient, in many cases so great as in the proportion of 37 to 1, and that such reduction would effect a constant clearance of all deposit, and prevent those accumulations of decomposing matter which made the drains and sewers of towns only extended systems of cesspools, the cleansing of which occasioned as great an annual expense as would be required for the substitution of an entirely new set of works. (*Idem*, p. 201.)

So empirical were the first works of land-drainage, that no estimate appears to have been made of the service required by the pipes,—the like faults of construction to those of the common town sewers were displayed. The flat-bottomed tile drain was productive of the same results as the flat-bottomed town sewer,—the flow of water was retarded and deposit was occasioned; but *safety* had been sought by the undertakers at the expense of the employer by the construction of drains of so large a size, that the process of deposit might go on for a long time before they became completely obstructed.

As might be expected, the first drainers set out with drains of this erroneous construction, as may be seen by the diagrams in Mr. Smith of Deanston's first pamphlet. Thus his minor drains were of no less than eighteen inches sectional capacity. Now, a single drain of this capacity will, when running half full at the outlet, discharge in twenty-four hours about six hundred tons of water, equal to a rain-fall of nearly six inches in depth on an acre. One inch in depth is a very heavy fall in a day, and it generally takes two days for the water after rain to drain fully from deep drained land; yet Mr. Smith provided eighteen such drains per acre, having a total sectional area of 324 inches, and capable of discharging when only half filled, 4½ inches of rain-fall from an acre in a single hour. That is in six hours more than the whole annual rain-fall of the London district.

The smaller the amount of water to be discharged, the greater ought to be the care in the concentration of the flow and in the exactitude of the construction of pipes or the channels of conveyance. Some trial works as to the flow of water through drain pipes of different materials present results which appear to be available for the construction of pipes for land-drainage. Thus it was found that with pipes of the same diameter exactitude of form was of more importance than smoothness of surface; that glass pipes which had a *wavy* surface discharged less water at the same inclinations than Staffordshire stoneware clay pipes which were of perfectly exact construction. By passing pipes of the same clay—the common red clay—under a second pressure obtained by a machine at an extra expense of about eighteen pence per thousand, whilst the pipe was half dry, very superior exactitude of form was obtained; and by means of this exactitude, and with nearly the same diameters, an increased discharge of water of one fourth was effected within the same time. (*Vide Appendix No. 2. to the Report on the Supply of Water to the Metropolis*, p. 184.)

The conclusions appear to be, that by a more careful construction of agricultural drain pipes, the same effects might be produced with pipes of less size than those commonly in use. The same trial works showed also that accuracy in the forms of jointing was of greater importance to the well-working of any system of small drains than is commonly imagined.

In respect to town-drainage, the practice of architects and engineers was to enlarge the area of any main pipe in the proportion of the sectional area of each junction into it; whereas it was found by the trial works, that the addition of eight junctions, each of three inches diameter, into a main line of pipe of only four inches diameter so increased the velocity of the stream, that there was no increase of its sectional area. (*Appendix No.* 2. *to Report on Water Supply, Medworth*, p. 191.)

It was a practice in town-drainage, and defended too by professional men, to make junctions of streams at right angles, and is now the common practice to form the junctions of land-drains at right angles and with projecting pieces, so as positively to impede the flow. On a large scale it was found that when equal quantities of water were running direct at a rate of 90 seconds,—with a turn at right angles the discharge was only effected in 140 seconds,—whilst with a turn or junction with a gentle curve, the discharge was effected in 100 seconds. (*Vide Sanitary Report*, 1842, p. 57.)

The hydraulic formulæ in use even among engineers of the greatest eminence who have had the direction of the largest expenditure in such works of town-drainage appeared to be erroneous as to the requirements of pipes for the discharge of water. The old formulæ were founded on experiments mostly on a small scale, and applicable only to very different circumstances, and when applied to common drainage works, they presented differences of more than one third even in the discharge through six-inch pipes; and observations preparatory to actual experiments were made which showed that the differences between the fact and the common practice, as well as the common formulæ, increased in a still greater ratio with the larger discharges of water; but the further prosecution of these trial works was stopped, and the consequent economies of structural arrangements yet remain incompleted. Though enough was shown to demonstrate the entire insufficiency of the data on which the common practice and formulæ are founded, yet more varied trials, checked by different observers, appear to be requisite for the attainment of complete exactitude and definite limits of economy, as well as efficiency in hydraulic works of this description.

Observation of the runs of water from outfalls to sets of drains of the existing constructions and arrangements may be recommended for the improvement of land-drainage works in the better adjustment of the sizes of pipes to the discharge of surplus water and the removal of deposit, and in order to deduce, from the run through the outfall, what ought to be the size of the branch pipes. Thus, if it be observed, as it frequently has been, that a three-inch pipe which serves as the main outfall for the drainage of an area of ten acres of land is never more than half filled, it may be asked, what must be the size of the run or thread of water in the forty contributory branch pipes which the main receives? Need the sectional areas of the tributaries be so much as ten times larger than the main outfall? Will not the spreading out of the small stream or thread of water render it more shallow, increase its friction, impede the flow, and diminish its power of removing accidental obstructions?

The conclusions indicated would be, the expediency of making land-drainage pipes yet smaller, improving their manufacture, and making them more exact in form, laying them more accurately. There is no doubt that this would necessitate more skilful and even delicate adjustment than may now be readily available from common workpeople; but the question for investigation, for the improvement of these works, is, whether it would not be remunerative?

In answer to the objection of the excessive size of the pipes in proportion to any volume of water they could be required to discharge, it has been suggested, that although the additional space in the pipes might not be required for the discharge of water, it might be serviceable for the permeation of air. This object was not originally suggested as a reason for the size of the pipes, and, although it is supported by horticultural theory and practice (*vide ante*), its applicability to the pipe drainage of land has not been generally considered. Indeed no superior exit was originally or is usually provided to facilitate the free permeation of the air through the drains, and it is an operation which remains to be investigated. On the other hand, it is generally admitted that the reduction of the sizes has hitherto been advantageous, and there appears to be no valid reason why yet closer adaptation of the pipes to the quantity of water they can be required to carry may not be made with further advantage.

By Order of the Board,

Henry Austin, *Secretary*.

*Whitehall,*

30*th January* 1852.

# APPENDIX.

## No. I.

In calculating the expense of forming drains or ditches, one of the chief items is the quantity of earth that has to be thrown out, which depends on the size of the drain. The cost of the labour will necessarily increase with the weight of earth that has to be removed; hence it is convenient to know the solid contents, or the number of cubic yards of cutting, in a drain of any given dimensions. This is found by multiplying together the length, depth, and mean width of the drain. Thus if a drain is 300 yards long, and the cutting 3 feet deep, 20 inches wide at the top and 4 inches wide at the bottom, the mean width would be 12 inches (or the half of the sum of 20 and 4), and if we multiply 100, the length, by 1, the depth in yards, and by $\frac{1}{3}$, the mean width in yards, and the product would be 100 cubic yards. The following table will serve to facilitate such calculations.

TABLE showing the NUMBER of CUBIC YARDS of EARTH in each ROD ($5\frac{1}{2}$ Yards in length), in Drains or Ditches of various Dimensions.

| DEPTH. | MEAN WIDTH. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | 7 In. | 8 In. | 9 In. | 10 In. | 11 In. | 12 In. | 13 In. | 14 In. | 15 In. | 16 In. | 17 In. | 18 In. |
| 30 | ·89 | 1·02 | 1·146 | 1·27 | 1·40 | 1·53 | 1·655 | 1·78 | 1·91 | 2·04 | 2·164 | 2·29 |
| 33 | ·98 | 1·12 | 1·26 | 1·40 | 1·54 | 1·68 | 1·82 | 1·96 | 2·10 | 2·24 | 2·38 | 2·52 |
| 36 | 1·07 | 1·22 | 1·375 | 1·53 | 1·68 | 1·83 | 1·986 | 2·14 | 2·29 | 2·244 | 2·60 | 2·75 |
| 39 | 1·16 | 1·324 | 1·49 | 1·655 | 1·82 | 1·986 | 2·15 | 2·32 | 2·48 | 2·65 | 2·81 | 2·98 |
| 42 | 1·25 | 1·426 | 1·604 | 1·78 | 1·96 | 2·14 | 2·32 | 2·495 | 2·674 | 2·85 | 3·03 | 3·21 |
| 45 | 1·34 | 1·53 | 1·72 | 1·91 | 2·10 | 2·29 | 2·48 | 2·67 | 2·865 | 3·055 | 3·246 | 3·438 |
| 48 | 1·426 | 1·63 | 1·833 | 2·04 | 2·24 | 2·444 | 2·65 | 2·85 | 3·056 | 3·26 | 3·46 | 3·667 |
| 51 | 1·515 | 1·73 | 1·95 | 2·164 | 2·38 | 2·60 | 2·81 | 3·03 | 3·25 | 3·46 | 83·6 | 3·896 |
| 54 | 1·604 | 1·83 | 2·06 | 2·29 | 2·52 | 2·75 | 2·98 | 3·20 | 3·44 | 3·666 | 3·895 | 4·125 |
| 57 | 1·69 | 1·935 | 2·18 | 2·42 | 2·66 | 2·90 | 3·14 | 43·38 | 63·63 | 3·87 | 4·11 | 4·354 |
| 60 | 1·78 | 2·036 | 2·29 | 2·546 | 2·80 | 3·056 | 3·31 | 3·564 | 3·82 | 4·074 | 4·33 | 4·584 |

Along the top of the table is placed the mean widths in inches, and on the left-hand side the depths of the drains, extending from 30 inches to 5 feet. The numbers in the body of the table express cubic yards and decimals of a yard. In making use of the table, it is necessary first to find the mean width of the drain from the widths at the top and bottom. Thus, if a drain 3 feet deep were 16 inches wide at the top, and 4 inches at the bottom, the mean width would be half of 16 added to 4, or 10; then by looking in the table for the column under 10 (width), and opposite 36 (inches of depth), we find the number of cubic yards in each rod of such a drain to be 1·53, or somewhat more than one and a half. If we compare this with another drain 20 inches wide at the top, 4 inches at the bottom, and 4½ feet deep, we have the mean width 12, and looking at the table under 12 and opposite 54, we find 2·75 cubic yards, or two and three-quarters to the rod. In this case the quantity of earth to be removed is nearly twice as much as in the other, and hence, as far as regards the digging, the cost of the labour will be nearly double. But in the case of deep drains, the cost increases slightly for another reason, namely, the increased labour of lifting the earth to the surface from a greater depth.

The following extract from Mr. Raynbird's Essay on Measure Work, which received the prize of the Royal Agricultural Society, will serve to convey an idea of the usual cost of the labour of forming drains:—

"The cost of the labour required in draining depends, firstly, upon the nature of the soil in which the drains are dug; and, secondly, upon the depth and materials used for filling up. Draining on a sound clay free from stones may be executed at a cheaper rate per rod in length than on almost any other kind of soil, as from the firmness of the clay the work may be done with narrow spades, and but a small quantity of soil requires to be removed by manual labour. The draining wet sands, or gravels, or clays in which veins of sand abound, is more expensive than on the sound clays, because a broader spade has to be used, and consequently a larger amount of soil removed; and draining stony or rocky soils is still more expensive, because the pick has to be used: this adds considerably to the expense. On the sound clays of Suffolk and Essex, the price for digging drains, and laying in stubble, heath, brushwood, peat, or whatever else is used, and filling up drains so far as cannot be done with the plough, is about 4*s.* or 4*s.* 6*d.* the score rods, and 6*d.* for each eye.* These drains are made about 30 inches deep; the first spit is ploughed out, the two next dug with narrow draining spades; half a score rods of this kind of draining is reckoned a fair day's work. Sometimes, however, half a score is above an average, for I know a case on a hard clay, lying just above the chalk, which was so tenacious that the men could hardly dig and fill in 6 rods in

* The mouth of the drain.

a day. The cost of digging, laying in tiles, and filling drains four feet deep on a clay soil intersected with veins of sand, may cost about 6*d*. a rod. We have just completed digging a drain in a meadow, of an average depth of three feet, the first six inches turned up by the plough. It took 30 days' labour for one man at 20*d*. a day to dig 101 rods of drain, one man a day and three quarters to lay in the tiles (tops and bottoms), and about eight days to fill up the drain, making a total cost of nearly 8*d*. a rod. The soil was very wet, stony, and hard. On a loamy soil drained to the depth of four feet with a clay subsoil, the upper ten inches ploughed out, one man would on an average dig three and a half rods per day—throwing out about ten cubic yards of soil—would lay in about 60 rods of soles and tiles in a day, and fill in 13 rods in a day."

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## No. II.

*On the Quantities of Rain falling on Land; the Quantities passing through it by filtration; and the Quantities evaporated.*

On this subject it is highly important that information should be obtained from the experience on well drained lands. The estimates first furnished are given in the following extracts from the writings of Mr. Josiah Parkes on Land-drainage:—

"The annexed Table, No. 1, contains the monthly and annual indications of the two gauges for the years 1836 to 1843 inclusive; those of the rain gauge being, Mr. Dickinson informs me, generally corroborated by another gauge kept by the Grand Junction Canal Company about 8 miles distant. Table 2 gives the mean result of the eight years' observations for each month, and the whole period in terms, of the depth of rain which fell on the surface; of the amount which filtered through the Dalton Gauge;* and of that which was evaporated, or again restored to the atmosphere in the shape of vapour, with two columns showing the proportion per cent. of filtration and evaporation.

"Table 3 presents to view the total amount of rain which fell in each year, with the per-centage of filtration and evaporation; and Table 4 illustrates the quantity of rain and the proportion of water disposed of by filtration and evaporation during the six hotter and six colder months of each year respectively. To these last tables I have added

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* Described at p. 53.

columns exhibiting the weight of rain in tons per acre, as that expression may perhaps convey to the farmer a better idea of its amount than the more usual mode of stating it in inches of depth.

"By means of this tabular analysis we shall find the phenomena, as they may be applicable to agriculture, clearly brought before us.

"The first important fact disclosed is, that of the whole annual rain, about $42\frac{1}{2}$ per cent., or $11\frac{3}{10}$ inches out of $26\frac{6}{10}$ inches, have filtrated through the soil; and that the annual evaporative force is only equal to the removal of about $57\frac{1}{2}$ per cent. of the total rain which falls on any given extent of earth, 3 feet in depth (Table 2).

"By a closer scrutiny we learn (Table 4), that only about 25 per cent. of the rain which falls from October to March inclusive passes back to the atmosphere by evaporation in the same period; whereas from April to September inclusive about 93 per cent. is evaporated. It appears, then, that there is even a balance on the side of rain over evaporation during the six hottest months, and we discover only two years, 1840 and 1841, in which no filtration occurred within that period. Table 2 shows that in August the soil is in its driest state; but even in that month some filtration takes place in three out of the eight seasons recorded. It will be understood that though a near balance is shown to subsist between rain and evaporation during the six hottest months on an average of years, the hygrometric condition of a soil, *i. e.*, its state of wetness or dryness at any particular time, is not indicated by the Dalton Gauge.

"A soil may be in a state of drought or of humid saturation at different times during these months, and according to the season. It is, however, manifest from these registers, that if all the water derived from rain during the six colder months were allowed to accumulate in a soil, such land must be perfectly *wet*; and coupling this fact with the performance of drains which I am now enabled to exhibit, it appears that six months are expended in maintaining by the sole unaided force of evaporation an undrained retentive soil in a tolerably uniform moist condition, whilst deep-covered drains relieve the same soils of excess of humidity in a few hours after every fall of rain, even in the wettest season.

"Table 4 shows that the mean excess of rainwater to be disposed of during the six coldest months by some other process than evaporation amounts to no less a weight than about 1,050 tons per acre.

TABLE I.

| Months. | 1836. | | 1837. | | 1838. | | 1839. | |
|---|---|---|---|---|---|---|---|---|
| | Gauges. | | Gauges. | | Gauges. | | Gauges. | |
| | Rain. | Dalton. | Rain. | Dalton. | Rain. | Dalton. | Rain. | Dalton. |
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| January - | 2·40 | 2·32 | 2·40 | 2·10 | 0·31 | 0·04 | 1·40 | 1·04 |
| February - | 2·04 | 2·04 | 2·85 | 2·92 | 2·65 | 0·86 | 1·45 | 1·51 |
| March - - | 3·65 | 2·51 | 0·75 | 0·01 | 1·55 | 2·73 | 1·92 | 1·22 |
| April - - | 2·57 | 1·74 | 1·32 | 0·00 | 1·35 | " | 1·65 | 0·71 |
| May - - | 0·70 | 0·03 | 0·94 | " | 0·84 | " | 1·22 | 0·10 |
| June - - | 1·80 | 0·01 | 1·86 | " | 2·85 | " | 3·31 | 0·05 |
| July - - | 2·29 | 0·10 | 1·30 | " | 2·35 | 0·09 | 4·36 | 0·15 |
| August - | 2·24 | 0·15 | 3·00 | 0·05 | 0·95 | " | 3·65 | 0·09 |
| September - | 2·60 | 0·07 | 1·38 | 0·05 | 2·47 | 0·03 | 3·22 | 1·50 |
| October - | 4·55 | 3·82 | 1·55 | 0·02 | 2·68 | 0·07 | 1·68 | 0·09 |
| November - | 3·95 | 3·14 | 2·05 | 0·18 | 3·55 | 2·91 | 4·40 | 4·70 |
| December - | 2·21 | 1·72 | 1·70 | 1·62 | 1·58 | 1·84 | 3·02 | 3·75 |
| Total - | 31·0 | 17·65 | 21·10 | 6·95 | 23·13 | 8·57 | 31·28 | 14·91 |

| Months. | 1840. | | 1841. | | 1842. | | 1843. | |
|---|---|---|---|---|---|---|---|---|
| | Gauges. | | Gauges. | | Gauges. | | Gauges. | |
| | Rain. | Dalton. | Rain. | Dalton. | Rain. | Dalton. | Rain. | Dalton. |
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| January - | 3·95 | 3·05 | 1·50 | " | 1·36 | 0·60 | 1·46 | 1·25 |
| February - | 1·32 | 1·00 | 1·02 | " | 2·02 | 2·10 | 2·42 | 1·95 |
| March - - | 0·34 | " | 1·65 | 0·53 | 2·20 | 1·62 | 0·88 | " |
| April - - | 0·34 | " | 1·85 | " | 0·47 | " | 2·10 | " |
| May - - | 2·62 | " | 1·68 | " | 1·85 | " | 5·00 | 0·74 |
| June - - | 1·33 | " | 3·00 | " | 2·00 | " | 1·56 | 0·25 |
| July - - | 1·68 | " | 2·80 | " | 1·93 | " | 2·09 | " |
| August - | 1·90 | " | 3·62 | " | 1·40 | " | 2·66 | " |
| September - | 2·31 | " | 4·00 | " | 4·50 | 1·30 | 0·63 | " |
| October - | 1·50 | " | 4·40 | 5·99 | 1·41 | 0·30 | 4·82 | 0·91 |
| November - | 4·25 | 2·57 | 4·28 | 4·87 | 5·77 | 5·00 | 2·45 | 2·70 |
| December - | 0·40 | 1·57 | 2·30 | 2·80 | 1·52 | 0·84 | 0·40 | 0·30 |
| Total - | 21·44 | 8·19 | 32·10 | 14·19 | 26·43 | 11·78 | 26·47 | 8·10 |

TABLE II.

| MEAN OF EACH MONTH, AND OF EIGHT YEARS. | | | | | |
|---|---|---|---|---|---|
| | Rain. | Filtration. | Evaporation. | Filtration. | Evaporation. |
| | Inches. | Inches. | Inches. | Per Cent. | Per Cent. |
| January - - | 1·847 | 1·307 | 0·540 | 70·7 | 29·3 |
| February - - | 1·971 | 1·547 | 0·424 | 78·4 | 21·6 |
| March - - | 1·617 | 1·077 | 0·540 | 66·6 | 33·4 |
| April - - - | 1·456 | 0·306 | 1·150 | 21·0 | 79·0 |
| May - - - | 1·856 | 0·108 | 1·748 | 5·8 | 94·2 |
| June - - - | 2·213 | 0·039 | 2·174 | 1·7 | 98·3 |
| July - - - | 2·287 | 0·024 | 2·263 | 1·8 | 98·2 |
| August - - | 2·427 | 0·036 | 2·391 | 1·4 | 98·6 |
| September - | 2·639 | 0·369 | 2·270 | 13·9 | 86·1 |
| October - - | 2·823 | 1·400 | 1·423 | 49·5 | 50·5 |
| November - | 3·837 | 3·258 | 0·579 | 84·9 | 15·1 |
| December - - | 1·805 | 1·641 | 0·164 | 90·9 | 9·1 |
| | 26·778 | 11·112 | 15·666 | 41·5 | 58·5 |

TABLE III.

| TOTAL OF EACH YEAR. | | | | |
|---|---|---|---|---|
| Years. | Rain. | Filtrations. | Evaporation. | Rain, per Acre. |
| | Inches. | Per Cent. | Per Cent. | Tons |
| 1836 | 31·0 | 56·9 | 43·1 | 3,139 |
| 1837 | 21·10 | 32·9 | 67·1 | 2,137 |
| 1838 | 23·13 | 37·0 | 63·0 | 2,342 |
| 1839 | 31·28 | 47·6 | 52·4 | 3,168 |
| 1840 | 21·44 | 38·2 | 61·8 | 2,171 |
| 1841 | 32·10 | 44·2 | 55·8 | 3,251 |
| 1842 | 26·43 | 44·4 | 55·6 | 2,676 |
| 1843 | 26·47 | 36·0 | 64·0 | 2,680 |
| Mean - | 26·61 | 41·5 | 58·5 | 2,695 |

TABLE IV.

| Years. | Rain. | Filtration. | Evaporation. | Filtration. | Evaporation. | Rain per Acre filtrated. | Rain per Acre evaporated. |
|---|---|---|---|---|---|---|---|
| APRIL to SEPTEMBER inclusive. | | | | | | | |
| | Inches. | Inches. | Inches. | Per Cent. | Per Cent. | Tons. | Tons. |
| 1836 | 12·20 | 2·10 | 10·10 | 17·3 | 82·7 | 212 | 1,023 |
| 1837 | 9·80 | 0·10 | 9·70 | 1·0 | 99·0 | 10 | 982 |
| 1838 | 10·81 | 0·12 | 10·69 | 1·2 | 98·8 | 12 | 1,082 |
| 1839 | 17·41 | 2·60 | 14·81 | 15·0 | 85·0 | 263 | 1,500 |
| 1840 | 9·68 | 0·00 | 9·68 | 0·0 | 100·0 | - - | 980 |
| 1841 | 15·26 | 0·00 | 15·26 | 0·0 | 100·6 | - - | 1,545 |
| 1842 | 12·15 | 1·30 | 10·85 | 10·7 | 89·3 | 131 | 1,099 |
| 1843 | 14·04 | 0·99 | 13·05 | 7·1 | 92·9 | 100 | 1,322 |
| Mean | 12·67 | 0·90 | 11·77 | 7·1 | 92·9 | 91 | 1,192 |
| OCTOBER to MARCH inclusive. | | | | | | | |
| 1836 | 18·80 | 15·55 | 3·25 | 82·7 | 17·3 | 1,574 | 330 |
| 1837 | 11·30 | 6·85 | 4·45 | 60·6 | 39·4 | 693 | 452 |
| 1838 | 12·32 | 8·45 | 3·85 | 68·8 | 31·2 | 855 | 393 |
| 1839 | 13·87 | 12·31 | 1·56 | 88·2 | 11·8 | 1,246 | 159 |
| 1840 | 11·76 | 8·19 | 3·57 | 69·6 | 30·4 | 829 | 362 |
| 1841 | 16·84 | 14·19 | 2·65 | 84·2 | 15·8 | 1,437 | 269 |
| 1842 | 14·28 | 10·46 | 3·82 | 73·2 | 26·8 | 1,059 | 387 |
| 1843 | 12·43 | 7·11 | 5·32 | 57·2 | 42·8 | 720 | 538 |
| Mean | 13·95 | 10·39 | 3·56 | 74·5 | 25·5 | 1,052 | 360 |

NOTE.—The quantities in the columns headed Filtration represent the required performances of drains in retentive soils. One inch of rain in depth amounts to 101·28 tons per acre.

## No. III.

The next estimates furnished are those contained in a paper " On suiting the Depth of Drainage to the Circum- " stances of the Soil, by J. H. Charnock, an Assistant Com- " missioner under the Drainage Acts," given in the Journal of the Royal Agricultural Society, vol. x. part ii. pp. 515 to 518.

" Let me now direct your attention to some of those meteorological effects which, without pretending to any very intimate knowledge of that interesting science, I nevertheless believe exercise an important influence in promoting the efficiency of drainage, as well as that completeness in that operation will in its turn have an equally observable effect over meteorological causes themselves. It is very common to speak of undrained land as being *cold*, and a more significant designation could hardly be given, for it is literally so, and that at a time when, for the purposes of vegetation, it ought to be the warmest. The following observations on evaporation and filtration (for which we are indebted to the patient and carefully conducted experiments of my relation, Mr. Charles Charnock, of Holmfield House, near Ferry-bridge,) present some curious facts for consideration, demonstrating the cause of, and suggesting the remedy for this baneful coldness. (See Table in next page.)

" In the first place, it is observable how much greater is the amount of evaporation from water than from land, and how near, as shown by columns 2 and 5, the evaporation from wet land is to that from water itself—hence the wetter the land the greater the evaporation, and, as the well-known consequence, the greater its excess of coldness. We have a familiar illustration of Nature's process in this particular, in the method often adopted to cool our wine on a hot summer's day, by wrapping a wet napkin round the bottle and exposing it to the full sun: as the moisture from the napkin is evaporated, the temperature of the wine declines to almost freezing-point. The schoolboy's experiment of producing ice before a fire, by incasing the vessel in wet flannel and adding a portion of salt to the water, is a similar example, with this additional lesson to the farmer—that to apply certain limes to wet land is only increasing the evil.

" You will then, in the second place, notice how much less the evaporation is in the shade than in the sun, and consequently that wet land must be the warmest when there is

An Account of Observations made, through a series of Five Years, at Holmfield House, near Ferrybridge, in the county of York,* by Charles Charnock, Esq., with a view to determine the amount of Evaporation and Filtration under the several circumstances on the Magnesian Limestone Soil.

**1842.**

| Months. | Rain. 1 On the Surface. | Evaporation. From Water. 2 Exposed to both Sun and Wind. | Evaporation. From Water. 3 Shaded from Sun, but exposed to Wind. | Evaporation. From Soil. 4 When Drained. | Evaporation. From Soil. 5 When Saturated. | Filtration. 6 Through the Soil from the Drain 3 feet deep. |
|---|---|---|---|---|---|---|
| January - - | 2·70 | 1·69 | 1·13 | 1·66 | 1·59 | 1·04 |
| February - - | 0·76 | 1·23 | 0·81 | 0·68 | 1·04 | 0·08 |
| March - - | 3·48 | 1·92 | 1·28 | 2·40 | 2·52 | 1·08 |
| April - - - | 1·51 | 2·98 | 1·99 | 1·11 | 2·31 | 0·40 |
| May - - | 2·98 | 4·14 | 2·76 | 2·89 | 3·82 | 0·09 |
| June - - - | 1·94 | 4·18 | 2·79 | 1·94 | 4·27 | — |
| July - - - | 3·74 | 4·16 | 2·73 | 3·26 | 3·89 | 0·48 |
| August - - | 1·49 | 3·36 | 2·24 | 1·37 | 2·39 | 0·12 |
| September - | 2·44 | 2·69 | 1·74 | 2·24 | 2·88 | 0·20 |
| October - - | 1·12 | 2·00 | 1·37 | 0·92 | 1·99 | 0·20 |
| November - | 3·19 | 2·26 | 1·50 | 2·49 | 1·83 | 0·70 |
| December - | 0·76 | 3·00 | 2·14 | 0·60 | 1·49 | 0·16 |
| Totals - - | 26·11 | 33·61 | 22·48 | 21·56 | 30·02 | 4·55 |

**1843.**

| Months. | Rain. 1 On the Surface. | Evaporation. From Water. 2 Exposed to both Sun and Wind. | Evaporation. From Water. 3 Shaded from Sun, but exposed to Wind. | Evaporation. From Soil. 4 When Drained. | Evaporation. From Soil. 5 When Saturated. | Filtration. 6 Through the Soil from the Drain 3 feet deep. |
|---|---|---|---|---|---|---|
| January - - | 1·48 | 2·57 | 1·71 | 0·69 | 1·87 | 0·79 |
| February - - | 3·25 | 2·65 | 1·10 | 2·29 | 2·78 | 0·96 |
| March - - | 0·95 | 3·05 | 2·03 | 0·72 | 2·43 | 0·23 |
| April - - - | 2·19 | 3·22 | 2·05 | 1·84 | 2·39 | 0·25 |
| May - - | 2·81 | 2·91 | 1·94 | 2·47 | 2·65 | 0·34 |
| June - - - | 2·31 | 5·12 | 3·41 | 2·10 | 4·86 | 0·21 |
| July - - - | 2·70 | 3·76 | 2·50 | 2·55 | 3·49 | 0·15 |
| August - - | 3·99 | 3·71 | 2·57 | 3·77 | 3·74 | 0·22 |
| September - | 1·07 | 2·06 | 1·34 | 0·90 | 2·18 | 0·17 |
| October - - | 1·10 | 1·80 | 1·20 | 0·82 | 1·93 | 0·28 |
| November - | 2·30 | 1·64 | 1·09 | 1·69 | 1·48 | 0·67 |
| December - | 0·28 | 1·68 | 1·78 | 0·27 | 1·39 | 0·01 |
| Totals - - | 24·49 | 34·17 | 22·72 | 20·11 | 31·19 | 4·28 |

**1844.**

| Months. | Rain. 1 On the Surface. | Evaporation. From Water. 2 Exposed to both Sun and Wind. | Evaporation. From Water. 3 Shaded from Sun, but exposed to Wind. | Evaporation. From Soil. 4 When Drained. | Evaporation. From Soil. 5 When Saturated. | Filtration. 6 Through the Soil from the Drain 3 feet deep. |
|---|---|---|---|---|---|---|
| January - - | 1·31 | 1·61 | 1·08 | 0·85 | 1·50 | 0·46 |
| February - - | 2·22 | 1·31 | 0·88 | 1·66 | 1·11 | 0·56 |
| March - - | 2·27 | 2·13 | 1·42 | 1·58 | 1·50 | 0·69 |
| April - - - | 0·27 | 3·83 | 2·55 | 0·27 | 3·42 | — |
| May - - | 0·42 | 5·77 | 3·85 | 0·42 | 4·86 | — |
| June - - - | 1·24 | 5·31 | 3·58 | 1·20 | 4·95 | 0·04 |
| July - - - | 2·76 | 4·17 | 2·78 | 2·43 | 4·28 | 0·33 |
| August - - | 2·85 | 4·70 | 3·14 | 2·44 | 4·63 | 0·41 |
| September - | 1·92 | 4·91 | 3·28 | 1·62 | 3·96 | 0·30 |
| October - - | 1·41 | 2·79 | 1·86 | 1·17 | 2·93 | 0·24 |
| November - | 1·98 | 2·84 | 1·80 | 1·47 | 2·78 | 0·51 |
| December - | 0·35 | 0·79 | 0·53 | 0·29 | 0·93 | 0·06 |
| Totals - - | 19·00 | 40·16 | 26·75 | 15·40 | 37·85 | 3·60 |

**1845.**

| Months. | Rain. 1 On the Surface. | Evaporation. From Water. 2 Exposed to both Sun and Wind. | Evaporation. From Water. 3 Shaded from Sun, but exposed to Wind. | Evaporation. From Soil. 4 When Drained. | Evaporation. From Soil. 5 When Saturated. | Filtration. 6 Through the Soil from the Drain 3 feet deep. |
|---|---|---|---|---|---|---|
| January - - | 1·74 | 1·53 | 1·02 | 1·28 | 1·49 | 0·46 |
| February - - | 0·73 | 0·71 | 0·47 | 0·43 | 0·94 | 0·30 |
| March - - | 1·88 | 2·91 | 1·94 | 1·33 | 2·89 | 0·55 |
| April - - - | 1·54 | 4·79 | 3·19 | 1·05 | 4·06 | 0·39 |
| May - - | 2·24 | 2·84 | 1·99 | 1·97 | 3·26 | 0·27 |
| June - - - | 3·18 | 3·10 | 2·06 | 2·93 | 2·98 | 0·25 |
| July - - - | 3·49 | 2·86 | 1·89 | 3·30 | 2·79 | 0·19 |
| August - - | 4·61 | 2·56 | 1·70 | 4·24 | 2·43 | 0·37 |
| September - | 1·36 | 2·79 | 1·86 | 0·95 | 2·29 | 0·41 |
| October - - | 3·36 | 2·77 | 1·84 | 2·69 | 2·89 | 0·67 |
| November - | 1·01 | 2·13 | 1·41 | 0·73 | 2·20 | 0·28 |
| December - | 3·04 | 3·57 | 2·38 | 2·36 | 2·87 | 0·68 |
| Totals - - | 28·18 | 32·56 | 21·75 | 23·26 | 31·09 | 4·92 |

**1846.**

| Months. | Rain. 1 On the Surface. | Evaporation. From Water. 2 Exposed to both Sun and Wind. | Evaporation. From Water. 3 Shaded from Sun, but exposed to Wind. | Evaporation. From Soil. 4 When Drained. | Evaporation. From Soil. 5 When Saturated. | Filtration. 6 Through the Soil from the Drain 3 feet deep. |
|---|---|---|---|---|---|---|
| January - - | 2·18 | 2·07 | 1·58 | 1·22 | 1·94 | 0·96 |
| February - - | 0·47 | 2·59 | 1·69 | 0·44 | 2·09 | 0·03 |
| March - - | 0·93 | 2·56 | 1·55 | 0·86 | 2·16 | 0·07 |
| April - - - | 5·97 | 1·91 | 1·27 | 2·98 | 1·49 | 2·99 |
| May - - | 0·82 | 4·52 | 3·02 | 0·73 | 3·89 | 0·09 |
| June - - - | 1·65 | 4·88 | 3·25 | 1·58 | 4·73 | 0·07 |
| July - - - | 2·90 | 4·44 | 2·96 | 2·74 | 4·39 | 0·16 |
| August - - | 2·65 | 3·08 | 2·05 | 2·46 | 3·28 | 0·19 |
| September - | 1·07 | 2·99 | 1·99 | 1·00 | 3·14 | 0·07 |
| October - - | 4·09 | 2·23 | 1·49 | 2·40 | 2·76 | 1·69 |
| November - | 1·15 | 1·63 | 1·09 | 0·88 | 1·74 | 0·17 |
| December - | 1·36 | 1·79 | 1·10 | 1·09 | 1·67 | 0·27 |
| Totals - - | 25·24 | 34·69 | 23·04 | 18·38 | 33·28 | 6.76 |

Explanation.—Column 1.—Shows the Depth of Rain fallen, as registered by the ordinary Rain-Gauge.
Column 2.—Is the Amount of Evaporation from a Surface of Water fully exposed to both Sun and Wind.
" 3.—Is the Evaporation from Water shaded from the Sun, but exposed to the Wind.
" 4.—Is the Evaporation from what represented drained or dry land.
" 5.—Is the Evaporation from the same when saturated.
" 6.—Is the Amount of Water which filtered through the soil.

Into a leaden vessel, of a foot square and three feet deep, was put two feet of gravel and calcareous sand, so as to represent the substratum of the farm, and the remainder filled up, to within an inch of the top, with an average quality of soil. At the bottom a pipe was inserted which conveyed all the water that was filtered through into a bottle, which was regularly emptied and registered. The vessel was inserted in the ground to within an inch of the surface, keeping the level of the soil, inside and outside, alike, with an inch of the vessel above, to prevent any communication of water from without. The soil was kept free from weeds, and occasionally stirred, that it might not be more than ordinarily compact.

To determine the evaporation from *saturated* soil, a leaden vessel of 13 inches deep, and a foot square, was filled to within an inch of the top with soil and placed in the ground, in the same manner as the previous vessel, with a pipe level with the surface of the soil to carry off the excess of top-water into a receiver. The same quantity of water was then daily supplied to this soil as the evaporating dish of Column 2 showed was evaporated. The soil was stirred as in the former case, and thus represented wet and undrained land.

* Mr. C. C. is one of the Vice-Presidents of the *Meteorological Society of London.*

the least sun. From which cause no doubt arises that too vigorous growth of young wheat, so often observable on such land in the winter and spring months, which never fails to produce serious injury to the crop in all its subsequent stages. And, thirdly, you will remark how comparatively small a proportion of the rain which falls is shown to be carried off by filtration. Taking the average of the five years' experiments, it will be seen that only 4·82 inches, out of 24·60 inches of rain, passed through the land to the depth of three feet. We might, therefore, be led at the first glance to infer that land in general stands less in need of drainage, or may be drained by a less perfect system, than is supposed to be requisite, did not daily experience oppose such a conclusion. We must, therefore, endeavour to reconcile this seeming incongruity, and deduce at the same time, from the facts disclosed, such data as may guide us in determining the essential requisites to ensure completeness of effect in drainage.

"Now, although there can be no reason to question the accuracy of the experiments on filtration made by Mr. Dickinson, and recorded in the Journal of the Royal Agricultural Society of England, vol. v. part i., yet there is a very considerable difference in the aggregate result, as shown by them and the account before us. 'The first important fact disclosed,' says the commentator, page 148, 'is that, of the whole annual rain, about $42\frac{1}{2}$ per cent., or $11\frac{3}{10}$ inches out of $26\frac{6}{10}$, have filtered through the soil:' whereas in the Holmfield House experiments there is only shown, as we have already said, 4·82 inches out of 24·60, or about $5\frac{1}{10}$ per cent. against $42\frac{1}{2}$ per cent. This is certainly a very great and somewhat irreconcileable difference in the result of two experiments made professedly to ascertain the same fact. Now, on referring to the 'Memoirs of the Literary and Philosophical Society of Manchester,' vol. v. part ii., you will find a paper on rain, evaporation, &c., from the pen of the celebrated Dr. John Dalton (the father of the science of meteorology), wherein he explains a series of experiments made by himself and his friend Mr. Thomas Hoyle junior, to ascertain the amount of evaporation and filtration, and giving the following table of results, viz.:—

| Months. | Water through the Two Pipes. | | | Mean. | Mean Rain. | Mean Evaporation. |
|---|---|---|---|---|---|---|
| | 1796. | 1797. | 1798. | | | |
| January - - - | 1·897 | ·680 | 1·774 | 1·450 | 2·458 | 1·008 |
| February - - - | 1·778 | ·918 | 1·122 | 1·273 | 1·801 | ·528 |
| March - - - | ·431 | ·070 | ·335 | ·279 | ·902 | ·623 |
| April - - - | ·220 | ·295 | ·180 | ·232 | 1·717 | 1·485 |
| May - - - | 2·027 | 2·443 | ·010 | 1·493 | 4·177 | 2·684 |
| June - - - | ·171 | ·726 | - - | ·299 | 2·483 | 2·184 |
| July - - - | ·153 | ·025 | - - | ·059 | 4·154 | 4·095 |
| August - - - | - - | - - | ·504 | ·168 | 3·554 | 3·386 |
| September - - - | - - | ·976 | - - | ·325 | 3·279 | 2·954 |
| October - - - | - - | ·680 | - - | ·227 | 2·899 | 2·672 |
| November - - - | - - | 1·044 | 1·594 | ·879 | 2·934 | 2·055 |
| December - - - | ·200 | 3·077 | 1·878 | 1·718 | 3·202 | 1·484 |
| | 6·877 | 10·934 | 7·379 | 8·402 | 33·560 | 25·158 |
| Rain - - - | 30·629 | 38·791 | 31·259 | | | |
| Evaporation - - - | 23·725 | 27·857 | 23·862 | | | |

" 'Having got a cylindrical vessel of tinned iron,' says the Doctor, 'ten inches in diameter and three feet deep, there were inserted into it two pipes, turned downwards, for the water to run off into bottles: the one pipe was near the bottom of the vessel, the other was an inch from the top. The vessel was filled up, for a few inches, with gravel and sand, and all the rest with good fresh soil. Things being thus circumstanced, a regular register has been kept of the quantity of rain-water that ran off from the surface of the earth through the upper pipe (whilst that took place), and also of the quantity of that which sank down through the three feet of earth, and ran out through the lower pipe. A rain-gauge of the same diameter was kept close by, to find the quantity of rain for any corresponding time.'

" You will notice that the general result of these experiments accords pretty nearly with that of the Holmfield account; and yet it may be readily conceived that circumstances of situation and stratification may often occasion as wide a difference in the amount of filtration as is shown between Mr. Dickinson's and Mr. Charnock's observations.

" On an examination of the *details* registered in the account before us, it will be evident that the amount of filtration is not exclusively dependent on the fall of rain; but that a variety of other causes combine to affect its proportion. For instance, in March, April, May, June, and July, of 1842, the fall of rain was 13·65 inches, and the filtration for the same period was only 2·05 inches; whilst in

April 1846 there was 5·97 of rain and 2·99 of filtration. Similar instances are also noticeable in Mr. Dickinson's details. From March to October, inclusive, of 1840, a fall of 11·52 inches of rain is recorded, without any filtration; but in November 1842 the rain was 5·77, with 5 inches of filtration. Dr. Dalton's table also shows the same variations. The lesson, therefore, derivable from these experiments, so far as regards filtration by drains, is one rather of a speculative than of a definite character; for, although we are assured filtration must be secured, we are left with a large and varying margin as to the proportion. We must not, however, overlook the fact, that all the registered details show occasionally an amount of filtration nearly equal to the rain that falls, and therefore, in determining the size of pipe to be used, the ready exit of this *maximum* quantity must be provided for.'

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## No. IV.

### *On the Fitness of Soil for the Reception of the Seed in vegetable Production.*

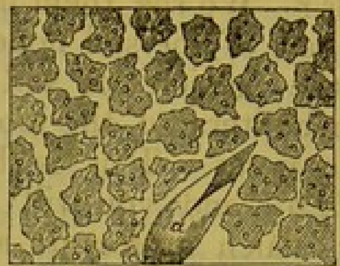
[Extract from a Lecture on Agricultural Science, by Dr. Madden, page 21.]

The first thing which occurs after the sowing of the seed is, of course, *germination;* and before we examine how this process may be influenced by the condition of the soil, we must necessarily obtain some correct idea of the process itself. The most careful examination has proved that the process of germination consists essentially of various chemical changes, which require for their development the presence of air, moisture, and a certain degree of warmth. Now it is obviously unnecessary for our present purpose that we should have the least idea of the nature of these processes: all we require to do, is to ascertain the conditions under which they take place; having detected these, we know at once what is required to make a seed grow. These, we have seen, are air, moisture, and a certain degree of warmth; and it consequently results, that wherever a seed is placed in these circumstances, germination will take place. Viewing matters in this light, it appears that soil does not act *chemically* in the process of germination; that its sole action is confined to its being the vehicle by means of which a supply of air and moisture and warmth can be continually kept up. With this simple statement in view, we are quite prepared to consider the various conditions of soil, for the purpose of determining how far these will influence the future prospects of the crop, and we shall accordingly at once proceed to examine carefully into the *mechanical relations of soil.* This we purpose doing by the aid of figures.

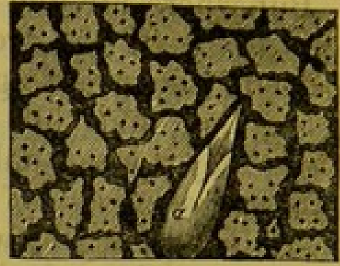
Soil, examined mechanically, is found to consist entirely of particles of all shapes and sizes, from stones and pebbles down to the finest powder; and, on account of their extreme irregularity of shape, they cannot lie so close to one another as to prevent there being passages between them, owing to which circumstance soil in the mass is always more or less *porous.* If, however, we proceed to examine one of the smallest particles of which soil is made up, we shall find that even this is not always solid, but is much more frequently porous, like soil in the mass. A considerable proportion of this finely-divided part of soil, *the impalpable matter* as it is generally called, is found, by the aid of the microscope, to consist of *broken-down vegetable tissue*, so that when a small portion of the finest dust from a garden or field is placed under the microscope, we have exhibited to us particles of every variety of shape and structure, of which a certain part is evidently of vegetable origin. In these figures I have given a very rude representation of these particles; and I must beg you particularly to remember that they are not meant to represent by any means accurately what the microscope exhibits, but are only designed to serve as a plan by which to illustrate the mechanical properties of the soil. On referring to Fig. 1 we perceive that there are two distinct classes of pores; 1st, the large ones, which exist *between* the particles of soil, and 2nd, the very minute ones, which occur in the particles themselves; and you will at the same time notice, that whereas all the larger pores—those between the particles of soil—communicate most freely with each other, so that they form canals, the small pores, however freely they may communicate with one another in the interior of the particle in which they occur, have no direct connexion with the pores of the surrounding particles. Let us now, therefore, trace the effect of this arrangement. In Fig. 1 we perceive that these canals and pores are all empty, the soil being *perfectly dry*, and the canals communicating freely at the surface with the surrounding atmosphere, the whole will of course be filled with air. If in this condition a seed be placed in the soil as at *a*, you at once perceive that it is freely supplied with air, *but there is no moisture;* therefore, when soil is *perfectly dry*, a seed cannot grow.

Let us turn our attention now to Fig. 2. Here we perceive

1.



2.

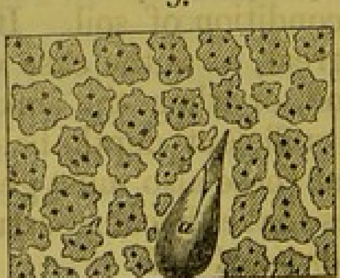


that both the pores and canals are no longer represented white, but black, this colour being used to indicate water; in this instance, therefore, water has taken the place of air, or, in other words, the soil is *very wet.* If we observe our seed *a* now, we find it abundantly supplied with water, but *no air.* Here again, therefore, germination cannot take place. It may be well to state here, that this can never occur *exactly* in nature, because water having the power of dissolving air to a certain extent, the seed *a* in Fig. 2 is in fact supplied with a *certain* amount of this necessary substance; and, owing to this, germination does take place, although by no means under such advantageous circumstances as it would were the soil in a better condition.

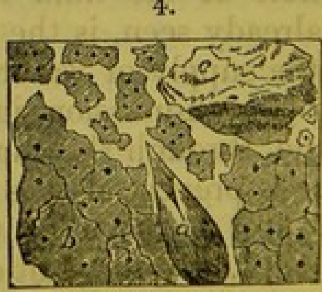
We pass on now to Fig. 3. Here we find a different state of matters. The canals are open and freely supplied with air, while the pores are filled with water; and consequently you perceive that, while the seed *a* has quite enough of air from the canals, it can never be without moisture, as every particle of soil which touches it is well supplied with this necessary ingredient. This, then, is the proper condition of soil for germination, and in fact for every period of the plant's development; and this condition occurs when soil is *moist* but not *wet*—that is to say, when it has the colour and appearance of being well watered, but when it is still capable of being crumbled to pieces by the hands, without any of its particles adhering together in the familiar form of mud.

Turning our eyes to Fig. 4, we observe still another condition of soil; in this instance,

3.



4.



as far as *water* is concerned, the soil is in its healthy condition —it is moist, but not wet, the pores alone being filled with water. But where are the canals? We see them in a few places, but in by far the greater part of the soil none are to be perceived; this is owing to the particles of soil having adhered together, and thus so far obliterated the interstitial canals that they appear only like pores. This is the state of matters in every *clod of earth*, *b*; and you will at once perceive, on comparing it with *c*, which represents a stone, that these two differ only in possessing a few pores, which latter, while they may form a reservoir for moisture, can never act as vehicles for the *food* of plants, as the roots are not capable of extending their fibres into the interior of a clod, but are at all times confined to the interstitial canals.

With these four conditions before us, let us endeavour to apply them *practically* to ascertain when they occur in our fields, and how those which are injurious may be obviated.

The first of them, we perceive, is a state of too great dryness, *a very rare* condition, in this climate at least; in fact, the only case in which it is likely to occur is in very coarse sands, where the soil, being chiefly made up of pure sand and particles of flinty matter, contains comparatively much fewer pores, and, from the large size of the individual particles, assisted by their irregularity, the canals are wider, the circulation of air freer, and, consequently, the whole is much more easily dried. When this state of matters exists, the best treatment is to leave all the stones which occur on the surface of the field, as they cast shades, and thereby prevent or retard the evaporation of water.

We will not, however, make any further observations on this very rare case, but will rather proceed to Fig. 2, a much more frequent, and, in every respect, more important condition of soil: I refer to an *excess of water*.

When water is added to perfectly dry soil, it of course, in the first instance, fills the interstitial canals, and from these enters the pores of each particle; and if the supply of water be not too great, the canals speedily become empty, so that the whole of the fluid is taken up by the pores: this, we have already seen, is the *healthy* condition of soil. If, however, the supply of water be too great, as is the case when a spring gains admission into the soil, or when the sinking of the fluid through the canals to a sufficient depth below the surface is prevented, it is clear that these also must get filled with water so soon as the pores have become saturated. This, then, is the condition of *undrained soil*.

Not only are the pores filled, but the interstitial canals are likewise full; and the consequence is, that the whole process of the germination and growth of vegetables is materially interfered with. We shall here, therefore, briefly state the injurious effects of an excess of water, for the purpose of impressing more strongly on your minds the necessity of thorough-draining, as the first and most essential step towards the improvement of your soil.

The *first* great effect of an excess of water is, that it produces a corresponding diminution of the amount of air beneath the surface, which air is of the greatest possible consequence in the nutrition of plants; in fact, if entirely excluded, germination could not take place and the seed sown would, of course, either decay or lie dormant.

*Secondly*, an excess of water is most hurtful, by reducing considerably the *temperature* of the soil: this I find by careful experiment to be to the extent of 6½ degrees Fahrenheit in summer, which amount is equivalent to an elevation above the level of the sea of 1,950 feet. So that, supposing two fields lying side by side, the one drained, the other undrained, and supposing them both equally well cultivated, there will be nearly as much difference in the amount and value of their respective crops, as if the drained one was situated at the level of the sea, and the other had an elevation as high as the most lofty of the Pentland Hills.* But, besides this, and what is nearly equally bad, the temperature is rendered unnaturally high during winter; whereas it has been proved that one great source of health and vigour in vegetation is the great difference which exists between the temperature of summer and winter, which difference amounts in dry soil to between thirty and forty degrees, while in soil very much injured by an excess of water the whole range of the thermometer throughout the year will probably not exceed from six to ten degrees.

These are the two chief injuries of an excess of water in soil which affect the soil itself. There are very many others affecting the climate, &c.; but these not so connected with the subject in hand as to call for an explanation here.

Of course all these injurious effects are at once overcome by thorough-draining, the result of which is to establish a direct communication between the interstitial canals and the drains, by which means it follows that no water can remain

* Of course the field of high elevation must be *thoroughly* drained to equal even the *undrained* field at the level of the sea.

any length of time in these canals without, by its gravitation, finding its way into the drains.

The 4th Figure indicates badly-cultivated soil, or soil in which large unbroken clods exist; which clods, as we have already seen, are very little better than stones, on account of their impermeability to air and the roots of plants.

Too much cannot be said in favour of pulverising the soil; even thorough-draining itself will not supersede the necessity of performing this most necessary operation. The whole valuable effects of ploughing, harrowing, grubbing, &c., may be reduced to this: and almost the whole superiority of *garden* over *field* produce is referable to the greater perfection to which this pulverising of the soil can be carried.

The immortal Jethro Tull has the honour of having first directed the farmer's attention forcibly to this subject; and so deeply impressed was he with its infinite importance, that he believed the use of manure could be entirely superseded, were this pulverising carried to a sufficient extent.

The whole success of the drill husbandry is owing, in a great measure, to its enabling you to stir up the soil well during the progress of your crop; which stirring up is of no value beyond its effect in more minutely pulverising the soil, increasing, as far as possible, the size and number of the interstitial canals.

Lest any one should suppose that the contents of these interstitial canals must be so minute that their whole amount can be of but little consequence, I may here notice the fact, that in moderately well pulverised soil they amount to no less than one fourth of the whole bulk of the soil itself: for example, 100 cubic inches of *moist* soil (that is, of soil in which the pores are filled with water while the canals are filled with air) contain no less than 25 cubic inches of air. According to this calculation, in a field pulverised to the depth of 8 inches, a depth perfectly attainable on most soils by careful tillage, every imperial acre will retain beneath its surface no less than 12,545,280 cubic inches of air. A familiar illustration of the space occupied by the spaces between the particles of loosened soil is afforded by the fact that when soil is disturbed it more than fills the space it previously occupied.

Taking into calculation the weight of soil, we shall find that with every additional inch which you reduce to powder (by ploughing, for example, 9 inches in place of 8), you call into activity 235 tons of soil, and render it capable of retaining beneath its surface 1,568,160 additional cubic inches of air. And, to take one more element into the calculation, supposing the soil were not properly drained, the sufficient pulverising of an additional inch in depth would increase the escape of water from the surface by upwards of 100 gallons a day.

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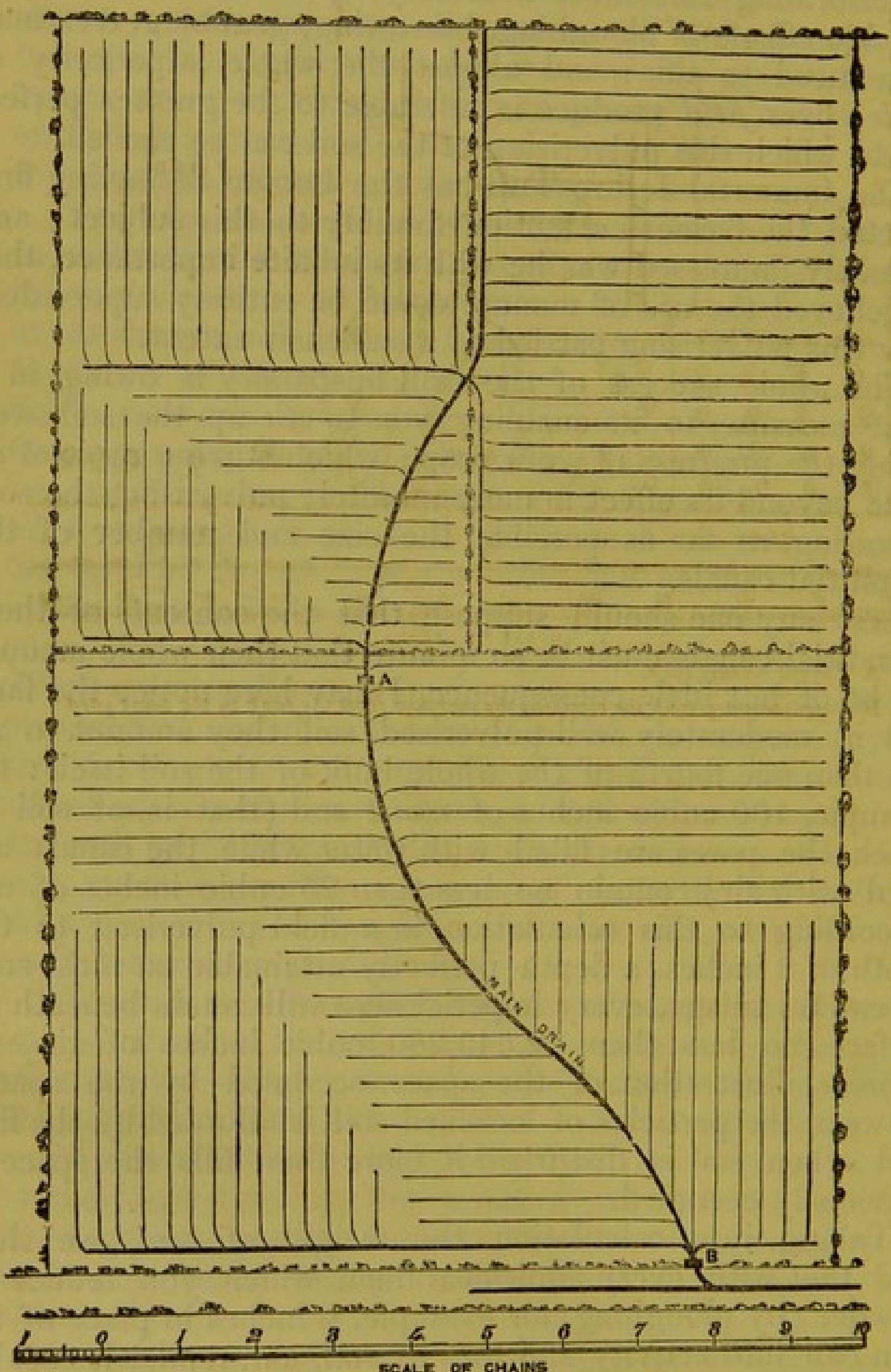
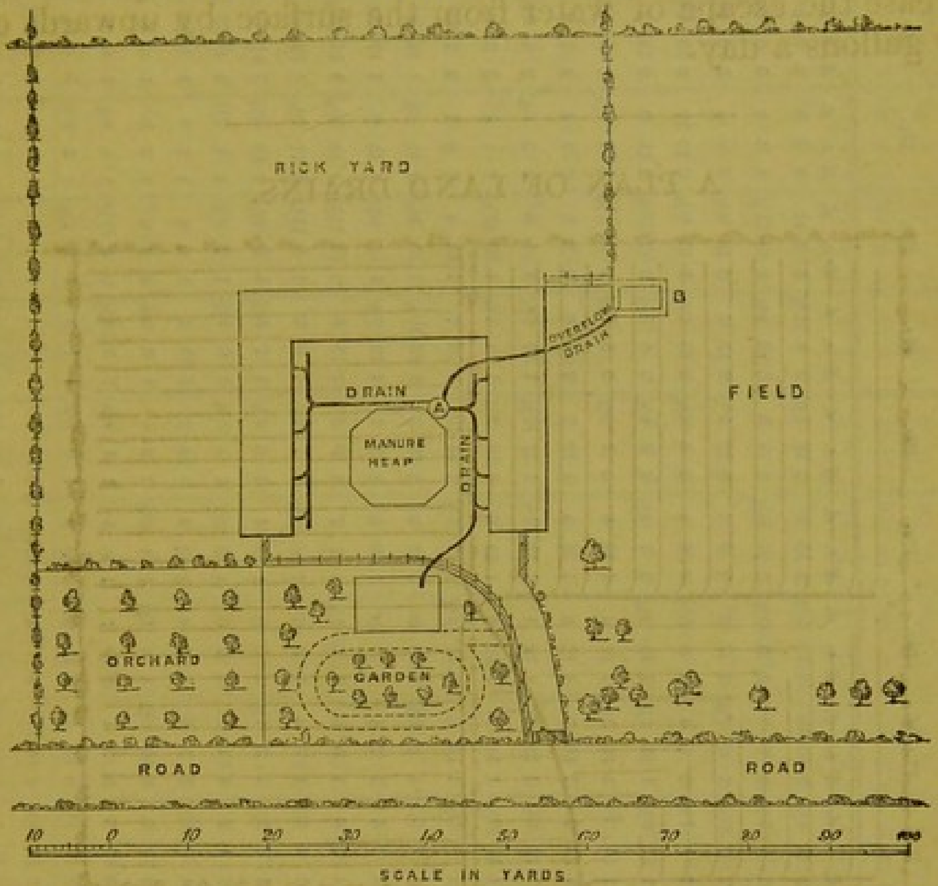
A PLAN OF LAND DRAINS.




*The letters* A B *indicate where the sand pits may be placed.*

PLAN OF FARM HOMESTEAD.




A *Liquid manure tank.*

B *Supplementary tank for receiving the overflow from the tank in the court yard.*

## No. V.—*Table of the Cost of Drain Tiles or Pipes, and Labour, per Acre.*

| Distance of Drains apart in feet. | Per Acre. Number of Rods of 5½ yards each. | Per Acre. Number of Feet or Tiles. | Cost of Drain Tiles or Pipes per Acre, at various Prices of Tiles per Thousand. 6s. | 10s. | 12s. | 15s. | 16s. | 17s. | 17s. 6d. | 18s. | 19s. | 20s. | 21s. | 22s. | 23s. | 24s. | 25s. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. |
| 15 | 176 | 2,904 1/3 | 0 17 5½ | 1 9 0¼ | 1 14 10¼ | 2 3 7 | 2 6 6 | 2 9 4½ | 2 10 10 | 2 12 3¼ | 2 15 2 | 2 18 0¾ | 3 0 11¾ | 3 3 11 | 3 6 9 | 3 9 8 | 3 12 7 |
| 16 | 165 | 2,722½ | 0 16 4¼ | 1 7 2¾ | 1 12 8½ | 2 0 10½ | 2 3 6½ | 2 6 3¼ | 2 7 7½ | 2 8 1¾ | 2 11 8½ | 2 14 5 | 2 16 8¼ | 2 18 11½ | 3 1 3 | 3 5 3¾ | 3 8 9½ |
| 16½ | 160 | 2,640 | 0 15 10½ | 1 4 6¾ | 1 11 9 | 1 19 8 | 2 2 3 | 2 2 10½ | 2 6 2¼ | 2 7 6 | 2 0 2 | 2 12 9½ | 2 15 5 | 2 18 0½ | 3 0 8 | 3 3 3½ | 3 6 0 |
| 18 | 146⅔ | 2,420 | 0 14 7 | 1 4 2¾ | 1 9 2 | 1 16 4 | 1 18 8½ | 2 1 1½ | 2 2 4 | 2 3 6½ | 2 6 0 | 2 8 4¾ | 2 10 9¾ | 2 13 2¾ | 2 15 10 | 2 18 0¾ | 3 0 6 |
| 20 | 132 | 2,178 | 0 13 1 | 1 1 9½ | 1 6 1¾ | 1 12 7½ | 1 14 10 | 1 17 0¾ | 1 18 1¾ | 1 19 2¾ | 2 1 4½ | 2 3 6½ | 2 5 8½ | 2 7 10½ | 2 10 0 | 2 12 2 | 2 14 5¾ |
| 21 | 125 | 2,075 | 0 12 5½ | 1 0 9 | 1 4 11 | 1 11 1½ | 1 13 2 | 1 15 3 | 1 16 3¾ | 1 17 4 | 1 19 5 | 2 1 5¾ | 2 3 6½ | 2 5 7½ | 2 7 8¾ | 2 9 8¾ | 2 11 10 |
| 22 | 120 | 1,980 | 0 11 10½ | 0 19 9½ | 1 3 8½ | 1 9 9 | 1 11 8 | 1 13 8 | 1 14 7 | 1 16 6 | 1 18 5 | 1 19 7 | 2 1 6 | 2 3 5 | 2 5 4 | 2 7 4 | 2 9 6 |
| 23 | 115 | 1,894 | 0 11 4½ | 0 18 11¾ | 1 3 9 | 1 8 5 | 1 10 1½ | 1 12 2¾ | 1 13 2 | 1 14 1 | 1 15 11¾ | 1 17 10½ | 1 19 9¾ | 2 1 8 | 2 3 6¾ | 2 5 5½ | 2 7 4½ |
| 24 | 110 | 1,816 | 0 10 10¾ | 0 18 2 | 1 1 9½ | 1 7 3 | 1 9 0½ | 1 10 10¾ | 1 11 9 | 1 12 8 | 1 14 6 | 1 16 3½ | 1 18 1½ | 1 19 11½ | 2 1 8 | 2 3 6 | 2 5 5½ |
| 25 | 105⅗ | 1,742 | 0 10 5½ | 0 17 5 | 1 0 11 | 1 6 2 | 1 7 10¾ | 1 9 7¾ | 1 10 6 | 1 11 4¾ | 1 13 1½ | 1 14 10 | 1 16 7 | 1 18 4 | 2 0 1 | 2 1 10 | 2 3 6½ |
| 27 | 97 2/3 | 1,613 | 0 9 9½ | 0 16 1½ | 0 19 7 | 1 4 2½ | 1 5 9½ | 1 7 5 | 1 8 2½ | 1 9 0 | 1 10 7 | 1 12 3 | 1 13 10¾ | 1 15 5½ | 1 17 0¾ | 1 18 6 | 2 0 3¾ |
| 28 | 94⅓ | 1,556 | 0 9 4 | 0 15 6¾ | 0 18 8 | 1 3 4 | 1 4 10½ | 1 6 4 | 1 7 1 | 1 7 10 | 1 9 5 | 1 11 1 | 1 12 7¾ | 1 14 2¾ | 1 15 9 | 1 17 3¾ | 1 18 0½ |
| 30 | 88 | 1,452 | 0 8 8½ | 0 14 6¾ | 0 17 5 | 1 1 9½ | 1 3 3 | 1 4 8 | 1 5 6 | 1 6 1½ | 1 7 7 | 1 9 0½ | 1 10 6 | 1 11 11½ | 1 13 5½ | 1 14 10½ | 1 16 3 |
| 32 | 82½ | 1,362 | 0 8 2 | 0 13 7½ | 0 16 4 | 1 0 5 | 1 1 9¾ | 1 3 1½ | 1 4 4 | 1 5 6 | 1 6 10¾ | 1 7 2½ | 1 8 7 | 1 9 11¾ | 1 11 3½ | 1 12 8 | 1 14 0½ |
| 33 | 80 | 1,320 | 0 7 11 | 0 13 2½ | 0 15 10 | 0 19 10 | 1 1 1¾ | 1 2 5¼ | 1 3 1½ | 1 3 9 | 1 5 1 | 1 6 4¾ | 1 7 8½ | 1 9 0½ | 1 10 4½ | 1 11 8 | 1 12 11 |
| 35 | 75⅖ | 1,244 | 0 7 5½ | 0 12 5¾ | 0 14 11 | 0 18 8 | 0 19 10½ | 1 1 2 | 1 1 9 | 1 2 5 | 1 3 8 | 1 4 10½ | 1 6 1½ | 1 7 4¾ | 1 8 7¾ | 1 9 10 | 1 11 1 |
| 36 | 73 1/3 | 1,209 | 0 7 3 | 0 12 1 | 0 14 6 | 0 18 2 | 0 19 4 | 1 0 6½ | 1 1 2 | 1 2 4 | 1 3 6 | 1 4 2 | 1 5 4 | 1 6 6 | 1 7 8 | 1 8 10 | 1 10 0 |
| 39 | 68 | 1,117 | 0 6 8½ | 0 11 2 | 0 13 5 | 0 16 9½ | 0 17 10 | 0 19 0 | 0 19 6½ | 1 0 1¾ | 1 1 2½ | 1 2 4 | 1 3 5½ | 1 4 7 | 1 5 9 | 1 6 9 | 1 7 11 |
| 40 | 66 | 1,089 | 0 6 7 | 0 10 11¾ | 0 13 2 | 0 16 4 | 0 17 5 | 0 18 6 | 0 19 1 | 0 19 7 | 1 0 8 | 1 1 9¼ | 1 2 10½ | 1 3 11½ | 1 5 0¾ | 1 6 2 | 1 7 5 |
| 42 | 63 | 1,037 | 0 6 2¾ | 0 10 4½ | 0 12 5½ | 0 15 7 | 0 16 7 | 0 17 1½ | 0 18 1 | 0 18 8 | 0 19 8 | 1 0 8¾ | 1 1 9 | 1 2 9¾ | 1 3 9½ | 1 4 10 | 1 5 10¾ |
| 45 | 59 | 974 | 0 5 10 | 0 9 9 | 0 11 8¾ | 0 14 6 | 0 15 5½ | 0 16 5¾ | 0 16 11 | 0 17 5 | 0 18 5 | 0 19 4 | 1 0 4 | 1 1 3 | 1 2 3 | 1 3 2½ | 1 4 2 |
| 48 | 55 | 907 | 0 5 5½ | 0 9 1 | 0 10 10½ | 0 13 7½ | 0 14 6 | 0 15 5 | 0 15 9¼ | 0 16 4 | 0 17 2½ | 0 18 1½ | 0 19 0½ | 0 19 11½ | 1 0 11 | 1 1 10 | 1 2 9¾ |
| 49½ | 53 1/3 | 880 | 0 5 3¾ | 0 8 9½ | 0 10 6½ | 0 13 3 | 0 14 1 | 0 14 11½ | 0 15 4½ | 0 15 10 | 0 16 8 | 0 17 7 | 0 18 5½ | 0 19 4 | 1 0 2½ | 1 1 1 | 1 1 11½ |
| 50 | 52 2/3 | 871 | 0 5 2¾ | 0 8 8½ | 0 10 5½ | 0 13 1 | 0 13 11 | 0 14 9½ | 0 14 5½ | 0 15 8¾ | 0 16 7 | 0 17 5 | 0 18 3½ | 0 19 1½ | 1 0 0 | 1 0 10¾ | 1 1 8½ |

| Distance of Drains apart in feet. | Per Acre. Number of Rods of 5½ yards each. | Per Acre. Number of Feet or Tiles. | Cost of Drain Tiles or Pipes per Acre, at various Prices of Tiles per Thousand. 27s. | 28s. | 29s. | 30s. | Cost of cutting and filling Drains per Acre, at various Prices per Rod. 2¾d. | 3d. | 3¼d. | 3½d. | 3¾d. | 4d. | 4¼d. | 4½d. | 4¾d. | 5d. | 5½d. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. |
| 15 | 176 | 2,904⅓ | 3 18 5 | 4 1 4 | 4 4 3 | 4 7 2 | 2 0 4 | 2 4 0 | 2 7 8 | 2 11 4 | 2 15 0 | 2 18 8 | 3 2 4 | 3 6 0 | 3 9 0 | 3 14 4 | 4 0 8 |
| 16 | 165 | 2,722½ | 3 12 7 | 3 14 10½ | 3 19 4½ | 4 1 7¾ | 1 17 9¾ | 2 1 3 | 2 4 8¼ | 2 8 1½ | 2 11 6¾ | 2 15 0 | 2 18 5¼ | 3 1 10½ | 3 5 3¾ | 3 8 9 | 3 15 7½ |
| 16½ | 160 | 2,640 | 3 11 3 | 3 13 10 | 3 16 6½ | 3 19 2 | 1 16 8 | 2 0 0 | 2 3 4 | 2 6 8 | 2 10 0 | 2 13 4 | 2 16 8 | 3 0 0 | 3 3 4 | 3 6 8 | 3 10 0 |
| 18 | 146½ | 2,420 | 3 5 4 | 3 7 9 | 3 10 2 | 3 12 7 | 1 13 7½ | 1 16 9 | 1 19 8 | 2 2 10½ | 2 5 11¼ | 2 9 0 | 2 12 0¾ | 2 15 1½ | 2 18 2½ | 3 1 3 | 3 7 4½ |
| 20 | 132 | 2,178 | 2 18 9½ | 3 1 0 | 3 3 2 | 3 5 4 | 1 10 3 | 1 13 3 | 1 15 9 | 1 18 6 | 2 1 3 | 2 4 0 | 2 6 9 | 2 9 6 | 2 12 3 | 2 15 0 | 3 0 6 |
| 21 | 125 | 2,075 | 2 16 0 | 2 18 0¾ | 3 0 2 | 3 2 2½ | 1 8 8 | 1 11 4½ | 1 14 0 | 1 16 7 | 1 19 2 | 2 1 10 | 2 4 5 | 2 7 0½ | 2 9 8 | 2 12 3½ | 2 17 5½ |
| 22 | 120 | 1,980 | 2 13 5 | 2 15 5 | 2 17 5 | 2 19 4¾ | 1 7 6 | 1 10 0 | 1 12 6 | 1 15 0 | 1 17 6 | 2 0 0 | 2 2 6 | 2 5 0 | 2 7 6 | 2 10 0 | 2 15 0 |
| 23 | 115 | 1,894 | 2 11 2½ | 2 13 0¾ | 2 14 11½ | 2 15 5½ | 1 6 4½ | 1 8 9 | 1 11 2 | 1 13 6½ | 1 15 11¼ | 1 18 4 | 2 0 9 | 2 3 1½ | 2 5 6½ | 2 7 11 | 2 12 8 |
| 24 | 110 | 1,816 | 2 9 1 | 2 10 10½ | 2 12 8½ | 2 14 5½ | 1 5 2½ | 1 7 6 | 1 9 9½ | 1 12 1 | 1 14 4½ | 1 16 8 | 1 18 11½ | 2 1 3 | 2 3 6½ | 2 5 10 | 2 10 5 |
| 25 | 105½ | 1,742 | 2 7 0½ | 2 8 9½ | 2 10 6½ | 2 12 3 | 1 4 2 | 1 6 4½ | 1 8 7 | 1 10 9 | 1 12 11½ | 1 15 2 | 1 17 4½ | 1 19 7 | 2 1 9 | 2 3 11½ | 2 8 5 |
| 27 | 97⅔ | 1,613 | 2 3 6 | 2 5 1 | 2 6 8½ | 2 8 4½ | 1 2 4 | 1 4 6 | 1 6 6 | 1 8 7 | 1 10 7½ | 1 12 8 | 1 14 8½ | 1 16 9 | 1 19 9½ | 2 0 10 | 2 4 11 |
| 28 | 94½ | 1,556 | 2 0 5 | 2 3 6 | 2 5 1 | 2 6 7¾ | 1 1 8 | 1 3 7½ | 1 5 7 | 1 7 6 | 1 9 6 | 1 11 6 | 1 13 6 | 1 15 5½ | 1 17 5 | 1 19 4½ | 2 3 4 |
| 30 | 88 | 1,452 | 1 19 2 | 2 0 7½ | 2 2 1 | 2 3 6¾ | 1 0 2 | 1 2 0 | 1 3 10 | 1 5 8 | 1 7 6 | 1 9 4 | 1 11 2 | 1 13 0 | 1 14 10 | 1 16 8 | 2 0 4 |
| 32 | 82½ | 1,362 | 1 16 9 | 1 18 1½ | 1 19 5½ | 2 0 10 | 0 18 11 | 1 0 7½ | 1 2 4 | 1 4 1 | 1 5 9 | 1 7 6 | 1 9 3 | 1 10 11½ | 1 12 8 | 1 14 4½ | 1 17 9½ |
| 33 | 80 | 1,320 | 1 15 6 | 1 16 10 | 1 18 1½ | 1 19 7 | 0 18 4 | 1 0 0 | 1 1 8 | 1 3 4 | 1 5 0 | 1 6 8 | 1 8 4 | 1 10 0 | 1 11 8 | 1 13 4 | 1 16 8 |
| 35 | 75½ | 1,244 | 1 13 7 | 1 14 10 | 1 16 1 | 1 17 4 | 0 17 4 | 0 18 10 | 1 0 5 | 1 2 0 | 1 3 7 | 1 5 2 | 1 6 9 | 1 8 4 | 1 9 11 | 1 11 5½ | 1 14 7 |
| 36 | 73⅓ | 1,209 | 1 12 7 | 1 13 9 | 1 15 0 | 1 16 3 | 0 16 9 | 0 18 4 | 0 19 11 | 1 1 5½ | 1 2 11 | 1 4 5 | 1 6 0 | 1 7 6 | 1 9 0 | 1 10 6½ | 1 13 6 |
| 39 | 68 | 1,117 | 1 10 2 | 1 11 3½ | 1 12 5 | 1 13 6 | 0 15 7 | 0 17 0 | 0 18 5 | 0 19 10 | 1 1 3 | 1 2 8 | 1 4 1 | 1 5 6 | 1 6 11 | 1 8 4 | 1 11 2 |
| 40 | 66 | 1,089 | 1 8 6 | 1 9 7 | 1 10 8 | 1 12 8 | 0 15 1½ | 0 16 6 | 0 17 10½ | 0 19 3 | 1 0 7½ | 1 2 0 | 1 3 4½ | 1 4 9 | 1 6 1½ | 1 7 6 | 1 10 3 |
| 42 | 63 | 1,037 | 1 7 10¾ | 1 8 11 | 1 10 0½ | 1 11 1½ | 0 14 5¼ | 0 15 9 | 0 17 1 | 0 18 4½ | 0 19 8¼ | 1 1 0 | 1 2 2 | 1 3 7½ | 1 4 11¼ | 1 6 3 | 1 8 10½ |
| 45 | 59 | 974 | 1 6 0 | 1 7 0 | 1 8 0 | 1 9 0 | 0 13 6¼ | 0 14 9 | 0 16 0 | 0 17 2½ | 0 18 5¼ | 0 19 8 | 1 0 11 | 1 2 1½ | 1 3 4¼ | 1 4 7 | 1 7 0½ |
| 48 | 55 | 907 | 1 4 7 | 1 5 6½ | 1 6 5 | 1 7 4½ | 0 12 7¼ | 0 13 9 | 0 14 11 | 0 16 0½ | 0 17 2¼ | 0 18 4 | 0 19 6 | 1 0 7½ | 1 1 9¼ | 1 2 11 | 1 5 2½ |
| 49½ | 53⅓ | 880 | 1 3 8½ | 1 4 7 | 1 5 5½ | 1 6 5 | 0 12 2 | 0 13 4 | 0 14 5½ | 0 15 7 | 0 16 8 | 0 17 9½ | 0 18 10½ | 1 0 0 | 1 1 2 | 1 2 3 | 1 4 5 |
| 50 | 52⅔ | 871 | 1 3 5 | 1 4 3½ | 1 5 1½ | 1 6 1½ | 0 12 0 | 0 13 2 | 0 14 4 | 0 15 5 | 0 16 7 | 0 17 8 | 0 18 9 | 0 19 10½ | 1 0 11¾ | 1 2 1 | 1 4 3½ |

G. DONALDSON, *Assistant Surveyor.*

## No. VI.

Cost at which tubular drain pipes were manufactured, in the course of experiments instituted by order of the Metropolitan Commissioners of Sewers as to the cost and manufacture of earthenware pipes:—

| Size of pipes, inches in diameter. | Materials. | | Cost of materials, labour, and burning, per 1,000 feet. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Clay. | Coals, 1 cwt. to a ton of clay. | Cost of clay, say at 7*s.* per ton, including royalty, digging, &c. | Labour in pugging, &c., at 2*s.* per ton. | Labour in moulding, carrying to drying shed, and attendance during drying. | Cost of coals, at 20*s.* per ton. | Extra for management, kiln-rent, waste, labour, packing, and drawing kiln. | Total prime cost per 1,000 feet in the field. |
| | ton. ct. lbs. | cwt. | £ *s.* *d.* | *s.* *d.* | £ *s.* *d.* | *s* *d.* | £ *s.* *d.* | £ *s* *d.* |
| 5 | 4 0 20 | 4 | 1 8 0 | 8 0 | 1 0 0 | 4 0 | 1 10 0 | 4 10 0 |
| 6 | 5 15 0 | 5¾ | 2 3 0 | 11 6 | 1 8 9 | 5 9 | 2 3 1 | 6 9 4 |
| 7½ | 6 16 70 | 6¾ | 2 9 9 | 13 7 | 1 14 2 | 6 9 | 2 12 0 | 7 16 1 |
| 8½ | 8 18 50 | 9 | 3 2 5 | 17 10 | 2 4 8 | 9 0 | 3 7 0 | 10 0 11 |

These pipes were moulded and burnt in the improved kilns of the Ainslie Tile Company. The above table shows the quantity of material, and the cost of each part of the production. The total shows what may be called the net prime cost of the goods at the kiln: a large percentage should of course be added for profit, carriage, &c. &c.

Each process of the manufacture is capable of very considerable improvement in respect of expense, time, and quality. It will, however, be seen by the following table, that, with the present incomplete and imperfect appliances, a very large reduction may be anticipated in the cost of these descriptions of goods, a result of the very highest importance, contemplating the immediate and large demand for sanitary purposes.

*Table contrasting the prices of tubular drain-pipes.*

Fifty per cent. is here added to the prices in the foregoing table for profit, carriage, &c. &c.

| Size of pipes, inches in diameter. | Lengths. | Red earthenware pipes, if made by contract. | Red earthenware pipes at the present sale prices. | Stoneware glazed at the present sale prices. | Average gain. On red earthenware pipes, if made by contract, over the present prices. | Average gain. On red earthenware pipes, if made by contract, over glazed stoneware pipes. |
|---|---|---|---|---|---|---|
| | | £ *s.* *d.* | £ *s.* *d.* | £ *s.* *d.* | £ *s.* *d.* | £ *s.* *d.* |
| 5 | Per foot | 0 0 1½ | 0 0 5 | 0 0 6 | 0 0 3½ | 0 0 4½ |
| | Per 1,000 feet | 6 15 0 | 20 16 8 | 25 0 0 | 14 1 8 | 18 5 0 |
| | Per mile | 35 12 9 | 110 0 0 | 132 0 0 | 74 7 3 | 96 7 3 |
| 6 | Per foot | 0 0 2¼ | 0 0 6 | 0 0 7 | 0 0 3¾ | 0 0 4½ |
| | Per 1,000 feet | 9 14 0 | 25 0 0 | 29 3 4 | 15 6 0 | 19 9 4 |
| | Per mile | 51 4 4 | 132 0 0 | 154 0 0 | 80 15 8 | 102 15 8 |
| 9 | Per foot | 0 0 3¾ | 0 0 9 | 0 1 0 | 0 0 5¼ | 0 0 8¼ |
| | Per 1,000 feet | 15 1 6 | 37 10 0 | 50 0 0 | 22 8 6 | 34 18 6 |
| | Per mile | 79 11 10 | 198 0 0 | 264 0 0 | 118 8 2 | 184 8 2 |

## No. VII.

*Queries issued at the request of the Metropolitan Sanitary Commissioners by the Right Honourable the Earl of Carlisle regarding the Drainage of Land; with Answers to the same by*

*James Smith, Esq., of Deanston.*
*Josiah Parkes, Esq.*
*Lucius Henry Spooner, Esq., Balmacara House, Loch Alsh.*
*Alexander Maccaw, Esq., Ardlochan, Maybole.*
*James F. Beattie, Esq., Surveyor and Valuator, Aberdeen.*
*Edward Scott, Esq.*
*Robert Neilson, Esq., Hallwood.*

(*November*, 1848.)

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1. Can you give any examples of the effects of thorough-drainage in improving the healthiness of localities as respects both the population and the cattle, or stock?

(*Mr. Smith.*) In the alluvial clay districts of Stirlingshire, and west of Perthshire, where the drainage was formerly effected by large open ditches, in the Dutch fashion, ague was periodically prevalent, and rheumatism, fevers, and scrofulous affections were much promoted, until the introduction of thorough-drainage, 40 years ago; after which period those diseases began to disappear, or to be greatly mitigated in severity. Few cases of ague now appear. Fevers are seldom known, except in the usual course of fevers which prevail epidemically over the whole country; and it is generally observed by the inhabitants that their cattle or stock are now less subject to diseases. In the undrained condition of those districts they were subject to dense fogs, especially in the autumnal months when much rain had fallen, communicating a chilly feeling to the inhabitants; but since the general introduction of thorough-draining those fogs seldom prevail, unless in a general foggy tendency of the atmosphere of the country.

On the farm of Deanston, in the west of Perthshire, consisting of about 200 acres, and which was the first farm on which the entire system of thorough-draining and subsoil-ploughing was introduced, there was a marked effect produced. The farm, after periods of rain, used to be covered with chilly fogs, which entirely disappeared after the thorough-draining was effected. The cattle grazing on the farm were much subject to the disease called "red water;" since the draining there has been no case of that disease. In other parts of Scotland and England similar results have been stated to have followed the introduction of thorough-drainage.

(*Mr. Parkes.*) The complete drainage of town and rural districts is universally admitted to be conducive to the health of both man and animals. The medical profession are, however, best qualified to give testimony to the one, and veterinary surgeons to the other.

The disease of foothalt in sheep and deer has been perfectly removed in many gentlemen's parks, and in extensive pasturage grounds, by deep under drainage. The earlier seasonable maturity of venison, and a greatly improved flavour, are also the acknowledged results of complete drainage. Foothalt, however, is known to occur where sheep are turned on very luxuriant herbage, kept continually moist from the state of the atmosphere, though the land be not wet; so that drainage alone will not, on all soils, and at all times, exempt animals from suffering from this disease.

In respect of increased salubrity induced in towns and rural districts by drainage, I may instance the acknowledged disappearance of ague and other periodical maladies consequent on the great drainages effected in Cambridgeshire—as in the Isle of Ely, &c.—and in the Lincolnshire and other great marshes.

As an example of the good effects arising from the drainage of swamps, I may state that the Commissioners of her Majesty's Woods and Forests, of which your lordship is the chief, have recently caused me to drain an extensive tract of country in the New Forest, called the Weare's Lawn and Bog, adjoining which is a small hamlet, whose inhabitants previously suffered much from intermittent fevers. The hamlet is now healthy; the offensive gaseous emanations from the soil have ceased; and the inhabitants are supplied with abundance of the purest spring water, discovered during the operations of drainage, and appropriated to their use.

(*Mr. Spooner.*) Beyond the general improvement in a sanitary point of view, and the diminution of fever and ague, acknowledged to have resulted from the drainage of the fen districts of Cambridgeshire and Lincolnshire, and the marshes of Essex, I am not acquainted with cases in which improvement in the health of population can be traced to drainage as a sole cause; but in respect to stock a striking instance can be adduced of improvement in healthiness resulting from drainage alone, and attributable to no other cause. In the Highlands generally, and more particularly on the west coast, there exists a well known and fatal disease among sheep, incurable by any treatment, termed "Braxey," which on undrained lands and in wet seasons is a cause of very serious losses. This is, in a great measure, prevented by drainage, and the diminution of casualties alone is more than sufficient to cover its cost, independently of the increased quantity and better quality of the fodder produced. This system has been extensively practised for several years, and invariably with the same beneficial results.

(*Mr. Maccaw.*) I cannot speak decidedly as to its effects on population; but from the evidence of parties still living fever and ague prevailed previous to the drainage of a marsh in my immediate neighbourhood, where that epidemic has not been known since. Similar instances of the same nature over the country have been well authenticated.

As to the health of cattle or stock I have the strongest evidence of the beneficial effects of drainage in many instances. On the lands which I possess, and on several others in the district, a disease called red water prevailed, in some years proving very fatal; but after drainage and cultivation of the marshy parts of the pasturage the stock has been free of that disease. I may mention that the first and most severe cases of pleura pneumonia in cattle that had occurred in this and a neighbouring county were on lands of a swampy undrained character. The surface drainage of sheep walks in every district is well known to promote the healthiness of the stock; and I believe the thorough drainage of a single swamp in any locality will be an important means of improving the health both of the population and stock connected with it.

(*Mr. Beattie.*) I am unable to state anything specially on this head. It is apparent that animals have more comfort and thrive better on dry lands than on wet.

I am aware of instances where marsh lands have been dried, and all the disagreeables and injurious effects arising from the swamps removed, such as frosts, fogs, and blights, &c. These lands have been again allowed to become wet, and all the evils formerly complained of have returned.

Where undrained lands produce bad herbage for the food of stock, and their influence in the neighbourhood are injurious to crops that produce the food of man, they must of necessity be injurious to the health of the population and stock, independent of the injurious influence of the atmosphere, which cannot be so easily determined.

(*Mr. Scott.*) The effects of thorough-drainage are very apparent in Roxburghshire within the last few years; formerly the agricultural labourers suffered greatly from the ague, and now a case seldom occurs. On well-drained lands cattle are not so subject to diseases of the lungs or violent colds.

(*Mr. Neilson.*) In the Altcar Meadows, belonging to the Earl of Sefton, a low level district about 8 to 10 miles north of Liverpool, a water-wheel was erected about 5 years ago, for the purpose of relieving the land from inundation; and though thorough-drainage has been very little adopted, the inhabitants already speak of the increased salubrity of the locality, while the equally increased fertility of the land has created a marked improvement in the condition of the stock. In my own neighbourhood, some low flat land of a stiff clay soil, and lying extremely wet, always had a scouring effect on the young stock turned on it in spring; and no application of manure produced any alteration. It was drained, and, without any other change in the management, the same species of stock throve on it extremely well.

This is easily accounted for; the wet prevented the manure from fermenting, and fostering that species of herbage best calculated to promote the vigorous growth of animal substances, and the land became covered with a verdure quite unsuited for that purpose.

The withdrawal of the water produced fermentation; the aquatic plants were superseded by a more food-producing species, carbonic acid gas was more speedily absorbed, and, instead of the exhalations of the marsh, a purer oxygen was evolved, increasing both the salubrity of the atmosphere and the condition of the stock.

I have also had several opportunities of witnessing similar effects in the West Indies, and particularly in British Guiana, where I resided several years. The surface is almost a dead flat, lower than the sea at high water, and drained only at considerable expense by large sluice-gates for each estate, which are opened each period of low water.

When an estate is abandoned this is neglected, and its neighbourhood is invariably the first to suffer on the approach of an epidemic; and I have known instances of the course of a fever thus produced being checked, and materially altered, by the neighbouring lands being drained, an alteration considerably accelerated by a small quantity of lime, in a finely-powdered state, being distributed on the lands during a windy day.

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2. Are there any instances of the application of drainage to forests, woods, and plantations? If so, with what effect, or with what expectations? Give especially any results applicable to suburban districts laid out as garden ground, or planted with ornamental timber?

(*Mr. Smith.*) Instances of the application of thorough-drainage to forests, woods, and plantations are few, although it is quite obvious that the application of the principle would be of immense advantage, both as regards the growth and quality of the timber, and as regards the influence on the wholesomeness of the atmosphere in the neighbourhood. About 25 years ago I made a comparative experiment of the effects of thorough-draining and subsoil-ploughing upon a small plantation on the farm of Deanston. I had in extent about an acre thoroughly drained and subsoil ploughed, adjoining several acres in a natural condition, but more dry. The whole was planted with forest trees, consisting of oak, elm, sycamore, larch, and Scotch and spruce firs. The trees upon the drained portion made rapid progress from the start, and at the end of a period of six years they had attained double the height of those on the undrained land, with a healthy and vigorous appearance. At the end of the sixth year I had those portions drained which had been left undrained at first, and the result was that the trees began to make more rapid progress, although they are not even now advanced so far as the trees which grow upon the land drained before planting. The general practice of drainage for plantations is to dig drains of from 12 to 16 inches in depth, but most commonly the former, in the decidedly wet places only, leaving the drains open, by which they get choked in a short time with leaves, &c.; and never, in their best state, can they, from want of depth, effectuate thorough dryness, or any complete percolation of the rain-water through the soil. I have long recommended the uniform and complete drainage of woodlands by deep *covered* drains, which would be sufficiently efficacious at double or treble the distance that is necessary in arable land; but I have never yet been able to induce any one to follow out the recommendation on an extensive scale.

In the Island of Lews, where I directed some land improvements, I had some extent of thorough-drainage executed in deep moss land to receive plantation. The drains were made from 4 to 4½ feet deep, and were placed at from 40 to 50 feet apart. This land has been planted about two years, and so far the plants seem to thrive well; but of course there can be no certainty of the successful growth of large timber. I have always observed that where ground in woodland was laid dry by any accidental circumstances, there trees of all descriptions were found to grow in a superior manner.

Blights are often found to affect crops on fertile cultivated lands from the passage over them of currents of damp air, arising from extensive tracts of damp woodland in their neighbourhood.

In several of the suburban districts of large towns, considerable expense has been incurred in many instances in the drainage of land for ornamental timber; and in many instances where thorough-drainage has been effected for agricultural purposes, timber growing in the fields and hedge-rows has been improved in growth from the effects of the drainage.

(*Mr. Parkes.*) The following statement of the cost of draining a village may be interesting to the Board, although I am unable to state results in respect of increased salubrity in this case, as the work is only just completed.

The village of Hatherop, near Fairford, Gloucestershire, consists of a main street about thirty chains long, with a branch street about eight chains long.

It contains, including the vicarage house and two farm-houses, thirty-nine dwellings, thirty-six of which are cottages. Its inhabitants number 169, exclusive of about twenty children, who attend the village school daily from adjoining districts.

In addition to the stabling and cattle sheds attached to the farm-houses, there are stables at the vicarage, and two other stables in the village.

| | | | |
|---|---|---|---|
| Total number of horses generally kept, about | | - | 34 |
| „ cattle | „ | „ - | 40 |
| „ pigs | „ | | from 60 to 80 |

the soakage from which, in many parts, stood in pools on the road-side and in front of the houses.

Hatherop Castle, the residence of Lord De Mauley, and the mansion of Sir M. H. H. Beach, Bart, are closely contiguous to the village, which is the property of the former.

A drain, laid four feet deep on the average, constructed of pipes of first-rate quality (from the works of Messrs. Peake, of Tunstall, Staffordshire), varying in their bore from four to nine inches, was laid throughout the village, partly along one side, and partly along both sides of the streets; from which drain issue thirty-three lateral branch pipes, destined to receive the water of drainage from the gardens and adjoining fields.

Eleven cesspools are formed in suitable parts of the main drain, six feet in depth, being two feet deeper than the drain itself, to receive the wash of the roads; these are severally covered with an iron grate, fixed in an oak frame, and secured with a bolt opened with a key, so that they can be examined and cleaned out when necessary.

The water passing through this drain is discharged into the ditch of a meadow of about nine acres in extent, which can be partially irrigated by it; but from the scarcity of water in the small village (which occupies the summit of a hill) irrigation cannot be more extended.

The cost of this little work has been as follows, viz.:

| | £ | s. | d. |
|---|---|---|---|
| Amount paid for labour - - - - | 29 | 11 | 2 |
| Grates and frames for cesspools - - - | 22 | 4 | 0 |
| Building cesspools - - - - | 6 | 10 | 0 |
| Repairs of tools and sundries - - - | 2 | 7 | 1½ |
| Pipes, and carriage from Staffordshire - | 108 | 3 | 9 |
| | £168 | 16 | 0½ |

The expense is borne as follows:

| | £ | s. | d. |
|---|---|---|---|
| By proportion of the work chargeable to Lord De Mauley for the use of the main drain for his fields and the village gardens | 20 | 0 | 0 |
| By Lord De Mauley (subscription) - - | 20 | 0 | 0 |
| By Sir M. H. H. Beech (ditto) - - | 20 | 0 | 0 |
| By the Rev. S. Burke, vicar (ditto) - | 5 | 0 | 0 |
| The remainder has been advanced by Lord De Mauley, and will be repaid to him in the course of three years, by instalments out of the highway-rate, as per agreement with the ratepayers of the parish - - | 103 | 16 | 0½ |
| | £168 | 16 | 0½ |

Besides the drainage of the streets, the main drain will serve to receive the water of drainage from the gardens attached to each of the cottages, and from about twenty-five acres of land adjoining.

A similar system is undoubtedly applicable to the improvement and drainage of many suburban districts with which I am acquainted; but the details and cost of the work will necessarily be modified by the circumstances of each particular case, the cost greatly depending on the proximity of a good tilery.

Many gardens have been deeply drained, and with uniformly beneficial results; and, although gardens necessarily contain numerous trees, and plants not annuals, no obstruction has yet occurred to the drains during several years. I may instance, among others, Mr. Woolryche Whitmore's garden, at Dudmaston, Shropshire; Sir Robert Peel's, at Drayton Manor, Staffordshire; and the Duke of Wellington's, at Strathfieldsaye, Hampshire, all of them having been drained without inconvenience from the roots of annuals, biennials, or trees. The productiveness of these gardens, their forwardness, and the perfection of the crops, have been greatly enhanced.

Fruit trees, which had previously been barren, have been thrown into fruit-bearing by deep and perfect drainage; and an instance of early ripening occurred last year (1848) at Strathfieldsaye, which may be cited, though a very simple fact, as illustrative of the advantage derived from deep drainage, by removing water from the roots of trees, and thereby greatly elevating the temperature of the soil. Morelli cherry trees occupy a wall in the Duke of Wellington's garden, facing the north; the plot in front of this wall was drained in the autumn of 1847, to the depth of five feet, the subsoil consisting of the well known retentive plastic clay of that district. One of the results of this drainage was the ripening of the Morelli cherries one month earlier than had been previously known (the time of gathering being annually recorded by the gardener), although the year 1848 will be long remembered by the gardeners and farmers of the midland and southern districts of England, as the wettest, perhaps, on record, and certainly remarkable for an uncommon absence of sunshine and ripening power.

As regards the application of drainage to forests, woods, and plantations, I may observe that woods and forests, if of ancient growth, cannot be expected to be improved by drainage; very old and dying trees seem to be more quickly killed by drainage if standing in very wet soils; sound trees, as oak of fifty years to three centuries growth, are not injured by drainage, whether standing single or in masses; but young plantations undoubtedly thrive much more vigorously if the land be prepared by draining previously to planting, in spaces left at proper distances. Numerous deep under-drains have also, to my knowledge, been carried through young plantations without inconvenience from stoppage by roots, proper precautions having been taken to secure the pipes with collars and other contrivances.

The drainage of churchyards and cemeteries is but too much neglected. When done in a very effectual manner, at depths greater than the usual depths of graves, it has, to my knowledge, given the greatest satisfaction to the inhabitants of the district, and drainages so effected have been accompanied, as I have been informed, and can well believe, with an appreciable increase of salubrity.

(*Mr. Spooner.*) I am acquainted with a few instances where surface-drainage has been beneficial to young plantations in the early stages of their growth; though, as a general rule, the drier situations are selected for plantation. But, on the other hand, instances are numerous of the effect produced by well grown woods on the general climate of districts, and this evidently not so much by the shelter they afford, as from the large quantity of water absorbed and kept in constant circulation for their support and increase. I have repeatedly observed instances where dry arable land, situated below plantations, has become springy and wet after the removal of the trees.

In populous districts the value of land for other purposes has been a hindrance to its employment for plantation to such extent as to manifest, or possibly to produce, sensible effects on the climate; but in the northern counties, where produce in plantation yields value to the owners equal, or nearly so, to that obtained from land under cultivation, and consequently extensive tracts have been planted, an undoubted improvement has been produced in the climate. That portion of Ross-shire called the Black Isle, situated between the Cromarty and Moray Firths, affords a good illustration of this remark; the climate of which is acknowledged, by all who have known it for any number of years, to have improved most materially within the last half century, during which time the great bulk of extensive woods now growing on it have been planted, and this improvement is generally attributed to the plantations; for although large portions of it have been brought into cultivation within that period, but little under-drainage has been practised till within the last two years.

(*Mr. Maccaw.*) Drainage, where effected on woods, forests, &c., has proved in its results equally beneficial as when applied to culture lands; the contrast between drained and undrained woods being as fully marked, the trees on the former appearing more vigorous in growth, free of moss, the bark healthy, and not bound to the tree. The reverse may be noticed where plantations exist on marshy undrained land.

I could refer to many cases over the country,—

1st. Of a plantation put down in 1833 on probably the worst land in the district, but well surface drained, and 2 feet deep; the timber now appears the best of its age, and forms a great contrast to other woods of the same standing on superior land, not so drained.

2d. Where a former plantation had failed from the wet nature of the soil, the ground has been drained as above; and the new plantation put down now looks most thriving. I may also record an instance of deep thorough-drainage with pipes, now four years executed, where trees of about fifteen years standing, the ground was wet and marshy and the trees were stunted in growth, but are now progressing with vigour.

As regards suburban districts, I might refer to many instances of nursery grounds, gardens, &c. where the beneficial effects of thorough drainage have been highly satisfactory.

(*Mr. Beattie.*) There are none of any moment in this neighbourhood.

(*Mr. Scott.*) There are instances of the good effects of drainage of woods and plantations by the superior growth of the timber and healthiness of the trees; also the great improvement in the climate by the removal of stagnant waters rendered unhealthy by the decay of vegetable matter. Instances of this kind can be produced in the woods in the vicinity of Raby Castle in the county of Durham.

The favourable results of drainage of garden ground and suburban districts is well established in the counties of Durham and Northampton.

(*Mr. Neilson.*) No experience.

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3. What are the obstacles to the introduction of drainage when the land is held in small plots and on different terms? and what are the modes of meeting such obstacles?

(*Mr. Smith.*) The chief obstacles to the drainage of land held in small plots and on different terms, is the difficulty in finding a concurrence of the parties; and that can only be effectually overcome by an enactment to enforce submission. From the extending knowledge of the advantages of good drainage, however, it may in most cases be practicable to induce concurrence by a conference with the parties. In many cases it may be necessary to provide money for the execution of the works, in the first instance, from some public fund, to be repaid, with interest, by an annual charge upon the land, divided over a period of 20 or 30 years, as is the case with reference to more extensive possessions under the Drainage Acts.

(*Mr. Parkes.*) Obstacles to the drainage of plots of land held in suburban districts, or elsewhere, by small proprietors, arise, firstly, either from the want of sufficient outfall belonging to a particular plot of land, or, secondly, from the expense of carrying an outfall through a neighbour's piece, even with his assent, or, thirdly, when the neighbour dissents; and in both these last cases an objection to drainage frequently arises from the difficulty of obtaining access to the neighbour's fields in order to repair drains.

An Act, commonly called "Lord Lincoln's Act," 10 & 11 Vict. cap. 38. was passed in order to enable parties to obtain compulsory outfalls, but with what success it has been attended I am unable to state, no one of my clients having had occasion to resort to it.

Nevertheless, I am aware that the knowledge of this enactment has prevented parties from objecting to drains being carried through their lands, although for the exclusive advantage of a neighbour.

(*Mr. Spooner.*) The chief obstacles to the introduction of general drainage when land is held in small plots, and on different terms, appear to me to be—

1st. The difficulty of getting a set of persons, whose opinions and interests differ, to unite for an object of common benefit.

2d. If agreed on this point, to assess the proportional amount of the general expense to be attached to each possession or tenement.

There is no provision with which I am acquainted adequate to to meet these obstacles in the different bearings of which they are susceptible, especially in situations where the interests are of so mixed a description as they are in suburban districts. The Act to facilitate the Drainage of Lands in England and Wales (10 & 11 Vict. cap. 38), the provisions of which, while they border on the question, seem only to authorize the encroachment on the property of another in cases where either benefit to the parties encroached upon would accrue, or, at least, no material detriment would result; whereas, in the present case, for a benefit derived by parties both far and near, individual interests might be not only not benefited, but possibly materially injured.

These observations apply more especially to the first-named obstacle; and as regards the second, it must be borne in mind how difficult it is to obtain correct valuations, real or contingent, of property of a mixed character, and to determine to what amount by such a general step one particular portion would be benefited, or another injured.

The only way of meeting these difficulties satisfactorily appears to me to be that of adopting a species of inquiry and examination similar to those instituted before a Parliamentary Committee in the case of railways or other similar projects.

(*Mr. Maccaw.*) The chief obstacles are want of proper outfalls, and where such would prove very expensive in relation to the extent of land to be drained; cases where an outfall has to be carried through another property on a lower level, where the owner or occupant is averse to any encroachment on his tenure, or where the outfall has to traverse garden or policy grounds, interfering with useful and ornamental trees; where heavy claims for compensation are demanded, or where heavy mortgages exist, and conflicting interests are involved; or, finally, where the owner or occupier cannot be convinced of the benefits arising from thorough-drainage.

I cannot presume to recommend to your board any additional means likely to prove available for meeting these numerous obstacles to the carrying fully out the drainage of wet and marshy lands in suburban districts, where the comfort and health of the surrounding population are involved, and where the parties are unwilling to confer upon themselves and their neighbours a positive benefit.

(*Mr. Beattie.*) The unwillingness of the holders to admit of any change, from prejudice or otherwise.

By ensuring the holders against ultimate loss, and compensating them for immediate or temporary damage during the execution of the works.

(*Mr. Scott.*) The great obstacle to the introduction of drainage where the land is held in small plots, is the want of unanimity amongst the owners and occupiers, which can only be met by a legislative measure, empowering the majority of the holders of such plots to drain the lands at the expense of the whole.

(*Mr. Neilson.*) The arrangement for the course and expense of excavation of the main drain is the principal difficulty, the party occupying the lowest level being independent of it. A B C D occupy portions of a line of declivity from A to D. D discharging his water at his lowest level requires no main drain, while the requirements of the other three increase according to their distances from the ultimate outlet.

A case of this kind occurred in the drainage of the Paddington estate, the property of Rowland Errington, Esq., by the Inclosure Commissioners, under my inspection.

The main watercourses came through the properties of the Earl of Shrewsbury, Mr. Errington, and Mr. Congreve, entering the estate of the latter at a depth quite insufficient for the drainage I contemplated executing.

I suggested to Mr. Stewart, the agent, to apply for permission to level into Mr. Congreve's land a sufficient distance to obtain the requisite depth, and to excavate it at his own expense. He did so this last summer, and has carried a very efficient main drain through Mr. Errington's property till it meets the lowest extremity of the highest line of small drains.

I have heard since that Lord Shrewsbury's agent intends applying for permission to take it on from this point into his lordship's estate.

A considerable extent of land has already been materially benefited by it; and one of the resident farmers told me last week that he considered it quite a "God-send, for it had taken the water from ditches and roads that he had never known dry before, but always filling the country with fogs and foul wind."

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4. State any obstacles that are found to occur to the drainage of land in some cases where the occupiers and owners are disposed to do all that lies with them towards it?

(*Mr. Smith.*) I have not experienced any obstacles under this head since the passing of the Act of 1847, providing for outfalls, &c. There may be a want of money by the parties, and there is no legal provision for supplying that want.

The chief obstacles to the drainage of land in the cases referred to arise partly from the frequent changes of ownership or occupancy, so that even when occupiers and owners are well disposed to do all in their power for the common benefit, their good intentions may be thus frustrated. Outfalls common to many may be neglected, it being no one's peculiar business to repair them, or to pay for their preservation, in the absence of a general compulsory measure to provide a common outfall, and maintain it.

(*Mr. Spooner.*) Supposing no obstacles to arise under the foregoing, and that all concerned in the land are agreed, and any objection from neighbouring parties overruled, two obstacles still present themselves, of which the one may prevent drainage in the ordinary way, the other injure or destroy it in after time.

The first of these is a want of natural outfall adequate at all times for efficient drainage, such as exists at the present time in the lands on the back or south side of Lower Rotherhithe and Deptford, and many other places similarly situated. Here the ditches are alternately filled and emptied as the tide advances or recedes in the Thames.

In such a case, the first object would be to prevent the river water from oozing through the soil, as it now does, by digging a ditch, in a course parallel to the river, of a depth somewhat greater than that of the proposed drainage, and filling it from top to bottom with closely-rammed clay, mixed with small gravel.*

The next object, that of securing an outfall, would be obtained by conveying the water to the river, when the tide is low, by drains, having sluice-boxes to exclude the entrance of the river water when the tide is high, or has risen above their level; or, if the supply of water from the land is greater than can be got rid of in this manner, it would be necessary to adopt the sytem practised in the fen districts, viz., that of collecting it into a reservoir, from which it is purified by the application of steam or some other mechanical force.

In either of these cases it is desirable that the leader drains should have a larger calibre than is found necessary in ordinary drainage.

The second obstacle, that of injury to the drainage in after time, may, and in suburban districts is not unlikely to arise, by the sinking of foundations for walls and other buildings down upon or through the drains. In providing against such a contingency, the situation and object to be secured would sanction a greater expenditure than in ordinary cases of drainage might be justifiable; and injury could be prevented by sinking the principal leaders to such a depth into the *solid* upon which foundations are laid as that they should be secure from interference, and constructing them of brick or stone similar to sewers, so as to enable them to bear greater weight than drains in the ordinary way have to sustain.

This suggestion is based upon the supposition of the tract being a deep sandy marsh, where the ordinary drainage would not

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* This mixture of clay with stones interspersed is less likely to contract and crack than clay alone.

reach the same depth as would be necessary to secure a foundation for heavy mason-work; and such, I think, will be found to be the description of some of the marsh districts in the vicinity of the metropolis.

(*Mr. Maccaw.*) In landward districts a very frequent obstacle has been, a mill-dam dyke in a river, or at the natural outlet of an extensive marsh, the right of which is held by parties who have no direct interest in the land to be reclaimed by drainage, although an Act may be passed authorizing the removal of such obstacles, on due compensation being given. Not only the value of an existing mill is claimed, but also claims are submitted for mills or other works that may be erected on the same land, where the water from the same source can be made available, thus summing up prospective compensation. These demands, whether reasonable or not, if settled through the court, prove serious matters of burden on the land intended to be reclaimed, over that of mere drainage expenses, and prove obstacles in the way of parties who are willing to execute drainage

Obstacles of this kind have, I believe, arisen in the case of the Tarbolton marshes in the suburbs of that town in Ayrshire.

(*Mr. Beattie.*) I know of none, unless the land be below the level of the sea; or the want of money.

(*Mr. Scott.*) The chief obstacle to carrying out effective drainage is the want of capital.

(*Mr. Neilson.*) I know of no obstacle that can occur in this case, unless some obstruction exists in the watercourse receiving the outfall of the land in question, such as mill privileges, and the power of damming the water for mechanical purposes.

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## 5. Are there any other important improvements that drainage is found to pave the way for introducing?

(*Mr. Smith.*) Thorough-drainage will pave the way for introducing the most complete system of *garden* culture, whether in the field or in the garden. It will facilitate the introduction of the system of a succession of crops *in the same season;* it will greatly facilitate the modern improvement of applying manure in the liquid form; and, finally, it will afford great advantages in the application of a general system of irrigation on grass lands.

(*Mr. Parkes.*) In some places useful water-power has been obtained by the collection of the water of drainage on an estate, and without injury to other parties; but this method can only be practised in certain suitable situations. Lord Hatherton has executed a large work of drainage on this plan, with, I understand, economy and success.

The water of plain land-drainage, mixed with liquid farm manure, is often beneficially employed, by receiving it in pools, and using it for the irrigation of lands more lowly situated. The Duke of Portland's justly celebrated water meadows at Clipstone are a notable instance of the advantage of adding the soccage-water of a town (Mansfield) to a natural stream, as a vehicle of fertility by means of irrigation. It is my opinion that town sewerage water ought to be largely diluted with running water when applied to land closely adjoining towns, in order to guard against the effluvia from it becoming very prejudicial to human health, and the herbage injurious to the health of animals. It is also my opinion, that in all cases of the application of sewerage water, as well as in those of plain water, for the purposes of irrigation, land having a retentive subsoil should be first prepared by deep and effectual under-drainage, in order to cause the fluid to permeate, and not stagnate in the soil. Without this preparation, irrigated meadows are known to be eventually, and often quickly, converted into swamps; and evaporation from the dregs and deposit of sewerage water left on the surface must, in addition, contaminate the atmosphere.

(*Mr. Spooner.*) Apart from the benefits derived in an agricultural view, drainage on an extensive scale must ameliorate the climate of districts in which it is practised, and, in a great measure, tend to purify their atmosphere.

Water that is stagnant, shallow water, and water mechanically separated, as it is when held in soil, is far more susceptible of evaporation than when in motion as a river, or combined in a large body as in a lake or sea; and it is a well-known fact, that evaporation is always accompanied with a diminution of the temperature of objects from which it takes place. Now, the constant motion in which water is kept by drainage, and its removal at such a depth below the surface as to prevent its being acted upon by the sun's influence, must of necessity also prevent excessive evaporation, with its concomitant reduction of temperature.

Again, if ammonia and other gaseous products, the result of animal and vegetable decomposition, are, as there is every reason to suppose they are, the origin of miasma, and the fruitful source of fevers, their retention near the surface will be greater in proportion to the amount of water, the denser absorbent existing in or supplied to the atmosphere immediately surrounding that surface.

(*Mr. Maccaw.*) Thorough-drainage will be the means, as has been already proved, of introducing many great and important improvements, by the extended cultivation of root and green crops, thus increasing the fertility and extent of arable land over the kingdom, giving employment to our labouring population, increasing the quantity of and reducing the price of food, at same time raising the value of land thus improved, lessening the expense of labour and quantity of seed previously required for the same area of land that had been arable in its undrained state, and of increasing immensely the number of cattle and stock, which again will tend largely to increase substantial manures; it will also ameliorate our climate, and bring to earlier maturity our grain crops on the higher elevations of the country.

There are many other advantages to arise from extended thorough-drainage on soils of proper depth and character within the range of climate suited to bringing crops to maturity, and even in the production of permanent pasturage beyond that range.

In many other respects this question presents views for the consideration of the political economist. It is scarcely within my province, or suited to my ability, to enlarge on the prospective advantages of these improvements as connected with the social welfare of the country.

(*Mr. Beattie.*) Inclosing and sheltering, and in every respect admitting of a higher state of cultivation.

(*Mr. Scott.*) A superior course of husbandry, enabling the occupier of the lands to consume his green crops to the best advantage on the lands, to reap his corn crops earlier, and also facilitate the sowing of the grain during unfavourable seasons; a great saving of expense in the cultivation of all crops, and the destruction of many injurious weeds that will only vegetate in wet soils.

(*Mr. Neilson.*) The chief direct improvements by drainage are the increased salubrity of the climate and fertility of the soil; but the range of social improvement, emanating from these two by the field of profitable and productive labour thus opened out, is calculated to affect the comfort and wellbeing of every class of the community.

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6. Will you state generally the depths and distances of the drains that are in use in relation to the different descriptions of soil; what is the amount of discrepancy; and whether this is accidental, or ruled by district usages, or by the opinions of different engineers?

(*Mr. Smith.*) The depths and distances of drains that are in general use are very various, arising, not only from the proper difference necessary to suit the different nature of the soils, but also from the difference in the opinions of engineers and practical farmers. The soils being so varied in character, no settled rule can be laid down. The depths in use, since the introduction of thorough-draining, have varied from 2 to 3 feet, and, in occasional instances, 4 or 5 feet has been found preferable. The distances have ranged from 10 to 30 feet; whilst, in some cases, in peculiarly open subsoils, they have been extended to 40 feet with complete success. For a long time it was difficult to persuade practical men that depths beyond from 18 inches to 2 feet would be effectual in clay soils, at whatever distances they might be placed; but in the course of experience the results of the examples set by those who adopted depths of from 2½ to 3 feet have led to the general adoption of such depths for all clays or compacted drift soils. Where beds of gravel, sand, or other open strata occur within 4 or 5 feet of the surface, it is proper and usual to cut down to those beds when the outfall will allow; but these depths are seldom adopted except under such circumstances. Within the last four years depths varying from 4 to 6 feet, with distances of from 36 to 60 feet, have been advocated by some engineers under general circumstances, and several practical men have adopted the system, to some extent, on clay lands, in some instances, as they state, with satisfactory results; but in all such cases as have come under my observation the results have not warranted the appellation of "*thorough-draining*," when brought to the test of comparison with land drained at depths of from 30 inches to 3 feet, and with distances varying from 18 to 24 feet. Much of the soil that I have met with in the upland country in England, Scotland, and Ireland of the drifted formation is so difficult to cut at the greater depths, that the expense becomes too great to warrant its adoption unless under very obvious advantages; and it is yet an unascertained point how far is it beneficial to remove the free water to a greater depth from the surface than from 2½ to 3 feet. The advocates of the deeper system, so far as I have been able to observe, seem to be returning in practice to depths not exceeding 4 feet, and to distances varying from 24 to 30 feet.

An extent of about 10,000 acres has been drained in Scotland on one estate, none of the drains exceeding 2 feet in depth and 20 feet apart; yet, the thorough-drainage of a very stiff and compact clay has been accomplished to the satisfaction of the parties cultivating it, and to the satisfaction of agriculturists generally. Nevertheless, I am of opinion that from 2½ to 3 feet would have been preferable, as affording facility for a deeper working of the soil, without risk of injury to the channels of the drains.

Setting aside the moot question as to the proper depth at which free water should be retained, I do not so much object to greater depths than 3 feet as I do to greater distances in *all* soils, as I have invariably found, from experience, that when distances beyond 24 or 30 feet have been adopted in *compact* soils, there has not been a perfectly uniformly dry condition of the soil, especially when rain had recently fallen; so that, if expense is to be saved by greater distances, I would prefer incurring the expense to the diminution, in any shade or degree, of complete and quick drainage. The experience of a succession of seasons is necessary fully to test drainage; and the extent of deep and distant drainage, which has of late years been executed, will afford sufficient examples to test the practice in a cycle of seasons.

The circumstance which has the most influence in ruling the distances of drains, and through these in some degree the depths, is the arrangement of the existing ridges. The width of the ridges runs generally from 12 to 24 feet, most commonly 18 feet; and as the ridges are usually thrown up in the middle from 12 to 18 inches above the levels of the furrows, a great saving in the cutting is effected by placing the drain in the line of the furrow: and, besides, when the ridges are much raised, there is a tendency of the surface-water to run towards the old furrow, even after the land has been drained; and if there is not a drain below or near to the furrow, there is an undue collection of water, which obtains for some years after the drainage has been executed, and until the ridges have been levelled down and the subsoil fully opened. The loss by this wetness, or damp, or incompleteness of thorough and uniform dryness, is greater than the cost of having the drains somewhat less distant. There is also some difficulty practically in getting the drains cut to uniform depths, when the surface in the lines of the drains is of various altitudes from the datum level of the bottom of the drains. Practically, therefore, it is found to be a much more ready method, and upon the whole cheaper and much more immediately fully effective, to adopt the furrows for the lines of the drains. In some cases, when the ridges are under 12 feet in width, I have found it expedient to place a drain in every second furrow only; and in cases where an inequality in the width of the ridges existed I have found it proper to adopt those unequal distances for the drains. Where such distances have been adopted generally, it has been found that depths of from 2½ to 3 feet have, on all soils, and at all times, produced a thoroughly dry condition of the soil.

In Ireland, where the lazy-bed system of cultivation is followed, the practice is to place the drains in each alternate trench, which makes the distances about 18 or 20 feet, and the depths adopted vary from 2½ to 4 feet. As stones are plentiful, and labour cheap, the channels of the drains are generally formed of stones. Tiles and tubes are now being introduced, and these will no doubt be extended in use.

In bog and marshy land the drains require to be made the deepest, because from the nature of the structure of such land there is generally much bottom-water to be removed, and the soil of bogs and marshes contracts and subsides much after being drained.

In the floating bogs very much deeper drains are required; and where outfalls can be had, the depth of the drains should be as great as to remove, if possible, the whole of the bottom-water, which can generally be done with a few deep drains, and the removal of the surface-water can thereafter be effected by frequent parallel drains of the ordinary depths and distances.

(*Mr. Parkes.*) As to the practice of draining in respect of depth and distance, my opinion is that the usage of the country, until within the last few years, has been rather a matter of accident than determined by or referable to any sound principles of experiments. The great proportion of the older drainages of England, which were generally of shallow depths varying from eighteen inches to three feet, formed of imperfect materials and executed in an imperfect manner, have either been entirely removed, or are being gradually superseded by drains placed at greater depths formed of more perfect and durable materials. The Inclosure Commissioners could give the most authentic and abundant testimony to the difference in practice and to the cost of modern draining, as compared with that of earlier times.

The principles which have governed my practice as a drainer will be found fully developed in two papers published in the journals of the Royal Agricultural Society of England, now reprinted in a separate form, and entitled "Essays on the Philosophy and Art of Land-Drainage." Longman and Co.

(*Mr. Spooner.*) In looking back to the origin of parallel drainage, it is easy to discover how the rules of the distance apart of drains have arisen. Before under-drainage was practised, strong and wet lands were rendered capable of arable culture by being ploughed up into the waving shape, termed ridge and furrow, the bottom of the latter forming the drain for the water from the former; but in consequence of the crops perishing in and by the sides of the furrows (or thoroughs), the system of drawing off the water from them, by shallow drains below each, kept open with straw or brushwood, was adopted, and was termed furrow or thorough-draining. Hence the ordinary width of the lands or ridges in any particular district indicates the distance at which the drains were usually placed from each other; and the distances now most commonly in use in different districts, and on the different sorts of soil have all reference to a width of ridge that either formerly was, or now is, in use in those districts; and it is a fact worthy of remark, that throughout the country the statements of the number of feet from drain to drain is in almost every instance divisible (when reduced to inches) by eighteen, that being the space of ground in inches moved by a single turn of ordinary ploughing.

I am particular in mentioning this subject, because I consider that the long-established usages of a particular district indicate the requirements of that district, and that the distance from furrow to furrow points out to a considerable extent the tenacity or porosity of the soil, or its capacity of retaining water on the one hand and transmitting it on the other.

The discordances in opinion existing among practical men on the subject of drainage appear to me to have arisen in a great measure from a want of due observance of these differences, and from the too frequent attempt to establish rules of general application founded on the successful practice of some one locality.

The following statement is intended to illustrate the concordance between the distance of drains and the usual width of lands in certain districts.

| Width of land or ridge. | Number of turns of the plough (18 inches wide) to the land. | Some of the districts in which the respective widths of ridge are in common use. | General character of the soil. | Distances from Drain to Drain in common use. |
|---|---|---|---|---|
| Ft. in. | | | | |
| 7 6 | 5 | Common in the county of Essex. | Tenacious and uniform clay. | Seven feet 6 inches; 15 feet, 21 feet, or every furrow, every other furrow, every third furrow, &c. |
| 16 6 | 11 | Parts of Surrey, Sussex, Kent, Middlesex, &c. | Same as above, fine and silthing clays, with beds of fine sand interspersed. | Drains 1 rod apart. |
| 18 0 | 12 | Parts of Yorkshire, Northumberland, South of Scotland, &c. | Clays, containing coarse sand and grit, interspersed with shale and slate fragments. | Drains 18 feet or 1 rod (Scotch measure) apart. |
| 21 0 | 14 | Common in the above and the Midland counties, &c. | Calcareous soils, and clays lighter than the above, with frequent intermixtures of sand and gravel. | Drains 21 feet apart. |
| 24 0 | 16 | Very common in the Midland counties and the Highlands. | Clays similar to the above, with rotten sandstone rock and more frequent intermixtures of gravel, &c. | Drains 24 feet apart. |
| 30 0 | 20 | Very generally adopted in the lighter clays throughout the country. | The lighter description of clays and clay gravels. | Drains 30 feet apart. |
| 33 0 | 22 | Parts of Berkshire, Herts, Suffolk, Cambridgeshire, &c. | Chalk districts, stone, brush, gravelly, and sandy soils; and the lighter description of lands, usually springy soils. | Drains 33 feet or 2 rods apart. |
| 36 0 | 24 | Same as above, and very general. | - - - | Drains 36 feet or 2 rods (Scotch measure) apart. The application of furrow drainage to the two last is comparatively of recent date. |

The above quoted widths are those most commonly adopted throughout the country.

As regards the depth of drains, general opinion appears to have undergone considerable change, resulting from the more extended experience of the last few years. It was at one time commonly supposed that in strong clays water on or near the surface could not descend to deep drains; but this having been found erroneous, the practice of draining strong lands deeper than formerly has become common, and with them others of a lighter description; and the difference may be represented by that which exists between eighteen to thirty inches in the one case, and thirty-six to forty-eight inches in the other. The question of the depth of drains is affected by two considerations: first, their permanency; secondly, their efficiency. It is without doubt an established fact, that in most soils shallow drains are choked in the course of time, and in some in a very few years, and an examination into the cause has shown that they have become filled with the fine particles of soil washed down through worm and mole holes, cracks, and cavities occasioned by the ordinary processes of tillage. On the other hand, deep drains, being removed from the active soil, are exempt from such casualties, and thus their permanency secured.

No better evidence of the efficiency of a deeper system of drainage can be adduced than that the practice is daily becoming more general in every variety of soil and situation, and is found amply remunerative even in land previously drained to all the extent that shallow drainage will effect.

I consider that in the generality of soils drains are not safe at a depth of much less than three feet, and that they may to greater advantage be laid at a depth varying from that to four feet; but I have not seen evidence to prove that a greater depth than this is attended with such advantages as to sanction the increased incident expenditure.

I have avoided uniting the consideration of the depth of the drains with their distance asunder, because I think material errors are not unfrequently committed, on the supposition that the one bears an invariable ratio to the other; at the same time I am fully satisfied that an increase in depth will sanction a greater distance of drainage, but not in a uniform proportion.

Speaking in general terms, I should say that it is to the suitable distance apart of drains that we are to look for the efficacy of drainage, and to their depth for its permanency.

(*Mr. Maccaw.*) The depths and distances of drains are various in relation to the different descriptions of soils:—

1st. On a thin clay soil and subsoil of great tenacity, drains were formerly 12 to 15 feet apart, and 2 feet deep. That depth increased afterwards to 2½ and 3 feet. Since the Drainage Act came into operation the distance apart of drains was extended to 21 and 24 feet; the depth to 3½ and 4 feet. Soon after, however, the distance apart was contracted to 16 and 21 feet; the depth remaining the same; and this system now prevails generally on soils of the description named.

2d. On a clay soil of less tenacity, having more sand or gravel in its composition, drains are now generally made from 3½ to 4 feet deep, and 21 to 27 feet apart.

3d. On soils of greater porosity, with less clay in their composition, and where spring-water exists, drains are being made from 4 to 5 feet deep, and from 27 to 40 feet apart.

The main drains are generally cut a few inches deeper than the branch drains.

In some cases rock lying near to the surface interferes. Where this occurs, drains are put in at more contracted distances apart, and, if practicable, the rock is cut, at least through its loose surface, to form the bed of whatever material is used as a conduit, and the lines of drainage are then wrought out at no uniform depth or distance apart.

In drainage of moss-lands, where the drains cannot be cut through the moss, they are now generally cut to 5 feet deep and from 18 to 24 feet apart; but where the moss can be cut through about this depth, the distance apart of drains is very much extended, depending on the nature of the subsoil, from, say 24 to 36 feet. Where this can be attained it is very effective.

Moss of a very wet and soft character cannot be properly drained in one season, particularly when of great depth. This description of moss generally occupies a very level position, and the inclination for the proper discharge of the water must be wrought out in the drains. After drainage it subsides more at its centre, or where its deepest body exists, than at its edges; consequently, the drains at those deep parts become depressed beneath their first levels, and often below that of their outlet, and hence the propriety of keeping the drains open during the first season at as great a depth as practicable. By cutting their sides perpendicular they are found to stand better than by sloping them. In the second season they are cut out and finished.

The discrepancy between the former system of shallow drainage, where the materials used were chiefly small or broken stones, or horse-shoe tiles of large dimensions, and that mode now generally adopted, when pipes partly connected with collars or socked pipes are used, cannot be better illustrated than by the estimates in these early applications under the Drainage Act submitted to the Inclosure Commissioners, which show an average acreable cost of about - - - - - £8 10 0

While on the present system it amounts to - - 5 10 0

Showing a difference in favour of the latter of £3 0 0

I believe this favourable discrepancy has arisen from various causes; chiefly from the known results of the beneficial effects of drainage formerly executed, and of experiments conducted with a view to ascertain the most effective system at the least cost, the great facility in procuring capital under the Drainage Act by parties desirous to improve their lands by drainage, and the pretty stringent regulations insisted on by the Inclosure Commissioners, under the Act, to have that money expended on drainage on the best known principles in regard to cost, efficiency, and durability, who, from their extended information, are enabled to decide as to the most approved methods, their opinions on this head being more generally adopted than ruled by the usages of any particular district or engineer.

(*Mr. Beattie.*) The depth of drains in agricultural lands are seldom made less than 3 feet.

On the rich clayish lands 3½ feet and 4 feet.

On marshy or mossy soils, from 4 feet to 6 and upwards, as circumstances may admit.

Every description of soil subsides after being thoroughly drained. Marsh lands in some instances will subside one or two feet. Ample allowance should be made in the depth of the outfalls and the drains for this subsidence.

Thorough-drainage, under the influence of the Inclosure Commissioners, has now become nearly an universal system, and most engineers agree that the deeper drainage at moderate distances apart is most effectual and permanent.

(*Mr. Scott.*) Drains are generally 3 to 5 feet deep and from 20 to 50 feet apart; in strong retentive pure clays, from 3 to 4 feet deep, placed at distances of from 20 to 36 feet apart, in porous subsoils, such as gravel or sand, 4 to 5 feet deep and 40 to 50 feet apart. In some cases the drains are made deeper and placed farther apart.

A great difference of opinion exists in different localities as to depth and distance of drains. It frequently occurs from prejudice, influenced by the custom that has prevailed in each district. There is a difference of opinion on this point by draining engineers, but the prevailing opinion is in favour of deep drainage.

(*Mr. Neilson.*) Though the depth and distances of drains are relatively, in a great measure, dependent on each other, I consider the former ought invariably to be regulated by the nature of the substratum in which it is laid and the soil through which it passes, presuming, of course, that the outfall is a good one.

In stiff clayey and tenacious soils the drains cannot act so promptly, and therefore I should not place them so distant, and consequently not so deep, as in gravelly, sandy, or more porous soils.

I am at present inspecting a considerable extent of drainage on the estates of the Marquis of Londonderry in the county of Durham, where the soil is principally of the former character. The depths have varied from 3 feet to 3 feet 9 inches, and the distances from 8 to 12 yards, according to the presence of more or less porosity of the soil, and the result has hitherto been highly satisfactory.

In other parts of England and Wales, in lighter and more porous soils, I have found 4 feet deep and from 15 to 18 yards apart equally efficacious; though in stiff clay greater depths and distances have not, in my limited experience, given similar satisfaction.

Though the prejudice is great among farmers of the old school against deep and distant draining, I consider much of the discrepancy of modern artists arises from the different doctrines of Mr. Smith and Mr. Parkes, both equally celebrated as farmers, but whose opposition to each other led them each to recommend one unvaried system of drainage to every species of soil.

7. Give two or three examples that would furnish fair specimens of the cost of the work in each leading class of the circumstances that commonly determine cost?

(*Mr. Smith.*) The following examples will afford a fair idea of the cost per acre for draining in the leading class of soils and under the most ordinary circumstances:—

EXAMPLE I.

*Alluvial Clay.*

Drains { feet deep. / feet apart.

| | £ | s. | d. |
|---|---|---|---|
| Cost of cutting and filing, per acre - | 2 | 1 | 10 |
| Cost of materials (tubes at 20*s.* per 1,000) | 2 | 2 | 0 |
| Chargeable per acre (average) for main drains, outfalls, engineering, &c. - - | 0 | 18 | 0 |
| Total cost per acre - - | 5 | 1 | 10 |
| The same, if executed with peat tubes, per acre - - - - - | 3 | 9 | 6 |

EXAMPLE II.

*Upland clay, or till, full of stones.*

Drains { 2 feet 9 inches deep. / 21 feet apart.

| | £ | s. | d. |
|---|---|---|---|
| Cost of cutting and filling, per acre - | 3 | 2 | 9 |
| Cost of materials (tubes at 20*s.* per 1,000) | 2 | 2 | 0 |
| Chargeable per acre (average) for main drains, outfalls, engineering, &c. - - | 1 | 2 | 0 |
| Total cost per acre - - - | 6 | 6 | 9 |

EXAMPLE III.

*Compact gravelly drift with boulder stones.*

Drains { 2 feet 9 inches deep. / 24 feet apart.

| | £ | s. | d. |
|---|---|---|---|
| Cost of cutting and filling, per acre - | 3 | 4 | 0 |
| Cost of materials (tubes at 20*s.* per 1,000) | 1 | 16 | 3½ |
| Chargeable per acre (average) for main drains, outfalls, engineering, &c. - | 1 | 1 | 0 |
| Total cost per acre - - - | 6 | 1 | 3½ |
| The same, allowing the drains to be 4 feet deep and 30 feet apart, per acre - - | 6 | 5 | 4½ |

Example IV.

*Open sand and gravel, with moorish bottom.*

Drains { 4 feet deep. / 40 feet apart.

| | £ | s. | d. |
|---|---|---|---|
| Cost of cutting and filling, per acre - | 3 | 6 | 0 |
| Cost of materials (tubes at 20*s.* per 1,000) | 1 | 1 | 9¼ |
| Chargeable per acre (average) for main drains, outfalls, engineering, &c. - | 1 | 2 | 0 |
| Total cost per acre - - - | 5 | 9 | 9¼ |

Example V.

*Peat moss, forming its own channel.*

Drains { 3½ feet deep. / 18 feet apart.

| | £ | s. | d. |
|---|---|---|---|
| Cost of cutting and filling, per acre - | 1 | 4 | 5 |
| Chargeable per acre (average) for main drains, outfalls, engineering, &c. - | 0 | 6 | 0 |
| Total cost per acre - - - | 1 | 10 | 5 |

(*Mr. Parkes.*) It would be difficult to cite any estate of magnitude the subsoil of which is composed of one uniform quality; whilst the cost of drainage necessarily varies with the texture of the soil, both as to expense of cutting and in respect of the distance to which water will filtrate through the land, so as to ensure a sufficiently quick and perfect drainage during and after rain. It has been found that the cost of draining land, at depths of from 4 to 6 feet, the drains being laid with pipes and collars, varies from about 3*l.* per acre, in free gravel and sandy soils gorged with water, to 5*l.* 10*s.* and 6*l.* per acre in clayey ground with rock at bottom, requiring to be blasted, a common case in hilly countries, or where bore-holes are required in addition to drains in springy lands. Plain pure clay drainage (which is the simplest and easiest of all drainage) does not exceed in cost from 4*l.* to 4*l.* 10*s.* per acre, according to its texture, which varies, however, more than any other distinctive quality of soil. Alluvial soils, such as the extensive warplands on the banks of the Humber and other estuaries, are drainable at the depth of from 4 to 5 feet, at a cost of from 3*l.* 10*s.* to 4*l.* 10*s.* per acre. It will be understood that all quotations of the cost of drainage must greatly depend on local circumstances, such as the proximity of tileries, the wages of labour, &c.

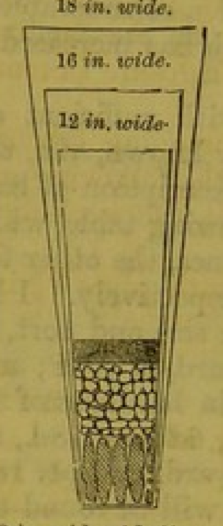
(*Mr. Spooner.*) The principal circumstances which determine the cost of drainage-works are :—The labour of cutting and filling the drains, the material of which the drain itself is formed, and the outlets for the discharge of water Of these, the last increases in proportion as the ground is steep and irregular, or unusually flat, and can only be included in a general estimate where the surface gently undulates: the material also varies greatly in cost, arising, in the case of tiles, in the supply being near at hand and equal to the demand, or otherwise, and in the case of stones, in the distance of carriage.

It was formerly considered that the cost of drainage was equally divided between that of the labour and material; and in 2½ to 3 feet drains filled with stones or horse-shoe tiles, on soles, this is about the case: but the more general introduction of pipes, and the improved methods of making them, have occasioned a considerable balance in favour of material, while increase of depth has increased the cost of labour.

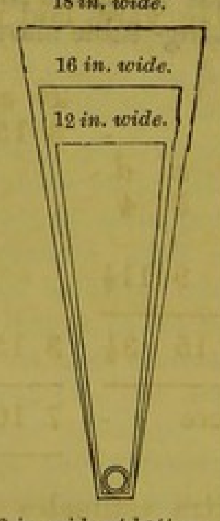
This latter item can be determined with sufficient accuracy by referring it to a standard pretty generally known, viz., the val ue of moving a solid yard of earth of any one description of hardness; and to illustrate this, I have drawn up the following table, which supposes two sets of drains, the one opened for stones, the other for tiles, and at depths of 3 feet, 3½ feet, and 4 feet, respectively. I have shown the average width of the cutting for each size and sort, the number of lineal yards required to equal a solid yard, in each; and assuming three descriptions of soil, the differences in hardness of which make the cost of moving their solid yard, 4*d.*, 6*d.*, and 8*d.*, respectively. I have calculated the labour-value per yard, and per rod, linear, of the different depths and sorts; and these will be found to tally very closely with the prices at which the work is done.

It is a common remark, that the cost of making drains is double, by every foot of increased depth given, and the same in proportion for every part of such increase: the following table shows that this is so.

| | Depth of each Drain. | Average Width of Drain. | Running yards of Drain to the cubic yard. | Sandy Soils, light Loams, and light Clays. Easy digging. At 4*d.* per cubic yard. | | | Stiffer Clay and Gravel, requiring some pickwork. At 6*d.* per cubic yard. | | | Hard Clay and close Soils, requiring pickwork before they can be done. At 8*d.* per cubic yard. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | per yd | per rod. | | per yd | per rod. | | per yd | per rod. | |
| | | Inches. | | *d.* | *s.* | *d.* | *d.* | *s.* | *d.* | *d.* | *s.* | *d.* |
| Stone Drains. | 4 feet | 14 | 2 + | 2 | 0 | 11 | 3 | 1 | 4½ | 4 | 1 | 10 |
| | 3½ feet | 12 | 2½ — | 1$\frac{3}{5}$ | 0 | 9 | 2$\frac{2}{5}$ | 1 | 1¼ | 3$\frac{1}{5}$ | 1 | 5½ |
| | 3 feet | 10 | 3½ + | 1$\frac{1}{7}$ | 0 | 6¼ | 1$\frac{5}{7}$ | 0 | 8½ | 2$\frac{2}{7}$ | 1 | 0½ |
| Pipe Tile Drains. | 4 feet | 10½ | 2½ + | 1$\frac{3}{5}$ | 0 | 9 | 2$\frac{2}{5}$ | 1 | 1¼ | 3$\frac{1}{5}$ | 1 | 5½ |
| | 3½ feet | 9½ | 3¼ | 1$\frac{3}{13}$ | 0 | 7 | 1$\frac{11}{13}$ | 0 | 10¼ | 2$\frac{6}{13}$ | 1 | 2 |
| | 4 feet | 7½ | 5$\frac{1}{13}$ | 0¾ | 0 | 4¼ | 1$\frac{1}{5}$ | 0 | 6½ | 1½ | 0 | 8½ |



8 *in. wide at bottom.*



3 *in. wide at bottom.*

The ( + ) and (—) signs attached to the third column of figures, imply a small fraction greater or less than the number stated.

In the price per rod, the fractional parts are reduced to the farthings nearest to them.

Thus it may be seen that the cutting, &c. of a stone drain of one depth, say 3½ feet, may cost 9*d.*, 1*s.* 1¼*d.*, or 1*s.* 5½*d.* per rod, according to the hardness or otherwise of the soil.

The cost of labour in a similar drain made for pipes would be 7*d.*, 10¼*d.*, or 1*s.* 2*d.* per rod.

So also a pipe drain in one description of soil may cost in labour but 4½*d.* per rod, the same in another description 8¼*d.* per rod, and the same, if for stone, 1*s.* 0½*d.* per rod.

Having ascertained the cost per rod at which the labour can be performed, it is easy to arrive at the number of rods of drains, and number of tiles, required for an acre, at any given distance of drainage; and many tables have been drawn up for facilitating these calculations. The one circulated by the Inclosure Commissioners is the best I have seen.

By referring to these tables, and the foregoing labour statement, we may arrive at the cost of the work in the following manner:—

Soil of the class No. 2. Clay and gravel, the working of which is worth 6*d.* per cubic yard.

Drains 24 feet apart, 3 feet deep, laid with pipes 1¾ inches in the bore.

| Per acre. | £ | s. | d. |
|---|---|---|---|
| 110 rods of drains, at 6½*d.* per rod - | 2 | 9 | 7 |
| 1,815 1¾-inch pipes, 12 inches long, at 21*s.* per 1,000 - - - - | 1 | 18 | 2½ |
| Total per acre - | 4 | 7 | 9½ |

Again, soil of class No. 3, at 8*d.* per cubic yard, laid with horse-shoe tiles on slate soles.

| Per acre. | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| 110 rods of drains, at 8¼*d.* per rod - | | | | 3 | 15 | 7½ |
| 1,815 2-in. by 2½-in. tiles, 12 inches long, at 25*s.* per 1,000 | 2 | 5 | 4 | | | |
| 1,815 slate soles, at 16*s.* 6*d.* per 1,000 - - - | 1 | 9 | 11½ | | | |
| | 3 | 15 | 3½ | 3 | 15 | 3½ |
| Total per acre - | | | | 7 | 10 | 11 |

In both these cases I have excluded extra estimates for leaders, and for larger sized tiles to lay in them, because I find that, as a general rule, when extended over tracts of any size, the estimated quantity exceeds the actual by an amount sufficient to cover the expenditure under that head.

I do not consider it necessary to multiply instances of cost, further than as illustrations of the manner of arriving at them, since the variety of circumstances is such as that the cost in one case cannot be taken as a criterion for that in another.

(*Mr. Maccaw.*) First Class.—Being drains on a very tenacious soil, averaging 18 feet apart, and 3½ feet deep:—

| Cost per acre. | £ | s. | d. |
|---|---|---|---|
| Cutting and filling 147 rods at 5*d.* - | 3 | 1 | 3 |
| 2,425 pipes, 12 inches long, 2 inches tube, at 20*s.* per 1,000 - - - | 2 | 8 | 6 |
| Cartage, say 4 miles, at 4*s.* per 1,000 - | 0 | 9 | 8 |
| Cost, extra, on mains, large pipes, outfall, &c. | 0 | 6 | 7 |
| | £6 | 6 | 0 |

Second Class.—Soil and subsoil less tenacious, drains 24 feet apart, 3½ to 4 feet deep:—

| | £ | s. | d. |
|---|---|---|---|
| Cutting and filling 110 rods at 6*d.* - | 2 | 15 | 0 |
| 1,815 pipes, 12 inches long, 2-inch tube, at 20*s.* per 1,000 - - - - - | 1 | 16 | 4 |
| One third connected with collars where bottom soft or sandy - - - | 0 | 4 | 2 |
| Cartage, say 4 miles - - - | 0 | 8 | 0 |
| Extra cost on mains, pipes, outfall, &c. - | 0 | 6 | 6 |
| | £5 | 10 | 0 |

Third Class.—Deep marshy soils; subsoil various, clay, running sand, gravel, &c.; springs exist; drains from 27 to 40 feet apart, say average 33 feet:—

| | £ | s. | d. |
|---|---|---|---|
| Cutting and filling 80 rods, 4½ feet deep to 5 feet, at 9*d.* - - - | 3 | 0 | 0 |
| 1,000 pipes, 2 inches bore, 12 inches long, with collars or socket pipes, at 26*s.* per 1,000 - - - - - - | 1 | 6 | 0 |
| 320 pipes, 3, 4, and 6-inch tubes, average 40*s.* per 1,000 - - - | 0 | 12 | 10 |
| Cartage, 4 miles, at 6*s.* 6*d.* per 1,000 - | 0 | 8 | 7 |
| Extra cost on outfall, days work, and superintendence - - - | 0 | 8 | 7 |
| | 5 | 15 | 0 |

| | £ | s. | d |
|---|---|---|---|
| Fourth Class.—Moss drains, 5 feet deep, 18 feet apart, 147 rods cutting and filling, wedge turf material, at 7*d.* per rod - - - - - - - | 4 | 5 | 9 |

| | £ | s. | d. |
|---|---|---|---|
| (*Mr. Beattie.*) The expense of furrow drainage at 3 feet deep and 24 feet apart, with tile pipes, may be reckoned at an average of - - - - - - | 6 | 10 | 0 |
| Outfalls and incidents, say 5 per cent. - - - | 0 | 6 | 6 |
| Per imperial acre | 6 | 16 | 6 |

In the drainage of extensive marsh lands the expense of the outfalls is generally a large item of the whole.

Large open cuts through soil may be estimated at from 6*d.* to 1*s.* per cubic yard, and through rock at 2*s.* to 4*s.* per cubic yard.

I am engaged at present in the survey of a marsh of about 200 acres, common to eight or ten parties; the outfall is a small stream that requires to be deepened 8 to 10 feet for half a mile.

The expense of the outfall and main subdivision ditches between each lot will be about 3*l.* per acre.

The expense of furrow-draining each lot, say 6*l.* per acre.

Incidental expenses, say 1*l.* per acre. In all 10*l.* per acre.

(*Mr. Scott.*) In pure clays, free from stones, the cost will amount generally to about 4*l.* 10*s.* per acre, calculating the drains to be made 4 feet deep and 30 feet apart, laid with pipe-tiles of 1¼ inches internal diameter; the price of the pipes not to exceed 15*s.* per thousand.

In strong clayey subsoils containing stones, and those with veins of sand and gravel, mixed with large stones, requiring the pipe-tiles to be collared, the cost will amount generally to about 5*l.* per acre.

In light easy working soils the expense ought not to exceed 4*l.* per acre.

(*Mr. Neilson.*) The principal circumstances that determine the cost of drainage are the prices of labour and tiles. The former varies considerably in different districts, and is influenced by the propinquity of a manufacturing town or a railway in progress of construction; the latter, according to the nature of the clay for making tiles, and the price of coals, or the price at which the tiles can be bought, including the cost of conveyance. To this must be added the expense of the main watercourse, which in some instances is considerable, and ought to be spread over the whole acreage to the drainage of which it is subservient. Digging and filling-in these drains is from ¾*d.* to 1*d.* per yard, and the price of tiles, with coals laid down at the yard at 11*s.* per ton, is as follows:—

| | | | | |
|---|---|---|---|---|
| Bore, | 1¾ in., | 13 in. long, at | 10*s.* 6*d.* | per 1,000 |
| " | 2¼ in., | " | 12*s.* 6*d.* | " |
| " | 2¾ in., | " | 20*s.* 0*d.* | " |
| " | 3 in., | " | 25*s.* 0*d.* | " |
| " | 4 in., | " | 35*s.* 0*d.* | " |

So that though the drainage of a single acre might only cost from 2*l.* 10*s.* to 2*l.* 15*s.*, I have generally found the average over a quantity of land to vary from 3*l.* to 3*l.* 10*s.*, and even 4*l.*

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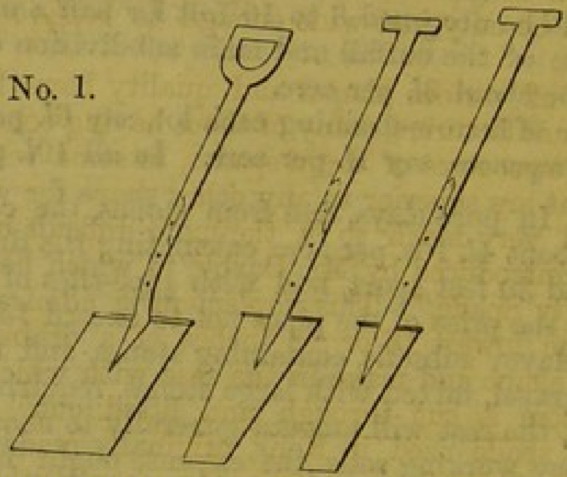
8. Are there any implements in course of being introduced that will tend to facilitate and reduce the expense of drainage?

(*Mr. Smith.*) I have heard of one or two implements that are about being introduced which are said to possess the power of facilitating and reducing the expense of drainage, but how far they will become efficient in this respect I have as yet had no means of judging. Ploughs to facilitate the cutting of drains have been in use for many years in districts where alluvial clays prevail, and when used they cheapen the cost of drainage considerably; but from the great number of horses (from 8 to 12) required to work them, and from the difficulty in managing so many horses and such large implements, the use has been confined to a few enterprising and energetic individuals.

No. 1.



The first plough of this sort was invented by a farmer on the Blairdrummond estate near Stirling. It is in the form of the old Scotch plough, but of large dimensions and of great length. It throws out at once a furrow 18 inches in depth and of considerable width; the remaining depth is taken out by spades of the usual draining form. The throwing out of the furrow costs from 2*d.* to 3*d.* per rood of 36 yards, and the farther spade-work and laying in of the tiles or tubes varies with the depth. For drains 2 feet deep from the surface, 6*d.*, 26 inches, 8*d.*, and for 3 feet, 1*s.* per rood of 36 yards, is paid.

Another farmer near Stirling brought forward an improved drain-plough, about seven or eight years ago, which with eight horses and six men takes out, at two cuts, a drain of from 2 feet to 30 inches deep, of very neat form; and the tiles or tubes are laid in either on the bottom left by the plough, or after taking out a levelling spit of from 6 to 9 inches, and in some cases 12 inches deep.

Many persons prefer making use of the common plough to facilitate the cutting of the drains, taking out by it one or two furrows; and unless, the land is very rough and stony, this plan may be adopted most advantageously.

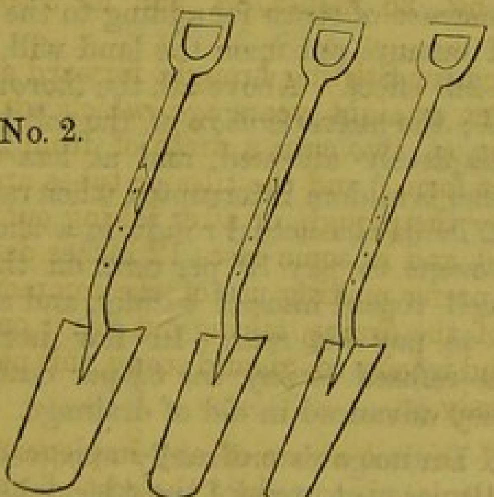
(*Mr. Parkes.*) I am not aware of any implements of recent invention which are calculated to reduce the cost of cutting drains, or to facilitate the execution. I refer to implements requiring the use of mechanical power. Plain draining tools undergo continual improvement.

(*Mr. Spooner.*) The cutting of drains is both facilitated and cheapened by the use of implements adapted to this species of work. In these the objects to be attained are as follows:—Strength, combined with lightness and handiness; width, sufficient to remove at one cut all the earth required to be taken out of a drain at any one part of it; shape of the blade, such as that it shall, when lifted, raise the earth cut, leaving the least possible quantity of crumb or broken earth to be removed afterwards.

Spades of different widths are required for cutting the different parts of a drain, so that it shall have a regular wedge shape, and a sufficient width at top to enable a person to work in it, while the bottom should be only just wide enough to receive the material to be laid.

Implements of various shapes and quality have been introduced by different manufacturers, many of them having considerable merit; but there are two sorts of drain-spades, in some respects similar to each other, that are superior to any other shape for working in ordinary soils, and very much so in the more difficult ones. Of these, one has been introduced by Mr. Darby, to which he gives the name of the "Markly Spade." This implement is admirably adapted for taking out the lowest 16 or 18 inches of a drain, and shows its superiority in shape and make in the ease with which a hard gravel or rocky bottom is cut through and lifted out. The other is a description of spade used in Kent, originally made to the order of Mr. T. P. Hilder, by F. Seeley, Aldington, near Hythe, and improved by Messrs Hunt and Sons, Brade's Steel Works, near Birmingham, who are now manufacturing them to a considerable extent. I have recently introduced them into Ross-shire and other parts of Scotland, where they are found both to improve the method of cutting the drains and materially to cheapen their execution. With implements such as these a drain 10 to 12 inches wide at top, 3 inches wide at bottom, and 36 to 40 inches deep, may be opened by a single cut from each of three sizes.

No. 2.



Drains 40 to 48 inches deep require a double cut in width and depth, by the largest of the three spades.

(*Mr. Maccaw.*) The implements for drainage have been improved from time to time, partly introduced from those in use by Mr. Parkes, and partly improved to suit the locality. On lands consisting of a stony subsoil, the implements required are somewhat different from those in use where a clay subsoil exists. Drains are now cut to a greater depth and with the removal of less earth than formerly.

(*Mr. Beattie.*) I do not know of any; but clever workmen frequently fashion their tools to give greater facilities to their labour, according to the obstacles met with.

(*Mr. Scott.*) The only implements which facilitate draining, and reduce the expense, are proper tools for the workmen to cut the drains and lay the pipes,—such as are manufactured by Messrs. Lyndon of Birmingham.

(*Mr. Neilson.*) Several attempts have been made to drain by different constructions of ploughs, and some assistance has been given, by thus throwing out a trench of 12 or 14 inches deep; but the expense thereby incurred has seldom been fully allowed for by the contract workman, who finishes the drain, and it has ceased to be much employed. Messrs. Nasmyth, the iron-founders, and Mr. Clyburn of Uley have both contemplated draining by steam-power, but nothing has, as yet, been produced to supersede the spade.

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## 9. What is the ordinary statement of the expectations of the return for the drainage outlay, and what is stated as to actual results?

(*Mr. Smith.*) The ordinary expectations of the results from thorough-draining varies very much according to the nature and previous condition of the land. A sixth of increase in produce of grain-crops may be taken as the very lowest estimate, and in actual result it is seldom less than one fourth. In very many cases, indeed, after some following cultivation, the produce is doubled, whilst the expense of working the land is much lessened. There is in every instance a great increase of straw for adding to the manure heap; and a less quantity of manure put upon the land will, in its altered condition, produce a full effect. Above all, the *thorough* cleaning of the *land* is facilitated; the *pulverisation* of the soil is at all times more certainly and completely attained, and at less expense; and the labour of the farmer is seldom interrupted when rain has not recently fallen. On most lands the actual result in a short course of years will enable the tenant to pay 10 per cent. on the cost of drainage, and he will be well repaid himself besides, and should be also in a better condition to pay his rent. In few instances in Scotland have the tenants refused to pay the 6½ per cent. demanded on the Government money advanced in aid of drainage.

(*Mr. Spooner.*) Drainage is ordinarily expected to yield a return of not less than 10 per cent.; and I consider, where the work is executed at a reasonable price and in an efficient and permanent manner, this estimate to be low. In many instances a return of fully 25 per cent. on the expenditure is realised, and in some even more. Such returns will not appear exaggerated on considering the various items of which the improvement consists; such as the increased quantity of every crop, the earlier cultivation, earlier seeding, and hence earlier maturity of corn, and, as a consequence, its improvement in weight and quality; the facility it affords of working the ground at most seasons of the year; the preservation of manures, and consequent economy in their application; and other minor or local advantages which in the long-run are productive of considerable profits.

I have statements in the course of preparation intended to show the average expense of the different items of improvement now in operation under the Drainage Act in those cases in which I am concerned, together with a comparison (so far as it can be ascertained from time to time) of the produce and value before and after improvement. The present occasion affords facilities which never before existed of ascertaining facts relative to the value of improvement on the different descriptions of land which I consider might be turned to very useful account.

(*Mr. Maccaw.*) The ordinary expectations are from 8 to 10 per cent. It is, however, difficult to state accurately what returns may be actually realized, owing to the various circumstances of the natures of soils, altitude of the land drained, proximity to population, &c. Other considerations are also involved with the cost of drains, by the fencing, cleaning the surface, and enclosing the land; the making of roads; building new or adding to existing farm buildings; and also the capital required, over and above this cost, to give profitable returns by thorough after-cultivation, without which drainage of itself would not, in many cases, repay the capital involved.

The returns are generally calculated from results actually realized out of lands already drained, of similar character to that intended for improvement by drainage; viz., by ascertaining the value of the land in yearly rent previous to drainage, and its subsequent value realized after drainage and cultivation. The following cases may serve as illustrations:—

Acreable Rates.

| Nos. | Character of Soil. | Original annual value. | Cost of drainage. | Present annual value. | Increased annual value. | Rate per cent. realized from outlay on drainage. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | s. d. | | s. d. | s. d. | Per cent. | |
| 1 | Deep soil, a part mossy. | 15 0 | Outfall £3 4 5<br>Drainage 6 16 1<br>£10 0 6 | 40 0 | 25 0 | 12½ | This piece of land consisting of lochs, water-meadow of little value. Expensive outfall. |
| 2 | Loamy soil. Springs existed. | 20 0 | £7 7 4 | 32 0 | 12 0 | 8¼ | Drained 4 feet deep. Land long under cultivation. |
| 3 | Thin clay soil; stiff subsoil. | 12 0 | £6 6 0 | 30 0 | 18 0 | 13¼ | Drained in 1843. Afterwards a 5 years rotation in cropping. |
| 4 | A weak thin soil; gravelly, with clay. | 20 0 | £5 10 0 | 36 0 | 16 0 | 14¾ | Drained in 1845. Near a town. Drains 36 feet apart, 3¼ deep. Crops sold by auction. |
| 5 | Mossy soil. | 2 6 | Drainage and trenching, £8. | 14 0 | 11 6 | 7 1/8 | Mossy surface; clay and gravel subsoil. High climate. |

The actual results realized from No. 3, after being drained, in a rotation of crops, 1st year, potatoes; 2d, wheat; 3d, hay; 4th, pasture; 5th, oats - - - - £49 0 0

| | |
|---|---|
| On which expended on drainage, subsoil ploughing, ordinary cultivation, rent, and all charges, for 5 years - - | 36 5 6 |
| Balance of profit in 5 years - - | £12 14 6 |

being at the rate of 2*l.* 10*s.* 10*d.* per acre annually. This was on land where green crops could not previously be raised, and on which the crop of oats preceding drainage (1843) did not yield more by public sale than an average of 2*l.* 5*s.* per acre.

No. 4. was drained in 1845. Three crops have since been disposed of by public sale, realizing - - - £32 0 0

| | |
|---|---|
| Expenses of drainage, cultivation, rent, manures, &c. - - - - | 21 0 0 |
| Profit - - | -£11 0 0 |

being at the rate of 3*l.* 13*s.* 4*d.* of annual profit.

In the case of a marsh drained on the same farm, the outfall costing at the rate of 2*l.* 10*s.* per acre, trenching 6*l.*, drainage 4*l.* 10*s.*, rent 5*s.*, planting potatoes, seed, and manure, total cost - - - - - £22 10 0

| | |
|---|---|
| £25 per acre was refused for the crop, which became afterwards slightly diseased, but sold for - - - | 22 0 0 |
| Thus proving one crop to have paid all costs, except - - - | 0 10 0 |

These are, however, rather favourable cases, from the superior cultivation and manuring over that generally given to land where drainage has been effected, and from the favourable nature of the seasons, and high rates received for crops, sold almost without any failure. Calculations of drainage returns cannot altogether be based on such favourable cases; great allowances require to be made. However, I could instance several farms which, after drainage and high cultivation, now keep more than double their former stocks of cattle, &c., and even exceed that in their increased grain crops. Indeed I know few cases, under the worst circumstances, where thorough drainage has been efficiently executed, that the parties concerned have not been satisfied of its beneficial results.

(*Mr. Beattie.*) From 10 to 20 per cent. On rich soils under agriculture, 33 to 50 per cent. has been satisfactorily shown as the improved value.

The expense of cultivating wet lands is frequently double that of dry lands, whilst the returns are of inferior quality and much less in quantity.

(*Mr. Scott.*) The general return for the drainage outlay is expected to be from 7 to 12 per cent. From my own experience, the actual results have been from 10 to 20 per cent.

(*Mr. Neilson.*) My experience and observation have chiefly been in heavy clay soils where the result of drainage is eminently beneficial, and where, taking quality and quantity into consideration, I should estimate the increased crop at 6 to 10 bushels per statute acre. But this is not the only benefit arising to the occupier by the drainage of heavy land, for the decreased wear and tear in both live and dead stock from the lighter draught, the increased facilities of working the land, and the greater number of days on which it is approachable by horse-labour during rainy weather, will enable him to work a farm of 220 acres on the four-course system, with one pair of horses and their appurtenances less than would be requisite for the same system of cultivation previous to its drainage; and if to this be added the amount gained in interest by the reduction of his invested capital, the clear saving to the tenant will be equal to 10*s.* per acre, exclusive of the advantage derived from the increased productiveness of the land.

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## 10. State any instances where drainage has qualified a soil for a species of crop that it was formerly unfit for?

(*Mr. Smith.*) There are innumerable instances of the effect of thorough-draining and deep-working having so changed the condition of soils as to fit them for the growth of plants they could not have carried to perfection previously. The whole of the heavy alluvial clays of the carses of Scotland, on which potatoes were seldom grown successfully, and turnips never, now carry freely heavy crops of both, more especially turnips, which are followed by excellent crops of wheat. Open or naked summer fallow is becoming more rare, as the farmers find it more profitable to fill their fallows up with green crops.

On all the clays of the upland country the thorough-draining has rendered the growth of wheat certain where previously it was precarious, and such lands have become safe turnip lands. The muirish and moss lands have also been made to carry abundant green crops. There is a capability of growing, by the aid of thorough-draining, almost anywhere over the Highlands of Scotland, turnips and hay for the full winter food of an increased stock of sheep and cattle.

(*Mr. Parkes.*) There can be no doubt that from the average of soils in England requiring drainage a return is obtained after drainage considerably exceeding the legal interest of the sum expended per acre. Large breadths of land previously unable to carry wheat have been rendered capable of producing superior crops. Land, also, which in its natural state is too wet for the growth of turnips, is commonly qualified by good drainage to produce that crop in perfection. The turnip system is, on many soils, the only sure preparation for grain crops, and, generally speaking, it is the secret of profitable husbandry.

To cite any particular instance of increase of produce would be simply the recital of the acknowledged effect of drainage in most instances.

(*Mr. Spooner.*) In districts in the north of Scotland instances are numerous of crops of all sorts being cultivated in land which, without doubt, would not carry them previous to drainage. Of such description are all the moss and marsh lands now under tillage; and, in the West Highlands, crops ripen in good season on the land, when drained, which barely ripen in favourable weather, and were cut green, having never ripened in wet weather, when the land was undrained.

There are other instances, of not uncommon occurrence, applicable to a remarkable extent to this question, in the case of low-lying situations which, in popular language, are said to be affected with mildew; and this is described as being a substance having the appearance of fog, at certain times overhanging the affected district; and where this occurs the crops are coated by that peculiar parasitical substance which goes by the name of mildew. And there are localities, the cultivation of which has been abandoned in consequence of the recurrence of this evil to such extent as to render cultivation profitless. This evil is removed by drainage.

(*Mr. Maccaw.*) Drainage has qualified thin clay soils in the higher districts of every county in Scotland where it has been applied to grow green and root crops. Lands where formerly marshes existed, and parts entirely covered over with water, and unfit for cultivation, now grow crops of all the various kinds, superior in many instances to those on the old and naturally dry cultivated lands. Instances of this character are to be noticed in almost every district. It might appear invidious were I to name solitary cases, when the fact is borne out by so many throughout the country. In Ayrshire alone there are many thousands of acres, formerly unproductive, or unfit for cultivation to repay, now producing grain and green crops; a result attributable to drainage.

(*Mr. Beattie.*) Stiff clays, both of rich and poor quality, and rich coarse soils, have been brought to produce turnip crops, by furrow-draining, previously quite unmanageable for that purpose.

Black and yellow soft loam, upon hard retentive subsoil, particularly where a pan existed, by furrow-draining have been made to yield fine grass and a close sward, where nothing beyond a scanty coarse herbage ever grew before.

(*Mr. Scott.*) On my own farm at West-side House, near Staindrop, I grow white wheat, barley, and turnips, upon lands that were incapable of growing those crops previous to draining.

(*Mr. Neilson.*) A portion of my present farm, which is of stiff clay, lies low and level. Previous to drainage, the waters of winter seldom disappeared before the heat of summer had opened a passage by cracking the land. My predecessor had endeavoured to get a green crop, but always failed. The crop, the year previous to my taking it, did not produce above three tons of turnips to the acre, in consequence of the inefficiency of the manure from the stagnant water.

I drained it the following winter, and the summer after I obtained 27 tons of turnips per acre off the whole field.

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### 11. What is the prevalent material used for forming the drains, and what is deemed on the whole the preferable?

(*Mr. Smith.*) The prevalent material for forming drains is now, in most parts of the country, tiles or tubes. When these are difficult to be had, and dear, stones are used. Stones, when properly executed, form a very perfect and durable drain; but tubes of from 1½ to 2 inches in diameter are decidedly preferable to all other kinds or forms of material.

Tubes made of peat earth or moss have lately been introduced, and have been well received by agriculturists, whose experience has assured them of the durability of peat. The tubes are made by a machine, and cost only from 5*s.* to 6*s.* per 1,000, dried in the open air. In Highland districts they will be a great boon.

(*Mr. Parkes.*) The most prevalent material now used in land-drainage consists of burnt cylindrical clay pipes, about 12 inches in length, and of various sized bores. This practice has become general during the last five or six years, although the use of pipes has been traced back fully forty years.

Broken stones have been heretofore much used in Scotland and in the North of England. This material is now, however, generally abandoned, as the drains formed with it are found to choke up, and the cost is very much greater than that of pipes. Horse-shoe tiles, with or without soles, have also been heretofore much used, and they are still used to some extent, but the conduit so formed is imperfect. These tiles are also more expensive than pipes, both as to first cost and carriage, and the use of them is fast passing away.

My own practice is to use cylindrical pipes, of 12 to 14 inches in length, of sizes adapted to the volume of water to be conveyed away; and in all cases where collars are procurable the pipes are joined freely together at the place of junction by means of this shorter and larger piece of pipe (called the collar), which centres each pair of pipes, and maintains an unbroken line of a true bore. This plan also secures a line of drain-pipes against the entrance of sand or deposit of any kind; and, in so far as the experience of a few years shows, drains thus constructed have been found to be safe against the entrance of roots, and of all earthy obstructive matter.

(*Mr. Spooner.*) The prevalent material used for laying in drains, at the present time, decidedly is tiles, or pipes, which, as the supplies increase, are daily becoming more so, and an increase in the supply is creating a greatly increased demand, in part resulting from their diminished price, consequent upon improved methods of making, and in part from the evident superiority of the material itself.

Where these cannot be procured, stones are employed; but much of the success of stone drainage depends on the manner in which the stones are placed, their size and quantity. Elkington's drains were usually built with an eye, and this is certainly a very efficient species of drain, but very costly.

Stone drains of every description are more liable to casualties than those laid with tiles on soles, or pipes; while the latter, even with a less apparent capacity, discharge the greater quantity of water.

In soils containing beds of running sand, stone drains are very liable to be silthed up, by sand accompanying the water as it enters them in small streams. This accident can be entirely avoided by the use of pipes, if immediately around them the earth be so closely packed that the water cannot collect into a stream, but passes into the pipe in the same minutely divided shape in which it percolates through the ground.

These are the prevalent materials used, and, with the exception of certain local usages, dependent upon the peculiar soil of certain districts, such as the wedge drain in moss, and the plug drain in clays that do not silth, are the only materials considered efficient and permanent.

For the above and other reasons I think pipes decidedly the preferable material, and that these should have a calibre of not less than 1¼ inch diameter, varying from that to 2 inches, for the ordinary drains, with an increase of size for leader or main carriers in proportion to their length and the quantity of water they will have to convey.

(*Mr. Maccaw.*) The materials first in use under the thorough-drainage system were small or broken stones, placed in the bottom of the drain in various methods so as to form a conduit; afterwards the horse-shoe tile was introduced, with a sole; and latterly pipe tiles of the cylindrical form, and in some cases collars to connect them, particularly with those pipes of less tube than 2 inches, or where the bottom of the drain is running sand, when collars are in request to connect those of 2-inch tube. The socket pipe has more recently been introduced, and is generally preferred to any other material, where it can be procured. Pipes for the mains are of larger tube, with holes in the sides of a few, to admit the smaller pipes from the branch drains.

Small or broken stones, when used in drains where the course is somewhat level and subsoil soft, have in many instances become inoperative, from the action of the water not being sufficiently rapid to clear the conduit of earthy matter taken in through its loose materials. On firm bottomed land, however, with sufficient declivity, and where stones are abundant, and the distance far from any other material, they are still used to a limited extent, with a proportion of pipes or tiles for the level or soft parts of the land, and for the main drains connected with stone drainage. Well-built stone drains with covers have long and efficiently done their duty where spring-water exists.

The horse-shoe tile with sole is still preferred by a few parties;

but the pipe tile of 2-inch tube is much more in request, even without collars, for general drainage. In the former, many cases of failure have been observed ; in the latter, few instances have yet been known ; and in my opinion they are preferable, and certainly very superior if connected with collars, or socketed, which I would prefer, for the following reasons :—

First.—The well-formed pipe combines the greatest strength with the least weight, requires less material in its manufacture, and its hollow tube will run a greater quantity of water in a given time than the horse-shoe tile with sole of greater cavity on the same inclination.

Second.—Water running in the hollow tube of the pipe with rapid action will carry more quickly to its terminus any earthy matters taken in at its junctions than when wandering over the flat surface of a tile-sole, as it runs with less velocity.

Third.—The best made horse-shoe tiles with soles are far from being closely joined, the greatest quantity of drainage water, therefore, enters between the tile and sole ; not at their vertical joints ; thus presenting too much orifice by which earthy matters are admitted with the water. Pipes do not present so much for the admission of either, but more, as has been ascertained, than necessary for all the water of drainage ever required to enter their tubes. This is proved by the rapid discharge at their outlets, which is much more quick than from the tile with sole. They have continued efficient in this respect for several years, and I do not see why they should not continue as long as the horse-shoe tile with sole.

Fourth.—If the weight of pipes discharging the same quantity of water be one third less than tiles with soles, as I believe it to be, the saving of cartage will prove to the same extent, and generally the cost is much less at the tilery. Under these views, with the general impression over the country in favour of pipes, I have no hesitation in concluding they are the most preferable of all materials yet in use for general drainage purposes.

In drainage of deep moss, the conduit of the drain is generally formed by the wedge turf, and in some cases with the peat tile. The latter, however, in a very damp season, cannot be sufficiently dried ; consequently the former is more in use, and has now for a considerable period proved satisfactory, when the conduit is left of sufficient dimensions.

I have presumed to extend my replies on the matter of materials probably beyond due limits ; but as much dubiety still exists upon the question with extensive proprietors, who have been and are still investing large sums in drainage of their lands, I have considered it my duty here to represent my views on the merits and deficiencies of the several materials in use.

(*Mr. Beattie.*) Tile pipes, from 1½ to 3 inches bore, 1 foot long; and broken stones, to pass through a ring of 2½ to 3 inches, put into narrow-bottom drains, 9 to 12 inches deep of stones ; wedge-shaped stones, set on end, in drains 9 to 10 inches wide in the bottom, and covered over with broken stones.

Pipes are the preferable, in respect that there are greater facilities in using them, and they afford a clearer channel for the water, with much less risk of its being obstructed. Moles and rats work down upon the stone materials and admit stuff and sand to be washed down and mixed with the stones. Pipe drainage is generally less expensive. Large pipes, glazed inside, and joined together, are used for outlets, culverts below streets, &c., and are preferable to masonry.

(*Mr. Scott.*) The cylindrical pipe-tile of from 1 to 2 inches in internal diameter, with collars for the pipes.

(*Mr. Neilson.*) Experiments are at present in progress by Mr. Whitehead of Preston in Lancashire, for making pipe-tiles of peat, which, if successful, will materially diminish the cost both of production and of cartage; but up to the present period pipe-tile draining is decidedly preferable to any other mode yet adopted, for cheapness, efficiency, and durability.

Open or horse-shoe tiles ought always to be laid on slate or flat tile soles. Pipe tiles, if less than 1½ inch in diameter, ought to be laid with collars; and for larger sizes the excavation of the bottom of the drain ought to be carefully scooped, to fit the periphery of the tile, so as to insure an unobstructed run for the water; and in all cases, though the drains may be cut by task-work, *the tiles ought to be laid by a trustworthy and careful man* at good day wages, to prevent his hurrying the work, and to induce him to take every precaution in laying them firm and even.

Drainage is as important as a building, and if well executed will last as long.

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## 12. What effects has extensive drainage had on the main watercourses of a district?

(*Mr. Smith.*) When surface-drainage became general, in consequence of the extended cultivation of the country, and the improvement of waste lands, and more especially when open sheep-drains were extensively adopted on the hill-grazings, it is notorious that the excess of floods was greatly increased, and that the streams of the country dried sooner in dry periods. The introduction of thorough-draining has, on the contrary, had a tendency to restrain the excess of floods, as the rain falling on the surface has to fill the vacuities of the drained soil, and it takes at least 48 hours to drain fully off after rain has fallen; so that the crisis of the flood from the surface-water of the undrained land has passed before the percolating water comes to increase its volume. The effects of a general thorough-drainage will be to diminish much the excess of floods in the streams, whilst the quantity of mud carried off will be vastly reduced, as the water from the thorough-drains generally runs nearly free from suspended matter.

During dry periods, more particularly in summer, the water in the streams is greatly lessened by thorough-draining; for there is so great a mass of comparatively dry and absorbent soil to receive the rain, that summer showers, unless very heavy and continuous, will be entirely absorbed.

(*Mr. Parkes.*) The intention and effect of a complete and systematic under-drainage is the liberation of the water of rain more quickly from the land than if it were not drained; and therefore the natural vents or rivers very generally require enlargement or deepening, in order to pass off the drainage water in sufficiently quick time, and so as to avoid flooding lower lands.

The sluggish rivers of the midland and southern counties of England especially oppose great obstacles to land-drainage, being usually full to the banks, or nearly so, and converted into a series of ponds, by mill-dams erected at a few miles distance below each other, so that frequently no effectual drainage of the richest alluvial soil composing the meadows can be made without forming embankments or by pumping, or by resort to other artificial and expensive means.

The greater number of the corn and other water-mills throughout England ought to be demolished, for the advantage of agriculture, and steam-power should be provided for the millers. I believe that such an arrangement would, in most cases, prove to be economical both to the landholder and the miller.

A striking example of the economical and beneficial result arising from the destruction of mill-dams, and the substitution of steam for water-power, has recently been exhibited under the operation of the Rye and Derwent Drainage Act, resulting from the wise and friendly co-operation of the Earls Carlisle and Fitzwilliam (the chief proprietors) with other landowners to knock down three mill-dams, give the millers steam, thereby restoring the river to its natural bed and proper function as the great artery of drainage, and enabling thousands of acres of land to be drained and reclaimed, or brought into more profitable cultivation at a very moderate cost. This excellent work has its terminus at New Malton in Yorkshire.

Every old authority and all modern writers on land-drainage in England have condemned water-mills and mill-dams; and if all the rivers of England were surveyed from the sea to their source, the mills upon them valued, the extent of land injured or benefited by such mill-dams ascertained, and the whole question of advantage or injury done to the landowner appreciated and appraised, I have little doubt but that the injury done would be found so greatly to exceed the rental of the mills, deduction being made of the cost of maintaining them, that it would be a measure of national economy to buy up the mills, and give the millers steam-power.

(*Mr. Spooner.*) The effect which extensive drainage produces on the main watercourses of districts is that of increasing the height of their rise at flood-times, and rendering the flow and subsidence more rapid than before. I have repeatedly heard the river Tweed adduced as a striking instance of this fact, and that the change has taken place within the observation of the present generation.

(*Mr. Maccaw.*) It has been observed that after extensive surface-drainage on the sheepwalks in the higher parts of the country, and when the lower lands were enclosed by ditches, and partially drained for the purposes of cultivation, all rivers flowing therefrom rise more rapidly after heavy rains or falls of snow, and discharge their surplus waters more quickly, than under former circumstances.

(*Mr. Beattie.*) It renders them more speedily flooded, and to a greater height, and they fall sooner.

Rivers are lower in summer and higher in winter.

(*Mr. Scott.*) I cannot speak to this from local knowledge.

(*Mr. Neilson.*) The immediate effect of the drainage of higher lands has often been to inundate the lower levels, because, generally speaking, the ordinary waters are barely sufficient to discharge the more protected approach of the waters from the previously undrained land; but when these courses have been properly adapted to the more rapid discharge of water consequent on the land being drained, they are, in most cases, maintained in order at less expense.

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## 13. Have any important applications been made of the additional water-streams thus derived, or are any possible applications apparent?

(*Mr. Smith.*) In a few places I have observed, and in some cases I have advised, the useful application of the water from drains for irrigation, &c. The most extensive and perfect application of water derived from thorough-draining which I have had an opportunity of examining, is upon the estate of Lord Hatherton in Staffordshire. His lordship has there had collected very cleverly the drainage water of the higher lands of his estate, he has erected several ponds for storing it, and he has it carried to his farmyard, where it drives a powerful water-wheel, which does all the thrashing, milling, chopping, &c., and drives a saw-mill besides. From the mill the water is carried in canals of gentle fall to lower meadow ground, where it is used in extensive and profitable irrigation.

Drain-water always contains more or less of the manure and soluble parts of the soil in suspension, and the fertilising properties of the drain-water on this estate are particularly marked by the very luxuriant growth of grass it produces on the meadows. This experiment forms a noble example of an economy in agriculture worthy of imitation, and is one which can be carried out to a greater or less extent on all farms having surfaces at different altitudes.

I have been long of opinion that it would be found profitable to have a large pond at the lowest point of every farm to receive and store the water from the drains, and to have a steam-engine to pump and convey it in pipes for watering the fields during dry periods. By this means the crops would be much refreshed, and whatever matter had been taken off the land by the drain-water would in great part be returned. This system would be the more profitable if the steam-engine and pipes were likewise used to distribute liquid manure over the fields, as is now done on a farm of 300 acres in extent near Glasgow.

(*Mr. Parkes.*) See reply to question 5th.

(*Mr. Spooner.*) The only useful purpose to which I can conceive water-courses derived from general drainage to be applicable is, that the additional quantity quickly supplied would render them the more valuable in situations where water meadows can be formed, as the greater rapidity and increase in quantity of the water passing down from the drains, through the smaller tributaries, the greater will be the sediment of fine earthy mater deposited at any one time, and the greater, therefore, I conceive, will be the benefit produced in such situations.

(*Mr. Maccaw.*) I am aware that water of drainage has, in some instances, been conducted into millponds to augment the usual supply in propelling machinery; it has also been conveyed to farm steadings for domestic purposes and the use of stock. Deep drainage has in many cases given a continued supply for the use of cattle in fields, the water being conducted into reservoirs where the natural supply had been indifferent in quality and deficient in quantity; in other instances it has been applied to the irrigation of meadow lands on a lower level. In some respects its extended application in this way may prove of much importance.

(*Mr. Beattie.*) None, beyond the usual application, as additional supply for machinery power, watering fields and houses, &c.

(*Mr. Scott.*) Water derived from the drainage of land may be applied for the irrigation of grass lands adjoining on a lower level.

(*Mr. Neilson.*) In many instances, where the undulation of the land allows it, the waters from the higher levels are collected, and beneficially applied for mechanical and other purposes, such as thrashing the corn, irrigating the lower levels, &c. &c.

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14. Are there any cases known where observations have been made as to the quality of the water derived from the land drainage, that is, as to its temperature, clearness, and as to the salts and vegetable and animal products that it contains, with a view, either of determining its fitness for domestic or other uses, or for finding to what extent it has carried down matters from the soil?

(*Mr. Smith.*) The water flowing from drains is generally very limpid and pure, although at times, when much manure has been recently put upon the land, it is impregnated to a considerable degree with soluble matter, and sometimes colouring. It is, nevertheless, usually fit for domestic purposes, and is much prized where there are but few springs, and where the people previous to the introduction of thorough-draining had to bring the water for domestic purposes from a distance, by carts, at great expense. They now form wells to retain a supply of the drainage-water for the dry seasons, by which their health and comfort have been greatly promoted. The cattle are also supplied with wholesome water in the summer.

The temperature of the water flowing from drains depends in a great measure upon its origin, as to what proportion comes from under-springs, and what from rain-water passing through the soil. The deep drains, of course, catch more of the spring-water than the shallow ones. The water yielded by drains that derive their supply chiefly from the rain which falls upon the surface of the land is frequently, during the summer months, raised considerably in its temperature, owing to the heated condition of the atmosphere and of the ground on which it has fallen.

Mr. John Wilson, an excellent chemist, at present manager of the Agricultural College at Cirencester, made a series of analyses of drain-water from a farm in East Lothian, in the year 1844; and he found a considerable quantity of salts and organic matter, especially after manure has been recently applied.* The following is a note of Mr. Wilson's analysis of two samples of drain-water:

### Analysis No. 1.

The water taken from drains upon the 29th April, when there had been a moderate fall of rain. The land was in plough as winter fallow.

18 lbs of drainage-water on evaporation gave 15·2 grs. of solid residue, or about ·844 gr. to the pound.

| | |
|---|---|
| Organic matter and water in combination | 3·4 |
| Silica | 0·9 |
| Silicate of alumina | 0·4 |
| Chloride of magnesium | 1·12 |
| Chloride of sodium | 0·8 |
| Chloride of calcium | 3·0 |
| Sulphate of alumina | 0·85 |
| Peroxide of iron | 2·1 |
| Phosphate of lime | 0·3 |
| | 13·87 |

* The particulars of this drainage are not stated exactly, but it would appear either that some water had reached the drains which had not filtered through the soil, or that manure had been applied in excessive quantity, that is, more than the soil could absorb; for Professor Way found that a moderate quantity of foul liquid, filtered through only six inches of soil, was deprived of all its manure. The following table gives the contents, in grains, of a gallon of the liquid before and after filtration, according to his analysis:—

| | Before. | After. |
|---|---|---|
| Organic matter and ammoniacal salts | 301·82 | — |
| " " destitute of nitrogen | — | 60·58 |
| Sand, &c. | 20·69 | — |
| Soluble silica | 12·51 | — |
| Phosphoric acid | 10·44 | — |
| Sulphuric acid | 14·73 | — |
| Sulphate of lime | — | 17·49 |
| Carbonic acid | 15·59 | — |
| Lime | 24·53 | — |
| Carbonate of lime | — | 104·98 |
| Magnesia | 2·87 | — |
| Peroxide of iron and alumina | 6·2 | — |
| Potash | 48·13 | — |
| Soda | 1·51 | — |
| Chloride of calcium | — | 8·89 |
| " magnesium | — | ·67 |
| Common salt | 33·24 | 52·73 |
| Loss | — | 3·16 |
| | 492·26 | 248·50 |

ANALYSIS No. 2.

The water taken from drains after the field had been sown with guano and barley seed upon the 16th May.

18 lbs. of drainage-water on evaporation gave 27·5 grs. of solid residue, or about 1·525 gr. to the pound.

| | |
|---|---|
| Organic matter, &c. - - - | 7·8 |
| Silica - - - - - | 0·7 |
| Silicate of alumina - - - | 0·2 |
| Protoxide of iron - - - - | 2·25 |
| Phosphate of magnesia - - - | 1·8 |
| Magnesia - - - - | 1·69 |
| Chloride of sodium - - - | 2·605 |
| Chloride of calcium - - - | 2·107 |
| Carbonate of alumina - - - | 2·7 |
| Phosphate of lime - - - | 3·1 |
| Phosphate of alumina - - - | 0·45 |
| | 25·412 |

(*Mr. Parkes.*) I am not aware of any analyses which have been made of the water of drainage. It is a subject which pre-eminently deserves attention in an agricultural point of view.

The results of my experience tend to show that the water issuing from deep under-drains in land is generally soft, that it is relished for drinking by stock, and approved for household and washing uses in villages and hamlets, where I have had to conduct water from the drainage of land to serve those purposes. The water derived from a shallow system of drainage is often troubled after rain or after the ploughing up of fields, and it is offensive to the taste and smell after the manuring of lands. The water of deep drainage is generally perfectly pellucid, and I should consider a drainage to be imperfect if sand or earthy matter were carried off from the soil by drains.

As regards the temperature of the water derived from drainage at different seasons of the year, I am unacquainted with any published facts. This is a subject of the highest import, as thermometric observations may be rendered demonstrative in the truest manner of the effect of drainage on the climate of the soil. I have myself paid attention for some years past to this subject, and am now collecting facts bearing upon it, in many counties in England. I am not, however, prepared at present to make known the results of these observations, and must limit myself to saying, that I have never known the water of drainage issue from land drained at Midsummer, to depths of 4 and 5 feet at a higher temperature than 52 or 53 degrees Fahrenheit; whereas, in the following year and subsequent years, the water discharged from the same drains, at the same period, will issue at a temperature of 60 degs., and even so high as 63 degs., thus exhibiting the increase of heat conferred during the summer months on the terrestrial climate by drainage. This is the all-important fact connected with the art and science of land-drainage, but into which I feel sure your lordship will excuse my entering at length, in thus cursorily replying to the questions of the Sanitary Commissioners.

(*Mr. Spooner.*) I am not acquainted with a sufficient number of comparative cases under this head to arrive at any certain conclusions.

(*Mr. Maccaw.*) I have found few instances of drainage-water being analysed, or extended observations made on its qualities, so as to enable me to submit to your Board that important information required on this question, as in my opinion any single instance or two may not prove sufficient to form conclusive evidence of the qualities, &c. of drainage-water in general over the country. I had submitted to your former president, the Earl of Carlisle, an analysis of water by Professor Penny, taken from drains in my farm in December 1848. This water was taken immediately after very heavy falls of rain. The drains were 36 feet apart and 3½ feet deep. The main drain, from which the water was taken, discharged the drainage-water of about 5 acres of land, the drainage of which was effected early in the season of 1847. Afterwards, the land was well manured with farmyard dung; 15 to 20 bushels crushed bones, and 3 cwt. Peruvian guano, per acre, applied to a turnip crop, one half of which was fed on the ground by sheep, afterwards a top dressing of lime and earth compost applied, and in 1848 a crop of wheat taken, sown out with grass and clover seeds; both crops excellent. The land had previously been in poor condition and wet, being a thin porous soil, on a subsoil of sandstone gravel, with a small mixture of clay. I have taken the liberty to mention these matters, as much may depend on the state of the land from which an analysis of drainage-water is taken. The following will show that the animal and vegetable products in the soil from this case have not been carried off by the water to any great extent. I may add, I had never noticed, on any former occasion after heavy falls of rain, a greater discharge from the same outlet than at the time this water was collected.

The following is the chemical analysis by Professor Penny of Glasgow:—

"The specific gravity of this water is 1·00018. An imperial gallon when evaporated to dryness left a solid residue which weighed 12·1 grains; this residue is the total amount of foreign matter contained in the water, and it contains the following ingredients in solid residue.

| | |
|---|---|
| Carbonate of lime and magnesia | 5·9 grains. |
| Sulphate of lime | 1·6 " |
| Animal and vegetable matter | 1·55 " |
| Common salts | 2·54 " |
| Chloride of magnesium | Trace |
| Silicious matter | 0·42 " |
| Alkaline sulphates | 0·09 " |
| | 12·1 " |

"Remarks.—This water is bright, clear, and colourless. It contains an insignificant quantity of floating or mechanically suspended matter, which readily subsides on exposure, and is completely and easily separable by filtration. It is comparatively a soft water, containing only a very small proportion of lime and magnesia, on which the quality of water termed 'hardness' depends.

"The ingredients given in the foregoing table of analysis exist in the water in a state of solution, and cannot therefore be separated either by filtration or subsidence; none of these ingredients are hurtful to health or animal life. This water is perfectly free from deleterious gases and from injurious metallic impregnations. It does not become offensive or putrescent on being kept, and will not give rise to noxious effluvia on being collected into ponds or other large reservoirs, and it cannot therefore obviously tend to produce or in any way to contribute to disease.

"This remark applies only to this particular sample, and not to drainage-water generally, which as yet has not been frequently enough analysed to warrant us in forming a conclusive or satisfactory opinion.

"This water contains nothing to render it unfit for domestic use, either as a beverage or as a detergent; it contains a less amount of foreign matters than many waters supplied to large towns; it has a slightly insipid taste, arising from the small proportion of lime salts dissolved in it, and also from a deficiency of fixed air or carbonic acid gas.

"From its comparative purity this water is well adapted for many manufacturing purposes."

Another instance of the analysis of drainage-water is recorded in the "Rural Cyclopedia," edited by the Rev. John Wilson, under the article "Manures."

The depths of drains are not mentioned, but it may be concluded that they were shallow, probably not more than 2 feet, the deeper system not then being introduced.

Three analyses were taken from three specimens of drainage-water caught from the discharge of subsoil drains of a farm in East Lothian.

1st. After the drains had been dry for many weeks, in November 1844;

2d. On 29th April; and

3d. On 16th May 1845, when the land had been sown with a grain-crop after a winter fallow; the manure applied to the crop was guano.

The result shows the quantity of salts and of vegetable and animal products found in the water to be a very serious affair in respect to the extraction of their valuable fertilising matters, while their retention in the water rendered it unfit for domestic purposes. In another analysis taken at the same time of the turbid water from the surface of the same land, the results appear to have been little different from those of the water from the subsoil drains.

These last analyses show very different results from that of the drainage-water from my farm. It occurs to me partly to have arisen from the water of the latter being that of deeper drains; it being evident, on inspection, that after heavy falls of rain, drains of little depth discharge their waters in a very turbid state, compared with that of drains of greater depth under similar circumstances; consequently those fertilising ingredients held in suspension by the water are more subject to be carried down into the shallow than to the deeper drain, the latter presenting a much greater body of soil for filtrating its water.

I have noticed in the suburbs of Glasgow, where liquid manure has been extensively applied over a large extent of land, by means of a powerful steam engine and pipes, that the water from the drains of about 2½ feet deep (the soil a tenacious clay) was highly impregnated with the liquid, and that all the open watercourses into which those drains discharged gave strong indications of the escape of this fertilising manure being rapidly carried off, chiefly by the drains.

The case appears different where the same process is being also extensively applied to lands in my immediate neighbourhood, where the soil and subsoil were porous, and the drains of four feet in depth, and at greater distances apart, the water being discharged from those drains comparatively pure.

A recent analysis of the water from a deep-seated spring, rising out of sandstone rock in the lower part of a town in my neighbourhood, showed that it contained a large quantity of animal and vegetable matter in a state of solution, proving that such, even by filtration through a great depth of soil, cannot be extracted from water.

I have no doubt that by the process of thorough deep drainage a considerable portion of valuable fertilising matters may be extracted with water from the lands, but not a tithe of what would be carried off by water from the same soil previous to drainage.

I have hitherto made no experiments as to the temperature of water from drains, but can instance a striking fact as to its effects on the temperature of the soil when deep drainage has been executed, which has now been confirmed by parties who have had their attention directed to it in different parts over the country; viz., that snow melts away much more quickly from drained than undrained land. I can instance a field in my neighbourhood, on which a portion has been drained under a shallow and imperfect system, and a part of it under a deep and thorough system; where I have observed repeatedly the fact of snow being much sooner cleared away on the surface of that portion under the deep drainage than from the shallow. This is still more apparent on soils of a similar character and exposure where drained and undrained; from which fact it is evident that the effects produced on temperature of soils by drainage is highly beneficial, and quite satisfactory, without the test of any minute experiments.

(*Mr. Beattie.*) I am not aware of any. Water from perfect thorough-drainage is always clear, and, I think, generally fit for domestic purposes.

The main streams are less adulterated by deleterious matter after extensive drainage.

The stagnate and putrid water on the surface of undrained marsh and moss lands is washed out every flood, in many instances rendering the rivers almost black. If these grounds were drained and cultivated the water would flow gradually away from the drains in a filtered and clear state.

(*Mr. Scott.*) Water that flows from deep drains is more pure and clear than that from shallow drains. The difference in the temperature of the water varies from 2 to 3 degrees in favour of the deep drains, I find, from my own observation.

Water from shallow drains frequently carries away the salts, vegetable and animal products, contained in the manures applied to land, which is very apparent where good farmyard manure has been laid on a fallow, and heavy rains follow immediately after.

(*Mr. Neilson.*) I have never made any chemical experiments sufficiently accurately to be given here.

I may, however, state, that in draining the fields I have already alluded to I cut through a stratum of ocherous gravel, about 4 inches thick, varying from 8 to 12 inches from the surface. During the green crop I subsoiled it, about 16 inches deep, and soon after the commencement of the autumn rains I observed the vegetation, at the sides of the watercourse into which the main drain was discharged covered with a yellow scum. I found the same appearance of yellow sediment in two or three places which I examined in the main drain, but before the winter was over this had all disappeared, and the water came away perfectly clear, and has done so ever since.

The temperature at daybreak in winter of water discharged from the mouth of the drain, after rain on the previous day, is higher than that lying on the surface of an undrained field immediately adjacent to it; and the difference between a thermometer plunged in the soil near a drain, and one placed at the same depth in an undrained part of the same field, varies from 5 to 8 degrees, according to the season; the colder the weather the greater the difference.

In conclusion, I beg to annex extracts from letters I have received from Mr. Pearson, the medical officer of Much Woolton, and Mr. Tyrer, the relieving officer of the Prescot Union.

These two places, between which I reside, have, for several years past, being visited each autumn with both typhus fever and dysentery, in great severity, owing to the want of proper drainage, and the stagnant cesspools caused by the excessive numbers of the lowest classes of Irish who nightly crowd their houses with men, women, and children indiscriminately, to the number of 12 or 14 in a room. As one of the county magistrates, I last year assisted these officers in enforcing some strict sanitary measures, and the following extracts are from their replies to some queries I lately made to them, with reference to the probable approach of cholera.

EXTRACT FROM MR. PEARSON'S LETTER.

"The sanitary improvement you enforced last year in the district of Much Woolton, assigned to my medical care, proved of the greatest possible benefit in the suppression of typhus fever and dysentery.

"Where it *was* carried out, fever quickly subsided, and eventually disappeared, and since then I have not seen a case of it; but where it *was not* carried out, we have had both fever and dysentery, and I have, at this time, several cases. In support of this I enclose a copy of my sick-list returns for the last half of last year, as sent weekly to the guardians, and also for the same period this year.

"I may also add, that last year we had in our dispensary 667 cases, whereas this year we shall not have more than 330, which I attribute entirely to the sanitary improvement alluded to.

| | Medical Relief List, Cases of Fever and Dysentery. List for 1847. | Woolton District, Prescot Union List for 1848. |
|---|---|---|
| July | 25 | None |
| August | 30 | 2 |
| September | 17 | 7 |
| October | 9 | 4 |
| November | 9 | 3 |
| December | 12 | No return |
| | 102 | 16 |

(Signed) "JOHN ARMITAGE PEARSON,
"Medical Officer."

EXTRACT FROM MR. TYRER'S, PRESCOT.

"I am strongly of the opinion that the result of the measures of improvement you enforced here last year, by drainage, has been most beneficial to the health of the inhabitants in the localities where the fever and dysentery committed such ravages previously, for I well know that there has been much less illness of any kind there since.

(Signed) "THOS. TYRER,
"Relieving Officer."

These opinions are of much value, particularly Mr. Pearson's, who has given much time and attention to the subject.

ROBERT NEILSON.

Hallwood, 2d December 1848.

## No. VIII.

The following description of Mr. Fowler's draining-plough is copied from a Report to His Royal Highness the President of the Commission for the Exhibition of the Works of Industry of All Nations on Agricultural Implements, Class IX, by Philip Pusey, M.P., published in the Journal of the Royal Agricultural Society, Vol. XII. No. xxvii., pp. 639—641.

### " The Draining Plough.

" But for the American reapers, Mr. Fowler's draining-plough* would have formed the most remarkable feature in the agricultural department of the Exhibition. Wonderful as it is to see the standing wheat shorn levelly low by a pair of horses walking along its edge, it is hardly if at all less wonderful, nor did it excite less interest or surprise among the crowd of spectators when the trial was made at this place, to see two horses at work by the side of a field, on a capstan, which by an invisible wire-rope draws towards itself a low framework, leaving but the trace of a narrow slit on the surface.

" If you pass, however, to the other side of the field which the framework has quitted, you perceive that it has been dragging after it a string of pipes, which still following the plough's snout, that burrows all the while 4 feet below ground, twists itself like a gigantic red worm into the earth, so that in a few minutes when the framework has reached the capstan, the string is withdrawn from the necklace, and you are assured that a drain has been invisibly formed under your feet. The jury decided as follows:—

" The implement went through the trial very well, laying in the tiles with great apparent ease, worked by *two* horses, with a capstan, which was firmly and easily fixed into the ground, and afforded a firm traction to the plough by means of a wire rope and pulley. Progress has been made since

* The machine is made by Messrs. Fowler and Fry, Temple-gate, Bristol.

the implement was exhibited at Exeter, in rendering the level of the drains in a degree independent of the level of the surface; but there is still room for further improvement in giving to the drain a *uniform* incline. The award, therefore, of the jury was honourable mention.

"Since that trial I have thought it right to make further inquiry into the work of the draining-plough. In the first place, the trial drains were opened, and laid bare from end to end. Straightness is, of course, one requisite, and the pipes were laid straight; closeness of contact another, and they were perfectly joined. In level, the point on which the jury doubted the perfection of the work, there was some deficiency which, on entirely flat ground such as this, was a decided fault. That fault, however, has since been remedied for clay land at least. As the plough was shown last year at Exeter, it could not possibly lay a level drain, because its under and upper parts being fixed at an unvarying distance, any unevenness of an undulatory surface must be faithfully copied by an undulating drain below. This year the two parts were so connected, that the workman by turning a screw can raise or lower the underground snout which burrows out the drain. But at the trial the use of this screw depended on the workman's judgment, which cannot give the drain absolute accuracy. A balanced level, however, has now been added to the plough, by which the changes of surface are made plain to his eye. Other improvements have also been made in the implement. The horse-power required has been reduced by a fourth, and the windlass at which the horses work need now be shifted only once in the day. As to the economy of using the draining-plough, it is too expensive to purchase, unless for a large landowner, but it may be hired by the year or the month. Its inventor is also ready to execute work at his own risk by contract, at a saving of from one third to two thirds on hand labour, the greater the depth the greater being the saving. I have only seen the actual cost of two drainages that have been made by this plough. They were both without tiles and shallow, being only 2½ feet deep; taking the highest of them, and adding the cost of tiles, the price of tile-draining land at that depth, and at 33 feet apart, would be 14*s*. only for work, and 1¾ inch pipes at 15*s*. per 1,000, 18*s*. 9*d*. for tiles; all together 1*l*. 3*s*. 9*d*., including horses and hire of machine.

" The plough goes as well, however, at a depth of 4 feet, nor could the additional cost be material. The plough has worked on the following farms :—

| | Acres. | Depth. | |
|---|---|---|---|
| " Mr. Fowler, Melksham | 14 | - 2 ft. 6 in. | with pipes. |
| " Mr. Newman do. | 10 | - 2 ,, 0 ,, | ,, |
| " Mr. Blandford, near do. | 30 | - 3 ,, 6 ,, | ,, |
| " Mr. Purch, Doun Ampney - - | 100 | | without pipes. |
| " Mr. Hall, Brentwood | 200 | - 2 ,, 6 ,, | with and without. |
| ,, Wormwood Scrubbs | 40 | from 2 ft. to 4 ft. | with tiles. |
| " Mr. Harris, Darlington (now working), 3 ft. 6 in. | | | |

" In clay subsoils, with a gentle fall, the success of this new implement seems to be beyond doubt; and in all circumstances the inventor is ready to undertake the risk of the execution."

# No. IX.

TABLE showing the equal ANNUAL AMOUNT of PRINCIPAL combined with INTEREST viz. from 3 to 6 per cent. per annum,

| Number of Years in which Loans to be repaid. | 3 per Cent. per Annum. Average Annual Instalment of Principal and Interest of | | 3½ per Cent. per Annum. Average Annual Instalment of Principal and Interest of | | 4 per Cent. per Annum. Average Annual Instalment of Principal and Interest of | |
|---|---|---|---|---|---|---|
| | £1. | £100. | £1. | £100. | £1. | £100. |
| | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. |
| 1 | 1·030000=1 0 7¼ | 103 0 0 | 1·035000=1 0 8½ | 103 10 0 | 1·040000=1 0 9½ | 104 0 0 |
| 2 | ·522611=0 10 5½ | 52 5 2¾ | ·526400=0 10 6½ | 52 12 9½ | ·530196=0 10 7¼ | 53 0 4¾ |
| 3 | ·353530=0 7 0¾ | 35 7 0¾ | ·356934=0 7 1¾ | 35 13 10½ | ·360349=0 7 2½ | 36 0 8¾ |
| 4 | ·269027=0 5 4½ | 26 18 0¾ | ·272251=0 5 5¼ | 27 4 6 | ·275490=0 5 6 | 27 10 11½ |
| 5 | ·218354=0 4 4½ | 21 16 8¼ | ·221481=0 4 5¼ | 22 2 11½ | ·224627=0 4 6 | 22 9 3 |
| 6 | ·184597=0 3 8¼ | 18 9 2¼ | ·187668=0 3 9 | 18 15 4 | ·190762=0 3 9¾ | 19 1 6½ |
| 7 | ·160506=0 3 2½ | 16 1 0¼ | ·163544=0 3 3¼ | 16 7 1 | ·166610=0 3 4 | 16 13 2¼ |
| 8 | ·142456=0 2 10¼ | 14 4 11 | ·145477=0 2 11 | 14 10 11¼ | ·148528=0 2 11¾ | 14 17 0¾ |
| 9 | ·128434=0 2 6¾ | 12 16 10½ | ·131446=0 2 7½ | 13 2 10¾ | ·134493=0 2 8¼ | 13 8 11¼ |
| 10 | ·117231=0 2 4¼ | 11 14 5½ | ·120241=0 2 4¾ | 12 0 5¾ | ·123291=0 2 5½ | 12 6 7 |
| 11 | ·108077=0 2 2 | 10 16 1½ | ·111092=0 2 2¾ | 11 2 2¼ | ·114149=0 2 3½ | 11 8 3½ |
| 12 | ·100462=0 2 0 | 10 0 11 | ·103484=0 2 0¾ | 10 6 11¾ | ·106552=0 2 1½ | 10 13 1¼ |
| 13 | ·094030=0 1 10½ | 9 8 0¾ | ·097062=0 1 11¼ | 9 14 1½ | ·100144=0 2 0 | 10 0 3½ |
| 14 | ·088526=0 1 9¼ | 8 17 0½ | ·091571=0 1 10 | 9 3 1¾ | ·094669=0 1 10¾ | 9 9 4 |
| 15 | ·083767=0 1 8 | 8 7 6¼ | .086825=0 1 8¾ | 8 13 7¾ | ·089941=0 1 9½ | 8 19 10½ |
| 16 | ·079611=0 1 7¼ | 7 19 2¾ | ·082685=0 1 7¾ | 8 5 4½ | ·085820=0 1 8½ | 8 11 7¾ |
| 17 | ·075953=0 1 6¼ | 7 11 10¾ | ·079043=0 1 7 | 7 18 1 | ·082199=0 1 7¾ | 8 4 4½ |
| 18 | ·072709=0 1 5½ | 7 5 5 | ·075817=0 1 6¼ | 7 11 7½ | ·078993=0 1 7 | 7 17 11¾ |
| 19 | ·069814=0 1 4¾ | 6 19 7½ | ·072940=0 1 5½ | 7 5 10¼ | ·076139=0 1 6¼ | 7 12 3¼ |
| 20 | ·067216=0 1 4¼ | 6 14 5¾ | ·070361=0 1 5 | 7 0 8¾ | ·073582=0 1 5¾ | 7 7 2 |
| 21 | ·064872=0 1 3½ | 6 9 9 | ·068037=0 1 4¼ | 6 16 1 | ·071280=0 1 5 | 7 2 6¾ |
| 22 | ·062747=0 1 3 | 6 5 6 | ·065932=0 1 3¾ | 6 11 10¼ | ·069199=0 1 4½ | 6 18 4¾ |
| 23 | 060814=0 1 2½ | 6 1 7½ | ·064019=0 1 3½ | 6 8 0½ | ·067309=0 1 4¼ | 6 14 7½ |
| 24 | ·059047=0 1 2¼ | 5 18 1¼ | ·062273=0 1 3 | 6 4 6½ | ·065587=0 1 3¾ | 6 11 2 |
| 25 | ·057428=0 1 1¾ | 5 14 10¼ | ·060674=0 1 2½ | 6 1 4½ | ·064012=0 1 3¼ | 6 8 0¼ |
| 26 | ·055938=0 1 1½ | 5 11 10½ | ·059205=0 1 2¼ | 5 18 5 | ·062567=0 1 3 | 6 5 1½ |
| 27 | ·054564=0 1 1 | 5 9 1½ | ·057852=0 1 2 | 5 15 8½ | ·061239=0 1 2¾ | 6 2 5½ |
| 28 | ·053293=0 1 0¾ | 5 6 7 | ·056603=0 1 1½ | 5 13 2½ | ·060013=0 1 2½ | 6 0 0¼ |
| 29 | ·052115=0 1 0½ | 5 4 2¾ | ·055445=0 1 1¼ | 5 10 10¾ | ·058880=0 1 2 | 5 17 7½ |
| 30 | ·051019=0 1 0¼ | 5 2 0½ | ·054371=0 1 1 | 5 8 9 | ·057830=0 1 1¾ | 5 15 8 |

*Rule.*—To find the Annual Instalment to repay any amount with Interest in any number of Years from 1 to 30, at any rate of Interest from 3 to 6 per cent., multiply the sum to be repaid with Interest in equal Annual Instalments by the fraction of £1, which would repay £1 with Interest at the given rate in the given period, as shown in the first column of the Table opposite the number of Years.

*1st Method:*— ·070682 × £5,722 = £404 8 10

```
or ·070682
      5722
   -------
    141364
   141364
  494774
 353410
 ---------
 404·442404
        20
 ---------
   8·848080
        12
 ---------
 10·176960=£404 8 10
```

*Note.*—These tables have been examined and certified by John Finlaison, Esq., Actuary of the National Debt Office.

which is requisite for the REPAYMENT of LOANS at the under-mentioned rates of Interest, in any period of from one to thirty years.

| 4½ per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1. | £100. | 5 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1. | £100. | 6 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1. | £100. | Number of Years in which Loans to be repaid. |
|---|---|---|---|---|---|---|
| £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | |
| 1·045000=1 0 10¾ | 104 10 0 | 1·050000=1 1 0 | 105 0 0 | 1·060000=1 1 2½ | 106 0 0 | |
| ·533998=0 10 8¾ | 53 8 0 | ·537805=0 10 9 | 53 15 7½ | ·545437=0 10 11 | 54 10 10½ | 2 |
| ·363773=0 7 3¼ | 36 7 6½ | ·367209=0 7 4¼ | 36 14 5 | ·374110=0 7 5¾ | 37 8 2¼ | 3 |
| ·278744=0 5 7 | 27 17 5½ | ·282012=0 5 7¾ | 28 4 0½ | ·288591=0 5 9½ | 28 17 2¼ | 4 |
| ·227792=0 4 6¾ | 22 15 7 | ·230975=0 4 7½ | 23 1 11½ | ·237396=0 4 9 | 23 14 9½ | 5 |
| ·193878=0 3 10½ | 19 7 9 | ·197017=0 3 11¼ | 19 14 0½ | ·203363=0 4 0¾ | 20 6 8¾ | 6 |
| ·169701=0 3 4¾ | 16 19 5 | ·172820=0 3 5½ | 17 5 7¾ | ·179135=0 3 7 | 17 18 3¼ | 7 |
| ·151610=0 3 0½ | 15 3 2¾ | ·154722=0 3 1 | 15 9 5½ | ·161036=0 3 2¾ | 16 2 0¾ | 8 |
| ·137574=0 2 9 | 13 15 1½ | ·140690=0 2 9¾ | 14 1 4½ | ·147022=0 2 11¼ | 14 14 0½ | 9 |
| ·126379=0 2 6¼ | 12 12 9 | ·129505=0 2 7 | 12 19 0 | ·135868=0 2 8¾ | 13 11 9 | 10 |
| ·117248=0 2 4¼ | 11 14 6 | ·120389=0 2 5 | 12 0 9¼ | ·126793=0 2 6¼ | 12 13 7 | 11 |
| ·109666=0 2 2¼ | 10 19 4 | ·112825=0 2 3 | 11 5 7¼ | ·119277=0 2 4¾ | 11 18 6½ | 12 |
| ·103275=0 2 0¾ | 10 6 6½ | ·106456=0 2 1½ | 10 12 11 | ·112960=0 2 3 | 11 5 11 | 13 |
| ·097820=0 1 11½ | 9 15 7¾ | ·101024=0 2 0¼ | 10 2 0½ | ·107585=0 2 1¾ | 10 15 2 | 14 |
| ·093114=0 1 10¼ | 9 6 2¾ | ·096342=0 1 11¼ | 9 12 8¾ | ·102963=0 2 0¾ | 10 5 11¼ | 15 |
| ·089015=0 1 9½ | 8 18 0¼ | ·092270=0 1 10¼ | 9 4 6½ | ·098952=0 1 11¾ | 9 17 11 | 16 |
| ·085418=0 1 8½ | 8 10 10 | ·088699=0 1 9¼ | 8 17 4¾ | ·095445=0 1 11 | 9 10 10¾ | 17 |
| ·082237=0 1 7¾ | 8 4 5¾ | ·085546=0 1 8½ | 8 11 1 | ·092357=0 1 10¼ | 9 4 8½ | 18 |
| ·079407=0 1 7 | 7 18 9¾ | ·082745=0 1 7¾ | 8 5 5¾ | ·089621=0 1 9½ | 8 19 3 | 19 |
| ·076876=0 1 6½ | 7 13 9 | ·080243=0 1 7¼ | 8 0 5¾ | ·087185=0 1 9 | 8 14 4½ | 20 |
| ·074601=0 1 6 | 7 9 2½ | ·077996=0 1 6¾ | 7 16 0 | ·085005=0 1 8½ | 8 10 0 | 21 |
| ·072546=0 1 5½ | 7 5 1 | ·075971=0 1 6¼ | 7 11 11½ | ·083046=0 1 8 | 8 6 1 | 22 |
| ·070682=0 1 5 | 7 1 4¼ | ·074137=0 1 5¾ | 7 8 3½ | ·081278=0 1 7½ | 8 2 6¾ | 23 |
| ·068987=0 1 4½ | 6 17 11¾ | ·072471=0 1 5½ | 7 4 11½ | ·079679=0 1 7¼ | 7 19 4½ | 24 |
| ·067439=0 1 4¼ | 6 14 10½ | ·070952=0 1 5 | 7 1 11 | ·078227=0 1 6¾ | 7 16 5½ | 25 |
| ·066021=0 1 4 | 6 12 0½ | ·069564=0 1 4¾ | 6 19 1½ | ·076904=0 1 6½ | 7 13 9¾ | 26 |
| ·064719=0 1 3½ | 6 9 5½ | ·068292=0 1 4½ | 6 16 7 | ·075697=0 1 6¼ | 7 11 4¾ | 27 |
| ·063521=0 1 3¼ | 6 7 0½ | ·067123=0 1 4¼ | 6 14 3 | ·074593=0 1 6 | 7 9 2¼ | 28 |
| ·062415=0 1 3 | 6 4 10 | ·066046=0 1 4 | 6 12 1 | ·073580=0 1 5¾ | 7 7 2 | 29 |
| ·061392=0 1 2¾ | 6 2 9½ | ·065051=0 1 3¾ | 6 10 1½ | ·072649=0 1 5½ | 7 5 3½ | 30 |

Or less exactly by proportion in sterling money,—as £100 is to the sum to be repaid, so is the Annual Instalment which would repay £100 in the given period, with the given rate of Interest, to the Annual Instalment required. The Instalment necessary to repay £100 is shown in the third column opposite the given number of Years. Example:—To find the Annual Instalment to repay £5,722 with Interest at 4½ per cent. per annum in 23 equal Annual Instalments.

*2d Method:*— As £100 : £5,722 : : £7 1 4¼ : £404 8 3¼

```
           20
          ---
          141
           12
          ---
         1696
            4
         ----
         6785
         5722
        -----
        13570
       13570
      47495
     33925
  -----------
  100)388237(70
     4)388237
    12)97059–¼
     20)8088–3
      £404 8 3¼
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# No. X.

TABLES of LOANS of different AMOUNTS repayable by equal INSTALMENTS of PRINCIPAL ANNUAL CONTRIBUTIONS from

## FIVE YEARS.

| Number of Houses. | Loan of 6d. per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 1s. per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 2s. 6d. per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 5s. per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 1l. per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 5l. per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 10l. per house. Average annual instalment of principal and interest at 5 per cent. |
|---|---|---|---|---|---|---|---|
| | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. |
| 1 | 0 0 1½ | 0 0 2¾ | 0 0 7 | 0 1 1¾ | 0 4 7½ | 1 3 1¼ | 2 6 2¼ |
| 5 | 0 0 6¾ | 0 1 1¾ | 0 2 10¾ | 0 5 9¼ | 1 3 1¼ | 5 15 5¾ | 11 10 11½ |
| 10 | 0 1 1¾ | 0 2 3¾ | 0 5 9¼ | 0 11 6¾ | 2 6 2¼ | 11 10 11½ | 23 1 11½ |
| 20 | 0 2 3¾ | 0 4 7½ | 0 11 6¾ | 1 3 1¼ | 4 12 4¾ | 23 1 11½ | 46 3 10¾ |
| 25 | 0 2 10½ | 0 5 9¼ | 0 14 5¼ | 1 8 10½ | 5 15 5¾ | 28 17 5¼ | 57 14 10½ |
| 50 | 0 5 9¼ | 0 11 6½ | 1 8 10½ | 2 17 8¾ | 11 10 11¾ | 57 14 10¾ | 115 9 9 |
| 100 | 0 11 6½ | 1 3 1¼ | 2 17 8¾ | 5 15 5¾ | 23 1 11½ | 115 9 9½ | 230 19 6 |
| 250 | 1 8 10½ | 2 17 8¾ | 7 4 4¼ | 14 8 8¾ | 57 14 10½ | 288 14 4½ | 577 8 9 |
| 500 | 2 17 8¾ | 5 15 5¾ | 14 8 8½ | 28 17 5¼ | 115 9 9 | 577 8 9 | 1,154 17 5¾ |
| 1,000 | 5 15 5¾ | 11 10 11¾ | 28 17 5¼ | 57 14 10½ | 230 19 6 | 1,154 17 5¾ | 2,309 14 11½ |
| 5,000 | 28 17 5¼ | 57 14 10½ | 144 7 2¼ | 288 14 4½ | 1,154 17 5¾ | 5,774 7 4¾ | 11,548 14 9½ |
| 10,000 | 57 14 10½ | 115 9 8¾ | 288 14 4½ | 577 8 8¾ | 2,309 14 11½ | 11,548 14 9½ | 23,097 9 7¼ |
| 15,000 | 86 12 3¾ | 173 4 7½ | 433 1 6¾ | 866 3 1¼ | 3,464 12 5¼ | 17,323 2 2½ | 34,646 4 4¾ |
| 20,000 | 115 9 9 | 230 19 5¾ | 577 8 8¾ | 1,154 17 5¾ | 4,619 9 11 | 23,097 9 7¼ | 46,194 19 2½ |
| 30,000 | 173 4 7½ | 246 9 2½ | 866 3 1¼ | 1,732 6 2½ | 6,929 4 10½ | 34,646 4 4¾ | 69,292 8 9¾ |
| 40,000 | 230 19 5½ | 461 18 11½ | 1,154 17 5¾ | 2,309 14 11½ | 9,238 19 10 | 46,194 19 2½ | 92,389 18 4½ |
| 50,000 | 288 14 4½ | 577 8 8¾ | 1,443 11 10¼ | 2,887 3 8½ | 11,548 14 9½ | 57,743 14 0 | 115,487 8 0 |
| 100,000 | 577 8 8¾ | 1,154 17 5¾ | 2,887 3 8½ | 5,774 7 4¾ | 23,097 9 7¼ | 115,487 8 0 | 230,974 16 0 |
| 250,000 | 1,443 11 10¼ | 2,887 3 8¾ | 7,217 19 3 | 14,435 18 6 | 57,743 14 0 | 288,718 10 0 | 577,437 0 0 |
| 1,000,000 | 5,774 7 4½ | 11,548 14 9½ | 28,871 17 0 | 57,743 14 0 | 230,974 16 0 | 1,154,874 0 0 | 2,309,748 0 0 |

## THIRTY YEARS.

| Number of Houses. | Loan of 6d. per house. | Loan of 1s. per house. | Loan of 2s. 6d. per house. | Loan of 5s. per house. | Loan of 1l. per house. | Loan of 5l. per house. | Loan of 10l. per house. |
|---|---|---|---|---|---|---|---|
| 1 | 0 0 0½ | 0 0 0¾ | 0 0 2 | 0 0 3¾ | 0 1 3¾ | 0 6 6 | 0 13 0¼ |
| 5 | 0 0 1¾ | 0 0 3¾ | 0 0 9¾ | 0 1 7½ | 0 6 6 | 1 12 6¼ | 3 5 0¾ |
| 10 | 0 0 3¾ | 0 0 7¾ | 0 1 7½ | 0 3 3 | 0 13 0¼ | 3 5 0¾ | 6 10 1¼ |
| 20 | 0 0 7¾ | 0 1 3½ | 0 3 3 | 0 6 6 | 1 6 0¼ | 6 10 0½ | 13 0 2½ |
| 25 | 0 0 9¾ | 0 1 7½ | 0 4 0¾ | 0 8 1½ | 1 12 6¼ | 8 2 7½ | 16 5 3 |
| 50 | 0 1 7½ | 0 3 3 | 0 8 1½ | 0 16 3 | 3 5 0½ | 16 5 3 | 32 10 6¼ |
| 100 | 0 3 3 | 0 6 6 | 0 16 3 | 1 12 6¼ | 6 10 1¼ | 32 10 6¼ | 65 1 0¼ |
| 250 | 0 8 1½ | 0 16 3¼ | 2 0 7¾ | 4 1 3¾ | 16 5 3 | 81 6 3½ | 162 12 6¾ |
| 500 | 0 16 3¼ | 1 12 6¼ | 4 1 3¾ | 8 2 7½ | 32 10 6¼ | 162 12 6¾ | 325 5 1¾ |
| 1,000 | 1 12 6 | 3 5 0½ | 8 2 7½ | 16 5 3 | 65 1 0¼ | 325 5 1¾ | 650 10 3¾ |
| 5,000 | 8 2 7½ | 16 5 3 | 40 13 1½ | 81 6 3½ | 325 5 1¾ | 1,626 5 8¾ | 3,252 11 5½ |
| 10,000 | 16 5 3 | 32 10 6 | 81 6 3¾ | 162 12 6¾ | 650 10 3¼ | 3,252 11 5½ | 6,505 2 10½ |
| 15,000 | 24 7 10½ | 48 15 9¼ | 121 19 5 | 243 18 10¼ | 975 15 5 | 4,878 17 2 | 9,757 14 3¾ |
| 20,000 | 32 10 6 | 65 1 0¾ | 162 12 6¾ | 325 5 1¾ | 1,301 0 6¾ | 6,505 2 10½ | 13,010 5 9 |
| 30,000 | 48 15 9 | 97 11 6½ | 243 18 10 | 487 17 8½ | 1,951 10 10½ | 9,757 14 4 | 19,515 8 7½ |
| 40,000 | 65 1 0¼ | 130 2 0¾ | 325 5 1½ | 650 10 3¼ | 2,602 1 1¾ | 13,010 5 9½ | 26,020 11 6 |
| 50,000 | 81 6 3½ | 162 12 6¾ | 406 11 5 | 813 2 10½ | 3,252 11 5½ | 16,262 17 2¼ | 32,525 14 4½ |
| 100,000 | 162 12 6¾ | 325 5 1¾ | 813 2 10½ | 1,626 5 8½ | 6,505 2 10½ | 32,525 14 4½ | 65,051 8 9 |
| 250,000 | 406 11 5 | 813 2 10½ | 2,032 17 1¾ | 4,065 14 3¼ | 16,262 17 2¼ | 81,314 5 11½ | 162,628 11 10½ |
| 1,000,000 | 1,626 5 8½ | 3,252 11 5½ | 8,131 8 7 | 16,262 17 2¼ | 65,051 8 9 | 325,257 3 9 | 650,514 7 6 |

NOTE.—In framing these Tables, in order to avoid the introduction of decimals, the nearest fraction and Interest in Five Years and Thirty Years, made to estimate the Amounts of Places of different Population.

FIVE YEARS.

| Loan of 20*l.* per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 25*l.* per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 50*l.* per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 100*l.* per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 250*l.* per house. Average annual instalment of principal and interest at 5 per cent. | Loan of 500*l.* per house. Average annual instalment of principal and interest at 5 per cent. | Number of Houses. |
|---|---|---|---|---|---|---|
| £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | |
| 4 12 4¾ | 5 15 5¾ | 11 10 11¾ | 23 1 11¼ | 57 14 10½ | 115 9 9 | 1 |
| 23 1 11¼ | 28 17 5¼ | 57 14 10½ | 115 9 9 | 288 14 4½ | 577 8 9 | 5 |
| 46 3 10¾ | 57 14 10½ | 115 9 9 | 230 19 6 | 577 8 9 | 1,154 17 5¾ | 10 |
| 92 7 9½ | 115 9 9 | 230 19 6 | 461 19 0 | 1,154 17 5¾ | 2,309 14 11¼ | 20 |
| 115 9 9 | 144 7 2½ | 288 14 4½ | 577 8 9 | 1,443 11 10¼ | 2,887 3 8½ | 25 |
| 230 19 6 | 288 14 4½ | 577 8 9 | 1,154 17 5¾ | 2,887 3 8½ | 5,774 7 5 | 50 |
| 461 19 0 | 577 8 9 | 1,154 17 5¾ | 2,309 14 11¼ | 5,774 7 4¾ | 11,548 14 9½ | 100 |
| 1,154 17 6 | 1,443 11 10¼ | 2,887 3 8½ | 5,774 7 5 | 14,435 18 6 | 28,871 17 0 | 250 |
| 2,309 14 11¼ | 2,887 3 8½ | 5,774 7 5 | 11,548 14 9¾ | 28,871 17 0 | 57,743 14 0 | 500 |
| 4,619 9 11 | 5,774 7 5 | 11,548 14 9¾ | 23,097 9 7¼ | 57,743 14 0 | 115,487 8 0 | 1,000 |
| 23,097 9 7¼ | 28,871 17 0 | 57,743 14 0 | 115,487 8 0 | 288,718 10 0 | 577,437 0 0 | 5,000 |
| 46,194 19 2¼ | 57,743 14 0 | 115,487 8 0 | 230,974 16 0 | 577,437 0 0 | 1,154,874 0 0 | 10,000 |
| 69,292 8 9¾ | 86,615 11 0 | 173,231 2 0 | 346,462 4 0 | 866,155 10 0 | 1,732,311 0 0 | 15,000 |
| 92,389 18 5 | 115,487 8 0 | 230,974 16 0 | 461,949 12 0 | 1,154,874 0 0 | 2,309,748 0 0 | 20,000 |
| 138,584 17 7¼ | 173,231 2 0 | 346,462 4 0 | 692,924 8 0 | 1,732,311 0 0 | 3,464,622 0 0 | 30,000 |
| 184,779 16 9 | 230,974 16 0 | 461,949 12 0 | 923,899 4 0 | 2,309,748 0 0 | 4,619,496 0 0 | 40,000 |
| 230,974 16 0 | 288,718 10 0 | 577,437 0 0 | 1,154,874 0 0 | 2,887,185 0 0 | 5,774,370 0 0 | 50,000 |
| 461,949 12 0 | 577,437 0 0 | 1,154,874 0 0 | 2,309,748 0 0 | 5,774,370 0 0 | 11,548,740 0 0 | 100,000 |
| 1,154,874 0 0 | 1,443,592 10 0 | 2,887,185 0 0 | 5,774,370 0 0 | 14,435,925 0 0 | 28,871,850 0 0 | 250,000 |
| 4,619,496 0 0 | 5,774,370 0 0 | 11,548,740 0 0 | 23,097,480 0 0 | 57,743,700 0 0 | 115,487,400 0 0 | 1,000,000 |

THIRTY YEARS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 6 0¼ | 1 12 6¼ | 3 5 0¾ | 6 10 1¼ | 16 5 3 | 32 10 6¼ | 1 |
| 6 10 1¼ | 8 2 7½ | 16 5 3 | 32 10 6 | 81 6 3½ | 162 12 7 | 5 |
| 13 0 2½ | 16 5 3 | 32 10 6¼ | 65 1 0¼ | 162 12 6¾ | 325 5 1¾ | 10 |
| 26 0 5 | 32 10 6¼ | 65 1 0¼ | 130 2 0¼ | 325 5 1¾ | 650 10 3¼ | 20 |
| 32 10 6¼ | 40 13 1¾ | 81 6 3½ | 162 12 6¾ | 406 11 5¼ | 813 2 10¼ | 25 |
| 65 1 0¼ | 81 6 3½ | 162 12 6¾ | 325 5 1¾ | 813 2 10¼ | 1,626 5 8¾ | 50 |
| 130 2 0¾ | 162 12 6¾ | 325 5 1¾ | 650 10 3¾ | 1,626 5 8¾ | 3,252 11 5¼ | 100 |
| 325 5 1¾ | 406 11 5 | 813 2 10¼ | 1,626 5 8½ | 4,065 14 3¼ | 8,131 8 7 | 250 |
| 650 10 3¾ | 813 2 10¼ | 1,626 5 8½ | 3,252 11 5¼ | 8,131 8 7 | 16,262 17 2¼ | 500 |
| 1,301 0 7 | 1,626 5 8¾ | 3,252 11 5¼ | 6,505 2 10¼ | 16,262 17 2¼ | 32,525 14 4¼ | 1,000 |
| 6,505 2 10¼ | 8,131 8 7¼ | 16,262 17 2¼ | 32,525 14 4¼ | 81,314 5 11¼ | 162,628 11 10¼ | 5,000 |
| 13,010 5 9 | 16,262 17 2¼ | 32,525 14 4¼ | 65,051 8 9 | 162,628 11 10¼ | 325,257 3 9 | 10,000 |
| 19,515 8 7¼ | 24,394 5 9¼ | 48,788 11 6¾ | 97,577 3 1¼ | 243,942 17 9¾ | 487,885 15 7¼ | 15,000 |
| 26,020 11 6 | 32,525 14 4¼ | 65,051 8 9 | 130,102 17 6¼ | 325,257 3 9 | 650,514 7 6 | 20,000 |
| 39,030 17 3 | 48,788 11 7 | 97,577 3 1¼ | 195,154 6 3 | 487,885 15 7¼ | 975,771 11 3 | 30,000 |
| 52,041 3 0 | 65,051 8 9¼ | 130,102 17 6 | 260,205 15 0 | 650,514 7 6 | 1,301,028 15 0 | 40,000 |
| 65,051 8 9 | 81,314 5 11¼ | 162,628 11 10¼ | 325,257 3 9 | 813,142 19 4¼ | 1,626,285 18 9 | 50,000 |
| 130,102 17 6 | 162,628 11 10¼ | 325,257 3 9 | 650,514 7 6 | 1,626,285 18 9 | 3,252,571 17 6 | 100,000 |
| 325,257 3 9 | 406,571 9 8¼ | 813,142 19 4¼ | 1,626,285 18 9 | 4,085,714 16 10½ | 8,131,429 13 9 | 250,000 |
| 1,301,028 15 0 | 1,626,285 18 9 | 3,252,571 17 6 | 6,505,143 15 0 | 16,262,859 7 6 | 32,525,718 15 0 | 1,000,000 |

of a penny has been taken, which will account for the slight difference in some of the amounts.

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