Sewer manure. Statement of the course of investigation & results of experiments as to the means of removing the refuse of towns in water, and applying it as manure : with suggestions of further trial works (for voluntary adoption) of the practicability of applying sewer water as manures by subterranean channels; prepared for the consideration of the Committee of Works / by Edwin Chadwick, Esq., C.B., with appendices.

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Metropolitan Sewers.

The result of a personal inspection of the chief cities and towns in Great Britain not long since, suggested the following observations:—

"Within the town 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 few, and 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, 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 the 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 burthens, and might be rendered productive of general advantage if due means, guided by science, and applied by properly-qualified officers, be resorted to."

The visible impressions which first suggested these observations were derived from spots in the rural districts in the immediate vicinity of Manchester and urban districts in Cheshire, from whence the candle-makers have hitherto obtained their best supplies of rushes. As compared with agricultural districts under high cultivation, the rural population close to several large and densely-populated manufacturing towns is remarkably thin and comparatively poor. A prize essay, in the Royal Agricultural Journal, shows that, for want of drainage, two-thirds of Cheshire is unfitted for sheep. The visible impressions derived from these local inquiries were confirmed on the inspection of the marsh

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districts bordering on the eastern suburbs of the metropolis, from whence marsh diseases are, even at this time, traced to the very interior of the metropolis itself. More particular illustrations will be found in the reports of Mr Donaldson, the Agricultural Surveyor, given in the Appendix to the Second Report of the Metropolitan Sanitary Commissioners, and again repeated in the examination of the vicinities of other seats of commercial and manufacturing industry and wealth.

Further investigations appear to me to present grounds for advancing, as general correlative propositions, that whilst, for the towns,

> ALL OFFENSIVE SMELLS FROM THE DECOMPOSITION OF ANIMAL AND VEGETABLE MATTER INDICATE THE GENERATION AND EXISTENCE OF DISEASE, AND DEFECTIVE LOCAL ADMINISTRATION,

the investigations extended to the rural districts establish, as a correlative conclusion, that

> ALL OFFENSIVE SMELLS FROM THE DECOMPOSITION OF ANIMAL AND VEGETABLE MATTER INDICATE THE LOSS OF FERTILISING MATTER, THE LOSS OF MONEY, AND BAD HUSBANDRY.

Of the first of these two propositions, any one may convince himself, who will obtain a list of the places repeatedly afflicted with typhus and other epidemic, endemic, and contagious diseases. He will find, as I found in traversing the wynds of Glasgow and Edinburgh, and the courts in York and other towns, that his own sensations would guide him to the seats of fever without any other direction. Amongst offensive smells are included those which are sickening, "depressing," or "deadening," as well as those which are pungent and offensive stinks. But though offensive smells—those especially which are distinguishable from the smells directly affecting the olfactory nerves, and which appear chiefly to affect the lungs by the depuration of the air by the admixture of irrespirable gases—always indicate danger, it does not follow that there is no danger where there are no such offensive or pungent warnings. The objects of the present paper are to indicate the evidence in support of the agricultural proposition, to state the improvements which have been made in the mechanical means of distributing manures, and to suggest further improvements for trial.

The common observation on the statement of the encumbrance of towns with the refuse is generally short, and apparently simple: "Let there be an additional number of scavengers appointed, and well superintended."

The expense of cleansing the main streets of the metropolis, and a mere pretence of cleansing the bye-streets and courts, is estimated in round numbers at upwards of 50,000*l.* per annum. If it could be done in no other way than by hand-labour and cartage, it would no doubt be cheap to pay a scavengers' tax for a more complete cleansing, and a comparatively quick removal of the surface refuse. The towns themselves, or the local administrative bodies, have not hitherto of themselves perceived the waste of money, merely, and would be slow to adopt such an opinion against the supposed immediate pressure of so large an additional tax. Moreover, there would be strong objections to the increase of the number (requisite on such a plan) of such labourers. The hand-labour of removing filth is offensive, though less offensive than the retention of the filth: it is a necessary and beneficial labour, but it is still an offensive labour—it is ill paid, and wretched labour. A society has been instituted for promoting the cleansing of the streets; which has announced that in this way employment might be found in our chief towns for 10,000 labourers. I have no doubt that, at this sort of labour, employment might be found for a greater number of men: but it is a sort of labour which in a great measure creates the sort of labourers, and the creation of a large army of scavengers would be in itself a heavy payment, socially considered, for the performance of the extra labour required. I have been repeatedly solicited to join the association in question, but I have declined. If it were necessary to take a part, I should, as a question of philanthropy, prefer joining the street-cleansing company, using all the influence in my power for the introduction of the street-cleansing machine, by which such labour will be superseded by labour and labourers of a higher order, and better paid and conducted.

Immense as would be the addition of labour requisite for the complete cleansing of the surface of the streets by hand labour, a yet greater addition of "nightmen" and labourers, and expense, would be requisite for the better cleansing of the site beneath and between the streets, the more frequent emptying of the cesspools, and the removal of the refuse from the cesspools, and the drains and sewers, which in their present condition are only extended cesspools. The attainment of this object by nightmen would require for the metropolis an additional expenditure probably of upwards of a quarter of a million of money per annum. The experience in some Flemish and German towns, where the town manure is better applied to agricultural production and more frequently removed than in our towns, and the constant pollution of the air there by the work of removal, shows, in respect to the cleansing of the subterranean refuse, good reason to doubt whether the sanitary benefits obtainable would well repay the expense.

A report on the cesspool system of Paris, which was made at the instance of the Metropolitan Sanitary Commissioners, by Mr Rammel the Engineer, affords striking illustrations of this conclusion. Until the obstacle created by the expense of hand-labour and cartage in the removal of refuse could be overcome—until cesspools can be emptied, and the refuse removed more frequently, — 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.

The result of investigations as to the means of overcoming the obstacles to the improvement of the sanitary condition of towns, created by the expense of cleansing by hand-labour, was the establishment of the principle that there are no means of removing refuse, or of cleansing, so cheap and effectual as removal in mechanical suspension or in solution in water:—

It appeared that this principle might be applied almost universally for the discharge of refuse from amidst towns. The water-closet and its connected apparatus as now constructed (and its whole expense may be reduced, and its action simplified and improved) is a cheaper arrangement than the cesspool of the poorer houses in towns. But, if cesspools be generally superseded, and the water-closet system generally introduced, as it has been in the newly-built portions of Hamburgh, then we should, in the old course of engineering service, only convert the rivers into immense sewers, which it is now the subject of complaint that the Thames has already become.

On the other hand, the avoidance of the pollution of rivers by the extension of the old system of cleansing by hand-labour and cartage would surround all the cities with mounds of ordure proportioned to the number of the population, or with establishments that like of the manufacturers at Paris, which it appeared would be a greater evil than the pollution of rivers. To prevent or to abate the evils from the systems of chemical accumulations of ordure near towns, manipulations have been proposed, but without sufficient evidence of the complete sanitary efficacy of any one plan (*vide Second Report of the Metropolitan Sanitary Commission Examinations as to the effects of the Deodorisers, Appendix*): and the experience obtained at Paris in relation to such manipulations, and the manufacture of *poudrette*, is unfavourable (see *Mr Rammel's Report*).

In this stage of the investigation we are driven, for relief, into the domain of agriculture, and to consider the various means of applying the refuse of towns, in suspension or solution in water—that is to say, sewer water, as a fertiliser. Being at that time individually charged with the sanitary inquiry, I ascertained the use which had been made of the refuse of towns, in the liquid form, for nearly half a century at Edinburgh, and for a longer period at Milan; and that a more recent, though in respect to sewerage a partial example, had been wrought out by the Duke of Portland, at the Clipstone Meadows, near the small town of Mansfield. I was informed of other small, scattered examples in different parts of the country. My friend Count Arrivabene was so good as to obtain for me an account of the irrigations at Milan (*vide Appendix, No.* 2.) The Edinburgh and the Clipstone irrigations I visited, and examined myself. A more recent and particular description of the Edinburgh irrigations is given in an extract from a letter in answer to some recent inquiries from Dr James Stark, of Edinburgh (*Appendix, No.* 3).

The examination of these examples and others establish the fact, that by the application of manures in the liquid form, a degree of continuous fertility is obtained, such as has yet been obtained by no other method. I consulted Mr Smith of Deanston upon the subject in 1841. His view then was simply an extension of the Edinburgh method of irrigation. He proposed to carry the sewer water to an outfall, and there receive it by means of a large scoop wheel, worked by steam power, and thence distribute it over the adjacent land, which was to be laid out in tables for its reception, and periodically flooded, in the common method of water meadows.

The examination at Edinburgh presented strong sanitary objections to this method, on account of the offensive and no doubt injurious emanations which the sewer water gave off when spread over the water meadows. The evils arising from the emanations from sewer water eight times a year in the vicinity of the town were, however, certainly much less than the perpetual decomposition and discharge of the emanations within the town, within and beneath the habitations—less than the emanations from ordinary top-dressings, and such as would have escaped notice, as copious emanations do when the emanations are constant instead of intermittent; but still the evil is undoubted, and though far the least, appeared to be worth much exertion for its removal. Moreover, the offensive emanations indicated an extensive waste of the manure itself. *Much of the offensiveness* of which the Town Council of Edinburgh made just complaint appeared, however, to arise, not from the irrigation of the surface of the meadows, but from the *open sewers* in which the sewer water was conveyed, and the *open tanks* in which it was improperly kept near habitations.

The observation of some casual examples of the increased vegetation marking strongly the course of house drains which run close to the surface of lawns, suggested the inquiry whether irrigation might not be conducted in covered instead of open channels of distribution. I put this as a topic of inquiry to Mr Smith, who was of opinion that the object was practicable, but he has never worked it out.

Such casual examples of subterranean irrigation on a small scale appeared to me to be demonstrative of the fact (shown experimentally by Sir Humphrey Davy, when he directed the neck of a retort under the soil, and discharged gas into the earth, which displayed afterwards an increased amount of fertility) that plants are supported by manure, in combination with moisture in a gaseous state. This was also shown by the increased fertility of the vegetation of turf coverings over manure tanks, where the roots must apparently derive their whole nourishment from the moist or gaseous emanations.

When we would obtain any end by mechanical means, when it is for the supply of a want which is likely to have been extensively experienced, the presumption is that it has been the subject of previous trial. There may be found much sound invention which has been out of place or out of time, which has succeeded perfectly, but has dropped from changes of populations, or from there being no one near of sufficient intelligence to carry it forward.

When upon the observation of the evil effects and the expense of permeable brick drains, I proposed the substitution of tubular earthenware drains, I was unaware that the simple expedient had ever been tried; but Mr Cresy traced out the tubular earthenware drains as systematically laid down in the Colosseum at Rome. The filth and evils observable in densely-populated districts, in the tall houses occupied by the labouring classes (which I venture to designate as perpendicular courts and alleys—and in Edinburgh they may almost be called perpendicular streets), suggested a vertical system of drainage for each separate habitation, story, or landing, if not for each separate room or habitation. Mr Layard promises me a specimen of an earthenware drain pipe with which he found each chamber of the habitations in the ancient Nineveh provided. The observations of the deleterious effects often produced by the passage of water for domestic purposes through leaden house-pipes, and the observations of the great strength which may be given to earthenware, suggested its introduction as the material for the construction of the greater proportion of the distributary apparatus for water in our towns. A friend at Zurich has forwarded to me a specimen of an earthenware pipe laid down by the Romans probably two thousand years ago, and which has worked until recent times under five hundred feet of pressure. Vitruvius points out the evils of lead and metal pipes for the distribution of water, and the advantages of earthenware pipes as substitutes. Miss Martineau recently found the remains of earthenware pipes laid down for the distribution of water through the ancient city of Petra. The remains of water-closets, which are thought to be an English invention, were found at Pompeii. They were in use in the East, whence, also, the practice of irrigation first spread over Europe. On one point, at least, the ancient mythology has, I apprehend, been corrupted and egregiously misinterpreted. The Egyptians at least did not ascribe fortune or abundance to a false source, to a blind chance, but to study and skilful labour; to that on which we must now rely, the application of mechanical science and skill to agriculture. The so-called wheel of fortune was the Noria, or water wheel, the great mechanical means of irrigation; and the female form with the cornucopia is the symbol of the grateful abundance thence resulting.

A Professor of Agriculture in Sicily informed me of the existence of examples of subterranean irrigation in Lombardy. I wrote in 1842 for information on this topic to the Count Manetti, the Superintendent of the Royal Gardens at Monza, near Milan, and he gave me the following information on the methods which he knew to be in use :—

"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 applied 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 soil by our irrigators, who in this point are the best agriculturists in the world.

"The irrigation by regurgitation (more properly subsoil 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.

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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 GREASY 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.

"Subsoil irrigation would not answer, however, when the water is also employed to convey manure, for it would lose three-fourths of the fertilising matter before it could reach the roots of the grass." [Captain Vetch informs me of instances of accidental subterranean irrigation which he observed in South America, where carcases had been buried in large pits. The vegetation in the direction of the subterranean run of water from these pits was strongly marked for their distances. There are other facts, which will be subsequently noticed, which tend to show that the Count is here mistaken in his assumption.] "In this case the irrigation by filtration appears the most convenient, as may be seen in the neighbourhood of Milan, where such meadows as are thus irrigated with the waste water of the city let at 870 francs the hectare, which is equal to about 14*l.* an acre.

"This kind of irrigation has a very beneficial action even with pure water; so that in the territory of Lodi, which about sixty years ago was but a sandy, barren plain, the *marcite** now yield a yearly return of 13,500 kilogrammes of hay per hectare,† besides 16,900 kilogrammes of grass, which, being cut in the depth of winter, enables the cattle of Lombardy to produce a very considerable quantity of exquisite milk in the severest weather. It is, however, necessary to remark, that the abundance of this winter crop proceeds in part from the temperature of the spring water with which the *marcite* are irrigated, the colder water of rivers never being half so beneficial."

I had learned of other examples of subterranean irrigation with water than the one of which Count Manetti informed me; but although I have never lost sight of the subject, I was unable to carry the investigation further at that time.

I had derived some information from Mr Oliver, of Lochend, a very able agriculturist, who held some portions of the irrigated meadows at Edinburgh. It appeared that he had drained some of his meadows, from which he obtained a large increase of fertility, showing the comparative loss of produce in the undrained meadows. He complained that the sewer water there was far too highly charged with

* This appellation is given to certain meadows, so levelled that during winter they can be covered with a light sheet of running water, which will protect the grass from frost and cold, and enable it to grow—a method of cultivation introduced in Lombardy before the beginning of the 15th century, and forming now one of the principal elements of the wealth of that country.

† The *hectare* is a measure of about 108,000 square feet, corresponding nearly to two acres and a half. As the kilogramme is equivalent to about two pounds, one may assume that these *marcite* produce 10,000 pounds of hay per acre, besides 14,000 pounds of grass.

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manure for the best application, and that the best herbage was obtained after the sewer water had deposited its fibrous matter and was transparent. The grass was better in quality after the sewer water had percolated through an extent of forty acres. The chief obstacle to the improvement of that irrigation was the want of water, and the want of means of dilution. The facts elicited by subsequent investigation, chiefly by reference to horticultural experience, appeared to me to establish the important conclusion, that an extent of dilution such as to extinguish offensive smells is the most favourable condition for absorption by the plant.

This conclusion could, however, only be carried out practically by repeated applications of the manure; and to these the immediate obstacles were the expense of the labour of such repeated applications, as well as the outlay for the formation of water meadows and the expense of obtaining the water.

In many places the expense of forming water meadows would be considerable. On some portions of the Duke of Portland's meadows, I was informed that the expense was as high as 50*l.* per acre to obtain perfect *panes* or tables. The quantity of water required to flood them was also very large. When these works near towns were completed, they would only serve for growing grass. It would be entirely inapplicable to arable cultivation.

In the course of inquiries as to the means of street watering and cleansing, I ascertained that where pipes are laid down, and water maintained in them at high pressure (about 150 feet), and plugs are fixed at proper intervals, two men may water, by means of a flexible tube and jet, an extent of surface equal to twenty acres in a day.

It suggested itself to me that this mechanism might be applied to the distribution of manures in the liquid form.

In the summer of 1842 I was staying with a friend, Mr Thomson of Clitheroe, where Dr Lyon Playfair was also staying. Mr Thomson has extensive print-works, where he employs about 1,000 persons, and from the works has much sewer manure. I then advised the application of this manure by means of the hose. So far as I am aware this was the first suggestion and experiment of the kind. The only modes of applying liquid manure then in use were by the method of irrigation, by the water-cart or by hand. The land adjacent to Mr Thomson's works was a stiff clay. I advised that it should be previously drained, and that Mr Smith of Deanston should be consulted as to the drainage, and on the mechanical appliances for applying the refuse. Mr Smith very soon entered into my views on this subject. The drainage was carried out as he recommended. Mr Henry Thomson, jun., who took great interest in the subject, carried out the first experiment of the application of the refuse by the hose, which appears to me to have been completely successful. In another place, in Lancashire, I advised a friend to apply the liquid refuse by means of the hose, and to engage Mr Smith to carry out the preparatory work of land-drainage. Mr Henry 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 rest of the farm. He found that under that eighty feet pressure, by means of the hose, with the labour of two men, one to remove the hose and another to direct the nozzle, they could distribute about 2,000 gallons of liquid manure in an hour. That is what he deemed to be a sufficient dressing of concentrated liquid manure for grass land.

The distribution was effected by means of a hose two inches and a half diameter and 800 yards long. Of course the rate of delivery from the jet varied with the inclination of the land. The important result obtained was this, that it was accomplished by the labour of two men; and suppose we give twopence halfpenny or threepence an hour, that delivery of the 2,000 gallons was accomplished for sixpence. They tried the water-cart (this was on land immediately adjacent to the farm): the water-cart, and expense of delivery of the same quantity by that, was, I think, about 5s.; the expense of leading and spreading stable dung was about 11s. That was about the relative mechanical cost, 6d. for the delivery by the hose, 5s. by the water-cart, 11s. or 12s. in the distribution of stable manure.—(Vide Appendix, in the account of this experiment as given by Mr Thomson.)

I also directed the attention of Mr Philip Holland, the Surgeon, of Manchester, who has so efficiently promoted the cause of sanitary improvement in that district, to the use of the hose and jet in the distribution of sewer manure. He was well aware of the value of improvements in the mechanical processes of removing and applying rapidly town manures, as means for preventing disease. He pursued the experiments with great labour and very successful results. He invented machinery for applying the manure, by steam pumps, from a barge or river. He dilutes night soil, or other town manure, in a tender, and by means of a hose and jet, worked by a steam-engine of nine-horse power, distributes as much as three hundred loads per diem. He found it practicable to use the hose on flat land, in lengths of one thousand yards. Worse land — heavy undrained clay, surcharged with water, in a moist climate, with upwards of 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 superior to the ordinary top-dressings with manure in the solid form.

One most important sanitary result obtained from these experiments, and corroborated by subsequent experience in other places, was, that after about three loads of night soil and urine in solution with about seventeen loads of water had been applied to an acre of land, in little more than half an hour no offensive smell was perceptible — indeed no smell whatsover to suggest what had been done. Most persons may be aware of what would be the nuisance created for days by the spreading of the ordinary quantity of that manure undiluted upon the surface as a top-dressing.

The following questions, which I put to Mr James Dean, an agricultural engineer, may assist the exposition of what appears to me to be 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, which, for a time, emitted offensive smells; and the amount of offensive smell, as indicating the extent of decomposition (it 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 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 by the plants 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, night soil, 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 it dissipates the ammonia. 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.

"You have stated that one day would in general suffice for the absorption of the liquid manure; whilst six days at the least would be necessary for the absorption of as much of the manure as could be absorbed from it when applied in the solid form as a top-dressing. With arrangements such as might be practicable for the application of manure in water, would not a favourable day be chosen for its application, and the valuable manure be placed at once, or during that day, in security amidst the roots of the plants in the permeable soil, whilst by the last process of top-dressing it is exposed to the atmosphere, not only to the loss of the six days' emanations under the most favourable circumstances, but to all the adverse chances of losses, such as you have described?—Yes, that is most certainly the essential difference of the two processes.

"In respect to the difference of productiveness of irrigation and top-dressing, instances have been adduced where lands, by the use of stable or town manure as a top-dressing, have only had the ordinary produce increased one-fold under favourable circumstances, whilst portions of the same land lying convenient for irrigation have had the produce increased at the least five-fold by the application of the same manure in the liquid form. Do such instances coincide with your own observations?—Yes, decidedly."

Some distributions of liquid manures have recently been made in the liquid form, in Hyde Park, which perfectly justify these reasonings, and 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 all the offensiveness of the common applications of manures on lands adjacent to towns avoided.

The greater proportion of what is lost by decomposition and evaporation in top-dressings, is saved by being diluted and carried in water beneath the surface of the soil into the midst of the roots. The more minute subdivision of the manures

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in the liquid form facilitates a rapid decomposition, and complete absorption of them. There are various examples to show that one load of solid manure, properly applied in dilution, will have four or five times the fertilising power that it would have in the solid form.

Mr Barber, of Muirdrockwood, had 27 acres of land before his house, and the land was so poor that it originally only fed two cows, and that poorly; he kept 40 cows and 4 horses in his stable close to his house. He put the dung of the 40 cows into a tank, and passed a rill of water through the tank, and irrigated with the solution 22 acres. With the miscellaneous refuse of his house, the scullery, he irrigated 5 acres. The produce now, from the same 27 acres of land, fertilised by the liquid manure, enables him to feed 40 cows and the 4 horses. It was a very important experiment as to the result of the comparison between the effects of the liquid and the solid manure, on the same land. There were some knolls of land close by, which were elevated, and he could not irrigate; he had not the use of the hose, and whilst he has got four or five-fold crops by the application of the 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 from the same sort of manure, the dung.

I have had a number of other experiments made, all to the same effect; and one thing I find, that by the horticulturists, those who grow large produce and obtain prizes, invariably, so far as I have heard, do it by the application of the manure in the liquid form. I have obtained this further very important conclusion from such facts as I have collected, that an extent of dilution such as extinguishes smell, is about the best for absorption or assimilation by the plant; that all the progress is made by diluting more and more, and applying more and more frequently. A very able horticulturist, Mr Pince of Exeter tells me that he has arrived at this point, that he applies the liquid manure twice a week, and with one of plain water, as he expresses it, 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 two conclusions are in favour of frequent applications of manure in solution, and of getting rid, as much as possible, of fibrous matter.

One practical reason for this course with horticulturists I find to be, the perception that not only does the fibrous matter tend to clog the pores of the soil, or in some way impede the least progress, but that every portion of fibrous matter is apt to become a *nidus* for animacula. It commonly escapes the farmer's attention, that each mass of exposed dung becomes an *officina gentium* of devastating insects, which he unwittingly in that form spreads over his fields, frequently with the seeds of unknown and inconvenient weeds.

Though the loss of manure by surface applications in the liquid form is reduced to the minimum, it is to be borne in mind that even by this method there is still some loss. The great object is undoubtedly to get the whole of the manure in the best form for decomposition beneath the roots; for all matter which is visible must be decomposed before it is absorbed. 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 them 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 are 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 blocking up of the pores of the vegetable tissue by the thick matter.

On the application of manures in a liquid state, Mr Knight, of Downton, observes—

"I have shown in a former communication that a seedling plum-stock growing in a small pot attained the height of nine feet seven inches in a single season; which is, I believe, a much greater height than any seedling-tree of that species was ever seen to attain in the open soil. But the quantity of earth which a small pot contains soon becomes exhausted, relatively to one kind of plant, though it may be still fertile relatively to others: and the size of the pot cannot be changed sufficiently often to remedy this loss of fertility; and if it were so frequently changed, the mass of mould which each successive emission of roots would enclose must remain the same.

"Manure can, therefore, probably be most beneficially given in a purely liquid state and the quantity which trees growing in pots have thus taken under my care without any injury and with the greatest good effect, has so much exceeded every expectation I had formed, that I am induced to communicate to the Society the particulars and the result of my experience.

"I have for some years appropriated a forcing-house at Downton to the purposes of experiment solely upon fruit-trees which, as I have frequent occasion to change the subjects upon which I have to operate, are confined in pots. These were at first supplied with water in which about one-tenth, by measure, of the dung of pigeons or domestic poultry had been infused; and the quantity of these substances (generally the latter) was increased from one-tenth to a fourth. The

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water, after standing forty-eight hours, acquired a colour considerably deeper than that of porter, and in that state was drawn off clear and employed to feed trees of the vine, the mulberry, the peach, and other plants. A second quantity of water was then applied, and afterwards used in the same manner; when the manure was changed, and the same process repeated.

The vine and mulberry tree being very gross feeders were not likely to be soon injured by this treatment; but I expected the peach-tree, which is often greatly injured by excess of manure in a solid state, to give early indications of being over-fed. Contrary, however, to my expectations, the peach-tree maintained at the end of two years the most healthy and luxuriant appearance imaginable, and produced fruit in the last season in greater perfection than I had ever previously been able to obtain it. Some seedling plants had then acquired at eighteen months old (though the whole of their roots had been confined to half a square foot of mould), more than eleven feet in height, with numerous branches, and have afforded a most abundant and vigorous blossom in the present spring, which has set remarkably well; and those trees which had been most abundantly supplied with manure have displayed the greatest degrees of health and luxuriance."

A single orange-tree was subjected to the same mode of treatment, and grew with equal comparative vigour, and appeared to be as much benefited by abundant food as even the vine and mulberry-tree."

Farmers who use town manures, which are too strong for immediate use in the solid form, are in the practice of fitting them for application by fermentation, that is to say, of weakening them by the process of decomposition, in which the loss of manure is proportionate to the length of the process. Instead of speaking of well-fermented dung, it would in general be more correct to say well-wasted dung. This waste is reprehensible enough when it takes place in the farm-yard, but, unfortunately, the process is too commonly allowed to take place amidst habitations, to the great injury of the population, and the prohibition of the practice is loudly called for; the remedy is in the engineering arrangements, by which the strongest refuse is immediately received in water, which is cold, and cold arrests decomposition, and to be conveyed away in covered conduits, to be kept in covered tanks, cool and protected from the influence of the sun. Instead of the manure being weakened by decomposition, it will be weakened, or rather extended and saved, by dilution, for application. It will be kept fresh, and its entire strength will be preserved, for application in the most convenient form. The horticultural experience in respect to the application of fresh manures is thus stated by Mr Knight:—

"Writers upon agriculture, both in ancient and modern times, have dwelt much upon the advantages of collecting large quantities of vegetable matter to form manure, whilst scarcely anything has been written upon the state of decomposition in which decaying vegetable substances can be employed most advantageously to afford food to living plants. Both the farmer and gardener, till lately, thought that such manures ought not to be deposited in the soil till putrefaction had nearly destroyed all organic texture; and this opinion is, perhaps, still entertained by a majority of gardeners: it is, however, wholly unfounded. Carnivorous animals, it is well known, receive most nutriment from the flesh of other animals when they obtain it most nearly in the state it which it exists as part of a living body; and the experiments, I shall proceed to state, afford evidence of considerable weight, that many vegetable substances are best calculated to reassume an organic living state when they are least changed and decomposed by putrefaction.

"I had been engaged, in the year 1810, in some experiments from which I hoped to obtain new varieties of the plum, but only one of the blossoms upon which I had operated escaped the excessive severity of the frost in spring. The seed which this afforded having been preserved in mould during the winter was, in March, placed in a small garden-pot which was nearly filled with the living leaves and roots of grasses mixed with a small quantity of earth, and this was sufficiently covered with a layer of mould which contained the roots only of grasses, to prevent in a great measure the growth of the plants which were buried. The pot, which contained about one-sixteenth of a square foot of mould and living vegetable matter, was placed under glass, but without artificial heat, and the plant appeared above the soil in the end of April. It was three times during the summer removed into a larger pot, and each time supplied with the same matter to feed upon; and in the end of October its roots occupied about the space of one-third of a square foot its height above the surface of the mould, being then nine feet seven inches."

Again, he observes:

"An opinion generally, though I think somewhat erroneously prevails, that many plants, particularly the different species and varieties of heath, require a very poor soil in pots; but these might, I conceive, with propriety be said to require a peculiar soil, for I have never seen the common species of this genus spring with so much luxuriance as from a deep bed of vegetable mould which had been recently very thickly covered with the ashes of a preceding crop of heath and other plants that had been burned upon it. And I believe, if the branches and leaves of the common species of heath were placed to decompose in water, and such water were afterwards given to the tender exotic species, that these, how heavily soever the water might be loaded with organisable matter, would be found as little capable of being injured by abundant food as the vine or mulberry-tree, though the species of food which would best suit those plants might prove to every species of heath destructive and poisonous.

"I had made in preceding years many similar experiments with small trees (particularly those of the mulberry when bearing fruit in pots) with similar results, but I think it unnecessary to trespass on the time of the Society by stating these experiments, conceiving those I have mentioned to be sufficient to show that any given quantity of vegetable matter can generally be employed in its recent and organised state with much more advantage than when it has been decomposed and no inconsiderable part of its component parts has been dissipated and lost during the progress of the putrefactive fermentation."

The experience of horticulturists and agriculturists in England I find corroborated by that of horticulturists abroad, above all by the practical experience of De Candolle, which I shall have subsequent occasion to cite at length. He lays it down as an important axiom, "That 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."

That it may be so, the great object has appeared to me to be, to facilitate and cheapen the expense of its collection, removal, preservation, and distribution by mechanical means.

Taking it as a general conclusion, that the manure should be applied in greater frequency and with more of dilution, the next point of inquiry is, then, as to the expense of the labour by which the operation may be accomplished. It is admitted by horticulturists and agriculturists in Flanders, and in those districts of the Continent where they are the most successful in the application of liquid manures but where the method of application is by hand labour, from vessels carried on labourers' backs, or by cartage after the mode of the water cart, that they apply them in too crude and concentrated a state. But if they dilute the manure in two, three, four, or five waters, or more, they proportionately multiply the expense of distribution. Hence we revert to the topic of the means of improving and cheapening the mechanical means of distribution.

In Mr Holland's experiments, nine loads of night-soil diluted in seventeen of water produced a more fertilising 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 as follows:—

	£	s.	d.
The labour of three men half a day, at 2s. 6d. .	0	3	9
Two horses half a day, at 10s. . .	0	10	0
Spreading, one man, one day . . .	0	2	6
With harrowing, horse and cart, 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, 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 10s., and three men, half a day, at 3s. 9d., or 13s. 9d., exclusively of the labour of making good the pouching.

The expense of the distribution of equivalent quantities of manure would be—

15 loads of the solid manure by cart . .	£1	7	0
15 loads of liquid manure by the water-cart; say	0	13	9
15 loads of liquid manure by 800 yards of hose and the jet at 100 feet of pressure . .	0	1	9
15 loads of liquid manure by a short hose from a stand pipe, on the same principle and at the same expense as street-watering . . .	0	0	6

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 that he could lift a given quantity of manure into a water-cart, say a seven-feet lift, would convey the same liquid as far as the hose may extend to the same level.

Mr Holland's steam engine of six-horse power, by the labour of one engineman and four distributers with hose and jets, distributes three hundred loads of liquid manure in ten hours, over fields much subdivided. 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 appears to me that this method of distribution by hose will be found to be cheaper, particularly when carried out on a larger scale, than by the water meadow.

Having called the attention of Mr Neilson, of Halewood, to the facilities of this method of distribution, by hand-pump and hose, as against the water-cart, he used the method with 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 the 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, about 100 tons of green crop of Italian rye grass and clover from one acre of land.

Night-soil and urine may be delivered in from five to seven and in upwards of eight times its own bulk of water, if delivered at proper seasons and times.

The season for the application of liquid manure 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. The best horticultural practice, however, as already stated, gives it twice a week, with one watering of plain water in each interval: 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 proper days for the application of liquid manure in agriculture are when the ground is not too dry, nor the sun bright, or the wind high, or when the circumstances are unfavourable to a 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 is not so excessively wet as to flood the manure away, but moist, and even showery, to assist in the absorption.

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.

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, Experience in Germany as stated by Sprengel.*

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.

One obvious *disadvantage* of the distribution of liquid manure, of which I would now speak, by the water-cart or the hose and jet, over grass, or over standing vegetation, is the waste of the manure upon the leaves and surfaces where it is not wanted, and some injury to the plant from evaporation and from clogging up its pores. This inconvenience is avoided or diminished when manure is distributed in showery weather, when the rain clears the manure from the leaves.

To facilitate the distribution of manures in dry weather, and to avoid the inconveniences above described, I have proposed the expedient of distributing it by lengths of flexible hose with lateral openings like the eylet-holes of stays. These lengths will be laid on the ground in elevated positions for shedding, and the distribution will take place in a manner similar to the overflow distribution of water by shedding from the carriers of water meadows.

Mr Donaldson has superintended the preparation and adjustment of the sizes of the lateral openings, and 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, which, it will be seen by Mr Holland's table of experiments, (*vide* Appendix,) greatly increases the friction.

As a less expensive means of distribution than the method of distribution by hose, I have proposed for consideration a surface shedding by means of lateral openings from earthenware drain pipes, formed, as I know to be practicable, with screw-joints. I believe that these may be made and laid down far cheaper than the carriers of water meadows, and so constructed as to be taken up and laid down at a comparatively low rate of expense.

I believe that the use of hose (which may now be had of a superior quality at about 1s. 3d. per yard, and will last, with ordinary wear and tear, about six years) in considerable lengths,—upwards of a thousand yards, over undulations of forty or fifty feet, which might be worked by the ordinary farm engine, would pay its expense as trial works, for the determination of arrangements of fixed systems of pipes and distributary apparatus. The hose may be carried over hedges, through ditches and streams. With a slight covering it may be carried temporarily over a road, or under it through a road-drain. Cart-wheels passing over it do not burst it or do it serious injury.

The advantages apparent from the use either of tile pipes or the flexible hose with lateral openings, either as water or manure carriers are: that three-fourths of the surface now used to form fixed carriers for water meadows would be saved; that the flexible hose carriers 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 that there will be the 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 mechanical conveniences and cost of the operation govern and determine the cases for the application of manure either in the liquid or in the solid form.

Great distances or great heights will, no doubt, form natural obstructions to the applications of liquid manures, unless where there is a demand for its application in such quantities as to pay for machinery for high lifts or for extensive pipeage.

My friends, the Rev. Mr Huxtable, and also Mr Graburn, have conducted very successful cultivation by dibbling manures. They place beneath each plant, at a suitable distance from the root, its store of food, and, except as to the supply of moisture, they render it independent of the composition of the soil for food, and in this system they have been eminently successful. I have no doubt that the superabundance of the town manures may be so applied extensively. It might be brought into use immediately, at distant places, before any distributary apparatus can be far extended from towns. For the application of special manures, it might in all cases serve as an auxiliary. It would seem to be a convenient mode of utilising as manure the flesh of dead dogs and other animals.*

It is a common objection to the distribution of liquid manure that its effects are

* There is a great amount of dead animal matter amidst town refuse, such as dead dogs, cats, &c., which would serve as a highly concentrated manure with preparation for transport to distant places.

Mr Graburn informs me that he has rendered down *rats* with sulphuric acid, and that he finds that turnips thrive upon them. Another agriculturist informs me, that having caught great numbers of them, he had them boiled and gave them with meal to his pigs, who had no prejudices, and, like the Romans and the Chinese, relished them much.

not lasting. Much evidence may be adduced to show that this objection is not generally applicable.

It may, however, be submitted for the consideration of agriculturists, as an important advantage of this form of applying manures in the liquid form, that its effects are immediate.

Suppose, for illustration, that bones, applied whole to land, last twelve years, as some bones do under ordinary circumstances. We will suppose further, that twelve tons are applied to a given surface of land, and that one-twelfth, or a ton in weight, is decomposed and given off annually. The slow operation of decomposition will be carried on at all times when the plant is not in a condition to take food, or take it with advantage, as well as in the times when it is. During these long intervals much of the matter given off by decomposition will be washed away by rain, or lost by evaporation.

Now, if, instead of applying the whole twelve tons of bones at once in the solid form, one ton of them were dissolved in the most complete manner, and applied at the proper time over the same extent of surface, the loss from decomposition and rains during the long unproductive intervals, and the risks of other losses, would be saved, and so much larger an amount of production would be obtained as usually to pay well for an additional annual operation in its application.

When the "lasting manures," that is to say, the manures of slow decomposition, are buried in the soil, a course of cultivation is sometimes induced or necessitated for the consumption of those particular manures which the change of the market or of other circumstances renders highly inexpedient. High and quick cultivation, especially market-garden cultivation in the neighbourhood of towns, renders immediate effects highly desirable and necessary. If there be insufficient or mistaken applications of manures, it is to the advantage of the cultivator that the effects should be seen, and the opportunity of correcting the mistake given in the least possible time.

It is an advantage gained to agriculture to diminish the risks of experiments. In cases of changing occupations, it will be mutually advantageous to both parties, and tend to prevent disputes, that the occupier should have the best opportunity of working out completely his own stock of manures, which may not suit his successor's course of cultivation.

Of course liquid manure is subject to the casualties of storms, and may be misapplied in wet weather; but practically it has not hitherto been found, as the farmers term it, so "risky" as top-dressings of solid manure. But the risks of single dressings of liquid manure are diminished in proportion to the frequency of the applications, and by this means may be rendered of very little account. By this mode of application, it may be taken as an axiom, time is saved and risk is saved.

In 1842 I proposed a set of questions on the subject to Mr Liebig, but I only learned in reply that he was unfavourably impressed with the practice of applying manures in their liquid form. His own view was subsequently expressed in a patent for a solid manure. I have not heard of any instance of its success, and I believe it is generally deemed a failure, at least commercially. This failure of the patent composition of solid manure, prepared for slow decomposition to avoid loss, as he expresses it, from "rain or drainage," but which I should contend must extend the exposure and loss during the long unproductive seasons, may have arisen from the reluctance of agriculturists to commit themselves for long periods to a slow and uncertain process, and the increasing desire to obtain more immediate results, which is most important for the saving of time and the advancement of agricultural improvement.

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 may raise and apply with the spoon. Deep colour, and strong consistency and smell, are the first quality 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. If subterraneous distribution be found practicable, we may even have applications of manures in an invisible vapour, in gaseous forms in combination with moisture, as Sir Humphrey Davy applied it successfully. At Milan and Edinburgh, the fibrous or solid matter which farmers now most regard, is found to be of comparatively little value, and the difficulty will apparently be how to dispose of it or turn it to account.

As sanitary results, then, there is little doubt that it is far less injurious to have the refuse of towns in water in the next river than underneath or amidst dwellings; 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 to the surface of land in the common method as top-dressings; but that by applications of manure in the liquid form at intervals, and by means of the hose and jet, or by shedding from the hose and jet, the extent of evaporation may be so far reduced in amount and time as to be inappreciable in effect on the atmosphere.

As agricultural results, these methods greatly reduce the expense of the conveyance and application of manure, and at the same time fit it for admission into land rendered permeable and absorbent by drainage, and by the minute division of the particles of solid manure facilitate its rapid decomposition and absorption as food by the plants.

Several market-gardeners, to whom sewer manure has been offered, have stated that for celery and other descriptions of produce, which they grow, they are apprehensive that the delivery of manure at the surface will not suffice, and that it is desirable, if it be not absolutely necessary, that the manure should be delivered at some depth in the soil. Heavy crops of wheat and barley have been raised by the surface application of liquid manure.

It has been stated to me that sewer manure has been used by a market-gardener near Nottingham with constant and extraordinary success; I presume by surface watering, but I have not received the particulars. Liquid manure has been applied by surface watering in the kitchen-garden at Worsley, and, as I am informed, at a number of other places, with as marked an effect as upon grass-land. Mangel-wurzel, cabbages, and turnips have thriven remarkably upon it. A merchant of Philadelphia (U. S.) who was fond of horticulture, beat all competitors at a show there by the enormous size of his cabbages and other produce. His gardener was seen to draw a liquid from a large hogshead and dispense it, from time to time, to the plants with the watering-pot. There was an intense curiosity to divine what might be the elixir which produced so wondrous an effect. The merchant informed me that he at length yielded to the importunity. He had the top of the hogshead taken off and displayed the contents, the remains only of common stable-dung. He had had stable-dung put into the hogshead, filled it with water, and ordered his gardener to water the plants twice a week with the solution, renewing the water in the hogs-head until no smell remained there from the dung. He had done no more than this surface-watering regularly twice a week.

Keeping in view such horticultural experience as the best guide for agricultural improvements, which will be effected chiefly by reducing the expense of the operations, the question as to the practicability of the distribution of manure by some method of subterranean irrigation is now again brought under consideration, by the market gardeners' declaration of the necessity of having the manure supplied at a depth below the surface, for the supply of the deep-rooted plants.

I submit the following particulars for the guidance of experiments and trial works to determine the practicability of the attainment of that object :—

One of the first points of inquiry appears to me to be, whether we may not avail ourselves of the faculty of the plants themselves to *seek* food or manures by their roots.

In the course of the investigation of the general underground work of drainage and supplies of water, instances were presented of the roots of trees seeking for food suitable to them.

When wooden pipes were in use for the conveyance of water under ground, for the supply of towns, before iron pipes were introduced, one cause of obstruction in the wooden pipes was the roots of trees getting into them. Mr Mylne, the Engineer of the New River Company, stated to me, that formerly if their wooden pipes were carried within thirty yards of trees, they were never safe from having the pipes in time stopped up by the roots. The roots "found" the joints and insinuated through them, and then spread out in "foxtails" of fibrous matter, two or three feet long, which have in time filled the pipes and seriously checked the flow of the water. Similar intrusions have been frequently found in earthen drains and water-pipes; but it has been reported to me by a good observer that roots have not, under similar circumstances, entered open water-pipes of iron or lead. If it should appear that the roots are repelled from entrance by the rust or injurious properties of the metals, that would seem to be an important fact as to the selective powers of the roots.

I have, however, been informed of instances where iron pipes, for the conveyance of warm water under ground, have been curiously surrounded by the root of the vine, which would appear to have sought the stimulus of the warmth.

On taking down the walls of Kensington Garden, which were very thick, it was found that the roots had forced their way through them, to get into a ditch on the opposite side. I have been informed also of instances where roots have forced their way through the walls of houses into house-drains; and one instance has been mentioned to me where, the roots having grown, have in time actually lifted up and split the outer walls of the house.

The strong attraction which the water of drains possesses for the roots growing in their vicinity, has been noticed by Mr J. E. Denison (*Jour. R. A. S. vol.* 1, *p.* 364); when describing the water meadows at Clipstone Park, he observes:—

"Too great care cannot be taken never to carry these deep drains within a very considerable distance of trees; their roots seem to be attracted in a wonderful manner by the moisture of the drains, and if they once find their way into the tiles, they throw out bunches of fibres, which soon mat together and stop the drains. It is astonishing the depth that the roots even of the smaller vegetables will descend after the water: a deep drain outside the garden-wall at Welbeck was entirely stopped by the roots of some horseradish plants at the depth of seven feet in the ground. At Thoresby Park, Lord Manvers's, a drain fourteen feet deep was entirely stopped by the roots of gorse growing at a distance of six feet from the drain. At Saucethorpe, an estate of Lord Manvers, in Lincolnshire, a drain nine feet deep was filled up by the roots of an elm tree which was growing upwards of fifty yards from the drain; but under these peculiar circumstances;—the elm tree grew at the end of a sunk fence, the wall of which was formed of turf. The root of the elm got between the turf wall and the solid bank, and worked its way along till it got into the drain, which it soon filled up. The roots of all trees will stop drains, but especially of soft-wooded trees, such as willow, alder, poplar, &c. Ash trees, too, are very dangerous neighbours to deep drains. In one case the roots of grass stopped a drain two feet deep in the parish of Mansfield Woodhouse; the drain had been carried across a field of old turf to convey water for cattle from a higher level. The explanation of this disposition of the roots both of vegetables and trees to strike deeper than ordinary in pursuit of drains appears to be this:—in digging the drains, the sides are cut down straight, and the ground left like walls on each side, while over the drain the earth is all moved; between the solid and the moved soil for a long time something like a fissure or crevice remains. When the roots in their progress through the solid land reach this fissure, they pass down it, and so follow its course into the drains."

It may be observed, however, that the thorn does not send its roots down far. By observation of the habits of trees, by carrying water in close pipes near trees whose habits are known, much land and road drainage may be conducted near hedgerows with trees.

Mr Knight of Downton has given the following instances of the government of

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the direction and growth of the roots of plants, by the position of the supply of food in respect to them.

"When a tree which requires much moisture has sprung up or been planted in a dry soil in the vicinity of water, it has been observed that much the largest portion of its roots has been directed towards the water; and that when a tree of a different species, and which requires a dry soil, has been placed in a similar situation, it has appeared in the direction given to its roots to have avoided the water and moist soil.

"A tree growing upon a wall at some distance from the ground, and consequently ill supplied with food and water, has also been observed to adapt its habits to its situation, and to make very singular and well-directed efforts to reach the soil beneath by means of its roots. During the period in which it is making such efforts, little addition is made to its branches, and almost the whole powers of the plant appear to be directed to the growth of one or more of its principal roots. To these much is in consequence annually added, and they proceed perpendicularly towards the earth unless made to deviate by some opposing body; and as soon as the roots have attached themselves to the soil, the branches grow with vigour and rapidity, and the plant assumes the ordinary habits of its species.

"Duhamel caused two trenches to be made so as to intersect each other at right angles, and a tree to be planted at the point of intersection; and taking up this tree some years afterwards, he found that the roots had almost wholly confined themselves to the trenches in which the soil of the former surface must have been buried.

"A trench which was twenty feet long, six wide, and about two deep, was prepared in my garden, in the bottom of which trench was placed a layer about six inches deep of very rich mould, incorporated with much fresh vegetable matter. This was covered eighteen inches deep with light and poor loam, and upon the bed thus formed seeds of the common carrot (*Daucus carota*) and parsnep (*Pastinaca sativa*) were sowed. The plants grew feebly till near the end of the summer, when they assumed a very luxuriant growth, grew rapidly till late in the autumn, and till their leaves were injured by frost. The roots were then examined, and were found of an extraordinary length and in form almost perfectly cylindrical, having scarcely emitted any lateral fibrous roots into the poor soil, whilst the rich mould beneath was filled with them.

"In another experiment of the same season, the preceding process was reversed, the rich soil being placed upon the surface and the poor beneath. The plants here grew very luxuriantly and acquired a considerable size early in the summer; and when the roots were taken up in the autumn, they were found to have assumed very different forms. The greater part had divided into two or more unequal ramifications, very near the surface of the ground; and those which were not thus divided tapered rapidly to a point at the surface of the poor soil, into which few of their fibrous roots had entered.

"In other experiments, seeds of almost all the common esculent plants of a garden were so placed that the young plants had an opportunity of selecting either rich or poor soil, which was disposed, in almost every possible way, within their reach; and I always found abundant fibrous roots in the rich soil, and comparatively few in the poor.

"The following experiment afforded the most remarkable result, and one of the least favourable to the hypothesis which I have advanced in a former paper, and to the conclusion which I shall now endeavour to support; and therefore I think it necessary to describe it very minutely. Some seeds of the common bean (*Faba vulgaris*)—the plant with which many former experiments were made—were placed upon the surface of the mould in garden-pots, in rows which were about four inches distant from each other. A grate, formed of slender bars of wood, was then adapted to the surface of each pot, so as to prevent both the mould and the seeds falling out in whatever position the pots might be placed, and the bars were so disposed as not at all to interfere with the radicles of the seeds when protruding. The pots were then directly inverted, and the seeds were consequently placed beneath the mould; but each seed was so far depressed into the mould as to be about half-covered, by which means each radicle, when first emitted, was in contact with the mould above and the air below. Water was then introduced through the bottom of the inverted pot in sufficient quantity to keep the mould moderately moist; and the pots being suspended from the roof of a forcing-house, the seeds soon vegetated.

"In former experiments wherever the seeds were placed to vegetate at rest, the radicles descended perpendicularly downwards in whatever direction they were protruded; but under the preceding circumstances they extended horizontally along the surface of the mould and in contact with it, and in a few days emitted many fibrous roots upwards into it just as they would have done if guided by the instinctive faculties and passions of animal life; and as I concluded before I made the experiment that they would do under the guidance of much more simple laws, whose mode of operating I shall endeavour to explain."

Another question suggests itself to me to put for investigation, whether we may not avail ourselves of 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; they would not take up the particles of charcoal and other substances which he diffused through water. Meyen and other naturalists found that the colouring matter of various infusions is not taken up by the roots, as imagined, and that when this has been supposed to have taken place it has arisen from mistaking a deposition of the colouring matter outside the plant for an absorption into it. This, which I venture to designate as the selective power of the roots of the plants, appears to be a most important property for practical application to the absorption of town manures, which, consisting of the *excretæ* of everything taken into the town, are in the highest degree miscellaneous. In the instance which I met with of one portion of a field irrigated with water which had passed through a pit of cow-dung, and another portion irrigated at the same time with the drainage from a house, the kitchen, scullery, &c., the 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. From other observations, I might deduce the general rule, that miscellaneous manures, the quantities being the same, are more fertilising than single manures.

The quantity of the refuse from dye-works, and the mineral 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 indigo and woad. Very little mineral matter is discharged from such works. 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 is a fact also corroborative of the view taken of the importance of the extensive diffusion of manures in water, and frequent applications in weak solutions, rather than single or unfrequent applications of concentrated solutions.

The selective property of the roots of plants has been turned to account by horticulturists, or at least by Mr Pince of Exeter, for so governing the formation of the roots of plants as to adapt them for easy and successful transplantation.

The roots of many plants, and especially of the Scotch firs and other coniferous plants, strike deep tap-roots which it is very difficult to transplant. To produce a short, wide-spreading fibrous mass of root, instead of the long tap, Mr Pince takes this course: He rakes out the beds to the depth of nine inches; at the bottom of the bed he places three inches of "well-decayed" dung; over that about four inches of earth; upon that the seed is placed, and over the seed a covering of about an inch and a half of earth. The roots never strike through the stratum of dung, but spread wide above it. They are thus grown in a condition to be easily taken up, and easily transplanted.

This formation of root is generally found to be the most advantageous. As a general rule, "shallow feeding" is the most productive: where the tap goes down deep, there is much wood and fibre, and little produce; the best average production is got by roots in beds of soil of about nine inches deep, and eighteen inches from the surface is a maximum depth. But though this is the result of horticultural experience as to the range within which roots may spread most advantageously, it is not the range within which the bed of earth requires to be prepared for the best vegetable productions.

Mr Pince drains and trenches his soil to the depth of from two to three feet from the surface; the object being to keep a bed of earth permeable at all times to the air; to that depth, at least, to let surface water permeate it freely; also to prevent the water being in such quantity as to fill up the pores of the earth, and as to render it impermeable to air. The rationale of the *modus operandi* of the quality of permeability in the substratum, does not appear yet to be completely made out. Though it has not been proved, there is reason to believe that there is a better warmth preserved by the permeability of the substratum: the fact, however, is undoubted, that though any influence from beneath might be supposed to be interrupted by the dressing or stratum of dung, plants grown as above described are greatly benefited by the deep trenching of the land. Mr Pince lays great stress also on the advantages of breaking the *bottom crust* of every trench, as deep as can be done. This soil is comparatively unfertile, and should therefore be only broken and turned over in the bottom of the trench; and as he says should not, on any account, be brought up to the surface. It may be observed further, by the way, that so much of the important theory of thorough-draining as proposed by Mr Smith of Deanston, of draining *through* the bed of earth instead of over it, as includes the preparation of a deep bed of earth permeable to air as well as water, has been in full practice for many years by the best horticulturists. It will be seen in the construction of their pots, with several holes to admit air, instead of the single hole which first sufficed for the purpose, the discharge of surplus water in the stratum of stones or pieces of broken pot, or other materials, which may admit that permeation of air, underneath the fertilising stratum, which it is the object of the subsoil-plough to accomplish, as it were, by wholesale and by cheaper mechanical means, in the substratum of the field.

I find, on further inquiry, important instances where the properties of the roots of plants have been used in connexion with means of the subterranean distribution of water to them. De Candolle mentions that in the Island of Corfu they place near the roots of orange trees porous earthen vessels filled with water, which gradually filtrates through.

Some of the hand-loom weavers in Lancashire, who have pursued zealously one branch of horticulture, and have cultivated gooseberries for prize-shows, have found out the property, and have placed permeable earthen vessels amidst the roots of their gooseberry trees, and filled them with water, so as to give the supply of water by a gradual infiltration.

Having indicated subterranean irrigation as a means of distributing manure, as well as of water, before speaking of the mechanical means of doing so, I will advert to the advantages to be derived from a subterranean distribution of plain water, as compared with the process of the common "surface-watering."

The practical *disadvantages* attendant on surface-watering for horticultural purposes are as follows:—

First, that,—varying with the temperature at the time of the application of water,—the water evaporates, and all evaporation lowers temperature. The cold water itself, or the evaporation of the water, chills the warm saps.

This circumstance limits the time of the application of water at the surface to those hours of the day when the sun's rays are the least powerful: whereas, it is at that time when the sun is the most powerful, when there are the full stimuli of the action of light and heat, that the plant is in the greatest want of support, and would feed the most freely. This is proved by the fact, that when some of the tropical plants are put in the shade by means of hothouse blinds in hot weather, they are freely watered in midday and thrive excessively, and are advanced in our hothouses beyond their native condition.

One incidental disadvantage of surface-watering is, that drops of water frequently act as lenses, and burn holes in, or blister the plants: another disadvantage incidental to the practice of surface-watering is, that when liquid matter or manure is thrown on the leaf, it is apt to clog the pores, and otherwise injure the plant.

Secondly, surface-watering washes or soddens or hardens the surface, and closes the surface to the permeation of air to the roots; and when the surface which has been so hardened cracks, it often lets in air in too great a quantity.

To obviate these disadvantages, it is the practice of able practical horticulturists to "mulch" the plants; that is to say, to cover the roots with two or three inches of rotten litter, or anything that tends to prevent the effects of the sun's rays, or to check the surface evaporation of the water. The watering takes place over this "mulch;" it falls through so irregularly, that it cakes the earth less than the direct surface-watering. The disadvantages of mulching are, that besides the labour and expense, it brings the roots or the spongioles to the surface in search of the water, and they are apt to suffer by the exposure when the "mulch" is removed: besides this, it harbours vermin, slugs, and the larvæ of all sorts of insects, and is a clumsy application.

To avoid or to diminish these disadvantages, a practice has been adopted amongst horticulturists, of spreading water over rough pavements in their hothouses; forcing water through extremely small apertures, so as to deliver it in the form of "a mist;" using all means to saturate with moisture the atmosphere in which the plant is placed; and causing as much water to be imbibed by the soil, and by the leaves, in every other way than by the common mode of the direct water shed on the surface.

For the delivery of plain water, then, as well as the delivery of manure, the subterranean irrigation, if it can be made practicable, will have great advantages.

Since an extent of dilution of manure to perfect transparency and fluidity is the most conducive to the growth of plants when gradually supplied, I propose for market and kitchen-garden and horticultural cultivation, in the first instance, an extension of the recited practice, and the conveyance of liquid manure, by the method of subterraneous infiltration, or irrigation.

The point for inquiry is whether the object may not be attained by conveyance in earthen pipes; first, entirely open at the extremities, or with large mouths to admit the roots as far as they choose to enter and grow; secondly, with extremities of small capillary tubes, for the emission of the liquid manure, so as to moisten the earth near or beneath the roots; thirdly, with extremities closed, but permeable from the porosity of the material.

It suggests itself to me that the system of permeable agricultural drain-pipes, which receives or conveys one description of liquid, *i. e.* simple water, (which not unfrequently, however, contains much soil or manure in suspension,) may be used for a reverse operation, and be made to convey liquid manure, and shed it from the openings along the whole length of the pipes into the soil, in the method in which Count Manetti informs me has been accomplished in Switzerland.

The pipes should be arranged at distances suitable to the plants, and with the stronger manures might be made to work on the principle described as carried on in the practice of Mr Pince. By means of a stand-pipe and hydraulic pressure, the manure might be expelled with whatsoever degree of force was required; and with a proper inclination, the superfluous liquid might be immediately withdrawn from the pipe.

Except for very deep distributions, I should conceive the pipes might be taken up, cleared from obstructions, relaid, changed in their direction, and re-adjusted, according to the requirements of the plants.

From what has before been said, it may be anticipated that the spongioles will enter the pipes and choke them up.

For the roots of trees, and of many plants, I would suggest that trial arrangements should be made expressly to give them admission into the open mouths of branch pipes from the main irrigators or feeders. It would be one object of experiment to ascertain what length and size of branch would suffice for them to keep them out of the reach of the main feeders. The branch or branches should be sufficiently large to allow the root to expatiate as it were, and admit a wave or feed of prepared liquid manure to pass through the whole length of the spongioles.

As already stated, it does not appear to be desirable to give the manure in such a state as to realise the apprehension expressed by Count Manetti, that it must clog up the conduits. If it be given in a state of intensity, as it may often be conveniently, the effect already described in the statement of the practice of Mr Pince may be produced, and the spongioles keep their own proper distance. By hydraulic force the liquid manures may be at once injected and placed for decomposition and absorption in nature's own laboratory, beneath and amidst the absorbents, the roots of plants.

It appears, on the other hand, to be practicable to deliver liquid manure in such a state of transparency, as to carry out, on a large scale, the method of subterranean irrigation with liquid manure which is in use at Corfu, with water, through porous pipes or permeable substances.

Earthenware wicks for lamps are now made with capillary tubes, by intermixing in the clay, cotton threads of the required size and direction. In the firing of the clay, the cotton fibres are decomposed, and the tubes which they have formed remain. Lord Ebrington has suggested that the object might, for agricultural purposes, be obtained with less expense by using some description of grass, or vegetable fibres of the required thickness, and sawdust, which is entirely consumed in the kiln, has been successfully mixed with clay to produce porous vessels. In some cases, wires might be used, to be drawn out before the pipes are placed in the oven. The tubes of tobacco-pipes are thus formed.

Porous extremities may be made, as the earthenware coolers or vessels for India are made, permeable (for cooling, by the evaporation of water from the surface) by a slight baking. In some cases, species of sandstone, such as those used for filters, and of which sandstone tubes have been formed, might be cemented with

Roman cement; in other cases, sponges or spongy materials, moss and peat, might be used for the purpose.

For the permeable earthenware extremities, it would be requisite that the liquid manures should be delivered perfectly transparent, and free from fibrous or viscid matter. The sandstone filters, in time, clog up; it might be requisite to provide by a proper joint for taking up this description of extremities, from time to time, for the purpose of cleansing. Tobacco-pipes which have been used are cleansed of soot in the tubes by putting them again in a fire: this or other modes might be used; but the permanent clogging-up of the pores may be avoided or diminished by passing all the liquid manure through a large sandstone filter: before it is allowed to pass into the pipes, care should be taken in respect to the capillaries, that they should gradually increase in size towards their extremities, so that particles which have once entered may have a progressively wider exit: when formed with this precaution, they may be cleared by simple hydraulic pressure.

The ascertained data all raise the confident presumption that the increased production will abundantly repay the expense of the apparatus, and the labour of keeping it in order.

It appears to be desirable to convey the supplies within reach of the spongioles of the plants, that is to say, at the extremities of their roots, but a little beneath them, so that the decomposed manure which ascends in moisture by capillary attraction, or in the gaseous forms, and so that the spongioles, may descend and adjust their own position. De Candolle observes, that in general the extremities of the roots are nearly at the same distance as the extremities of the branches; that nature has thus provided for throwing off the rain or giving the greatest quantity of moisture at the spot where are the spongioles, with the greatest capacity for its absorption; that the watering of plants should never therefore be beneath the outer branches.

Where a supply is afforded only to one portion of a root, as in the fortuitous instances first noticed, of a portion of the root of a plant finding its way into a water-pipe or drain, it would seem that the vessels of that portion must be overloaded, or that the production would be greatly advanced by giving occupation to each portion of the root as fairly and equally as possible.

The adjustment of the pipes and apparatus would require much experiment, but the most rude attempts could scarcely fail to be a gain on the existing practice.

The formation of curved and branch drain-pipes is a desideratum; but until that is obtained, we may, with Roman cement or dry clay moulds, form branches and make joints, and as a makeshift lay down straight pipes in hexagons round the roots of trees.

Tubular drains are made of clay which is stiff but moist, and which, it is stated, have been known to run for upwards of twenty years. Experimentally in hothouses, and as makeshifts, adjustments of tubular rolls of clay near the roots of plants, and opening from the earthenware pipes, might be tried.

For the equal adjustment of the distribution, the pipes should be laid upon a level. Where the surface of the ground undulates, they should keep the levels by contour lines of equal altitudes. By a stand pipe, or a force pump, equal pressure may be given at once over a whole line of pipes for the distribution of the supply.

Let us now consider what we may expect as the eventual economy of the principle of subterraneous irrigation.

Six years ago, no drain-tiles were to be had at less than 45s. or 50s. per 1,000. Now, a very superior drain-tile pipe may be manufactured at 10s. per 1,000; that is to say, 1s. per hundred of fourteen-inch pipes, or fourteen feet of piping for three halfpence. It is probable that the construction may be yet greatly improved by machinery: pipes with cone joints, which seem to answer extremely well, are made at Castle Hill, at double the expense, or at one farthing per foot. It seems probable that, manufactured on a large scale, and with improved machinery, curved and branch pipes might be made (and even laid down) with the adaptations requisite at a penny per yard.

We will assume that price as attainable for large quantities; and as the depths required would not be more than twelve or sixteen inches, the expense of laying the pipes would not be above a third more.

At the distance of a yard apart, an acre of land will hold 4,800 plants; perhaps 8,000 yards of pipes, for branches as well as mains, would afford a complete distributary apparatus for all ordinary cultivation; and this might be laid down probably at an expense of about from 25*l.* to 30*l.*, the depth required not being greater than might be accomplished by deep ploughing.

For the mains, pipes of an inch in diameter, and for the branches half an inch in diameter, might suffice: suppose 4,000 yards of piping of each size. Four thousand yards of pipes of one inch in diameter would require 406 gallons to fill them; 4,000 yards of half-inch pipe would require 100 gallons of liquid manure or water to fill them, or 25 cwt. of liquid.

Supposing each watering-pot to hold two gallons, we have here the means of distributing, in a few minutes, 300 pots of water, accurately, to nearly 5,000 plants. The process might be graduated to the slow infiltration which experience might direct for each species of vegetation.

With a common pump, one man might effect the delivery of 500 gallons of water to 5,000 plants in 20 minutes: with the hand and the watering-pot, that same man would require six hours to effect the same operation.

A horse-power will raise 330 gallons or 52 cubic feet of water 10 feet high in a minute. The powers of pumps vary; but it is stated that a good six-horse steam-engine will raise 1,500 gallons a minute 10 feet high by one of Burton's pumps, and would consequently do the work of 15 men for as many acres. This view of the power of steam in the distribution of liquid food to plants will not appear extravagant to one who considers the actual practical working of the same power in the distribution of water to houses. I have sat in chambers, and heard in the water-pipes the pulsation from the stroke of a steam-engine at some four miles' distance. At each stroke of that same engine, it was powerfully impelling the supplies to 50,000 houses. It is physically as possible to have distributed the supplies to 50,000 trees or plants by each stroke of the piston.

The power derivable from 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, without foundation as I conceive, from general agriculture, namely, the "market garden cultivation;" it is only imperfectly practised in horticulture. I have been informed of the successful watering of wheat under particular circumstances. In the market garden cultivation at Naples and Paris, effects unknown in this country are stated to me to be produced by skilful watering. 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, for which, however, the extra produce compensates. The distribution of plain water, by means of the hose and jet, I proposed in 1842; but the farmers near Worsley, who have had the opportunity, have not yet availed themselves of the power. Some of the more eminent market gardeners near London would, however, appreciate the advantages of any appliances for the cheap distribution of water as well as of the manure. The late Mr Knight, of Downton, thus stated his own experience of the benefits derivable from it:—

"The quantity of water which may be given with advantage to plants of almost every kind during warm and bright weather is, I believe, very much greater than any gardener who has not seen the result will be inclined to suppose possible, and it is greater than I myself could have believed upon any other evidence than that of actual experience.

"My garden, in common with many others, is supplied with water by springs which rise in a more elevated situation, and this circumstance afforded me the means of making a small pond, from which I can cause the water to flow out over every part of my garden whenever I wish. I am thus enabled to irrigate my strawberry-beds whilst in flower, and my Alpine strawberry-beds, and plants of every other kind through every part of the summer; and I cause a stream to flow down the rows of celery, and along the rows of brocoli and other plants which are planted out in summer, with very great advantage. But the most extensive and beneficial use which I make of the power to irrigate my garden by the means above mentioned, is in supplying my late crops of peas abundantly with water, by which the ill effects of mildew are almost wholly prevented, and my table is most abundantly supplied with very excellent peas through the month of October, as I have stated in a former communication. Several of my friends who have caused large quantities of water to be carried have obtained abundant crops late in the autumn of the variety of pea which bears my name; but they have complained that the birds have eaten the whole crop. This will almost always occur where means are not taken to prevent it; but there are only two species of bird which ever break open the pods of green peas,—the large black-headed, and the blue titmouse (the *Parus major* and *Parus cæruleus* of Linnæus), and both these are very easily caught. The coal-titmouse, the nuthatch, the chaffinch, and the robin, will eat the peas when the pods are opened, but neither of these ever break them. For the purpose of taking such birds I employ a little trap which

I invented when a schoolboy, and which secures without injuring them, and enables me to release the unoffending; and I do not find the smallest difficulty in preserving my crops of peas in any season.

"When water is delivered in the usual quantity from the watering-pan, its effects for a short time are almost always beneficial by wetting the surface of the ground. But if water thus given be not continued regularly, injurious effects frequently follow, for the roots of plants (as I have shown in the 'Philosophical Transactions,' in a paper upon the causes which direct the roots) extend themselves most rapidly wherever they find proper moisture and food; and if the surface alone be wetted, the roots extend themselves superficially only, and the plants consequently become more subject to injury from drought than they would have been if no water had been given to them; a circumstance which can scarcely have escaped the notice of any observant gardener. When, on the contrary, the soil is irrigated in the manner above recommended, it is wetted to a great depth, and a single watering once in eight or ten days is in almost all cases fully sufficient.

"I have found the advantage of being able to command by the means above-mentioned abundant water at all seasons, and at very small expense, so great that I feel confident that a market gardener could in many cases afford to give as much rent for one acre as he could, under ordinary circumstances, give for two acres; for he would not only be able generally to command more abundant crops, but by possessing exclusive advantages, he would often in unfavourable seasons be enabled to raise abundant crops of articles which in such seasons usually take a very high price. In selecting the site of a garden, the advantage of irrigating it by the means above-mentioned may very frequently be obtained, and the number of gardens above which a small tank or pond might be easily made is probably much greater than at a first view will be supposed.

"It may be objected that excess of rain is more often injurious in the climate of England than drought, but in wet seasons plants suffer owing to want of light and generally of warmth; and I feel confident that if the same quantity of rain which the soil receives in our wettest summer were to fall only between the hours of nine in the evening and three on the following morning, and the sun were to shine brightly and warmly through the whole of the day no injurious effects would follow; and every experienced gardener knows with what luxuriance and rapidity plants of every species grow in hot and bright weather after the ground has been drenched with water by thunderstorms."

The advantages which the combination of manuring and irrigation offers in permeable soils, would totally change the value of many which are now left waste. Bousingault observes upon this topic—

"A light, sandy soil, which in the south of France would only be of very inferior value, 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 nearly the whole of its interest. 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. Sandy deserts are sterile because it never rains. 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 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 transparent 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 of 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.

I have only to direct attention to the fact that the manure or water would not be lost by evaporation, or being distributed where it was not wanted, or where its action must be indirect or inefficient. The saving, therefore, which is promised, is—

In Labour,
In Time,
In Manure,
In Certainty and Exactitude of the Operation.

To what extent these objects may be obtained, could only be determined experimentally; but the experiments might probably be made at a very slight expense by those who will study the principle and the means of their application.

It is presumed that the land would be properly drained, and otherwise fitted for the discharge of surplus moisture and the permeation of air. By horticultural or market-garden cultivation, by high manuring, crops are often obtained from the same descriptions of land double those obtained by any ordinary agricultural cultivation.

It is admitted to be the great desideratum to transfer to agriculture, garden-cultivation; to economise the labour of garden-cultivation by labour to be effected by the application of machinery,—by the plough, by clod-crushers, and by other machines for preparing the land for the reception of the seed. It seems to me, in the situations under consideration, namely, those near towns and eligible for high cultivation, we may expect immense advantages from the application of steam power, the pump, and hydraulic apparatus of fixed pipes for subterranean irrigation, and the moveable hose for the distribution of manures and earths on the surface.

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APPENDICES.

No. I.—Mr Donaldson's Report on the Paper on Subterranean Irrigation.

February 14th, 1849.

Having read the paper prepared by Mr Chadwick on subterranean irrigation, I am of opinion that it may be carried into practice by various methods which readily suggest themselves on considering the subject, by which the liquid may be so applied that the plants may feed thereon according to their nature and habits of growth. For such as are termed gross feeders, the liquid may be applied by means of common agricultural drain pipes, laid in lines, suited to the distance apart of the rows of plants, at a depth suited to the roots of the plants. Pipes joined by collars will, I apprehend, be found well suited for this purpose, the collars serving to divide the outflow from each joint and diffuse it more equally throughout the soil. The pipes so laid down on a field of any given area may be supplied with the liquid by means of a cross pipe at one end of the field connected with one end of each line of pipes. And such cross pipe may be supplied by means of a trough or cistern placed at one end, into which the liquid may be received from the main pipes daily in such quantity as may be necessary.

The expense of this method will amount to little more than the price of the pipes required, as they can readily be laid down in the process of digging the ground; and having once been laid down, they will, with occasionally cleaning out and relaying, last for many years. An acre of ground laid with pipes in lines three feet apart (which probably will be found suitable for a great proportion of market-garden crops) will require 14,520 feet of drain pipes, which, at the present price, 22s. per thousand, will amount to the sum of 15*l*. 19s. 5d.; and an equal number of collars, at half the price of the pipes (the usual proportional rate), to a further sum of 7*l*. 19s. 9d.: making together 23*l*. 19s. 2d., being under the average cost of solid manure for one year according to the present system.

And when once the pipes have been laid down, the cost of applying the liquid manure (sewer water) in any quantity, must be very trifling; and when, in the course of two or three years, the pipes require to be taken up, cleaned, and relaid, the expense of doing so will not exceed 20s. or 21s. an acre.

By this mode of its application the liquid may be used at any time, and applied to the crops at any stage of their growth, without trampling the ground, or injuring the plants, or in any way interfering with the hoeing, weeding, or otherwise cultivating the surface: avoiding also the surface crust frequently produced by surface watering.

For plants of delicate growth, or where a liquid manure of greater value is to be applied, a system of impermeable pipes with cups of permeable surface placed under the roots of each plant, may be preferable.

For such purpose, pipes of the ordinary material, with socket-joints, and joined with a luting of well-prepared clay, will answer very well; such pipes having apertures at suitable distances apart for attaching the permeable cups for feeding the plants. By a method somewhat similar, a great many plants or crops may be grown in pots, arranged so as to admit of being supplied with the liquid from a pipe laid alongside them, having a little cup in each pot by which may be supplied the precise quantity of liquid necessary.

The objection raised by some market gardeners against the surface application of liquid manure "That thereby the fertilizing matter is placed too near the surface of the ground," is by subterranean irrigation completely obviated. Another point of some importance is, that by the use of a jet in applying the liquid a portion of the ammonia unavoidably escapes into the atmosphere and is lost, producing for a short time an effluvium which it is desirable to prevent. Another important point is, that by this method any required quantity of the liquid can without difficulty or loss of time, and at very little cost, be applied to any extent of land under crop, and at any stage of its growth, at the precise time when it is most suitable, there being no occasion for a number of hands being employed, as with the hose-pipes and jet. This will be found of more importance in practice than may at first appear likely; as it is probable that the liquid will be wanted upon a great many fields at one and the same time, and the possibility of any number of men with their apparatus of hose-pipes and jets being wanted at several places at once, on one day, and not wanted next day anywhere, is evident.

The process of growth and period of ripening of many crops may be in some degree regulated by a liberal application of the manure while they are growing, and withdrawing it when the proper time for ripening arrives; or, the growth of one portion of the field may be accelerated and that of another retarded by regulating the quantity applied at certain times.

In sudden changes of temperature, often injurious to crops in a state of luxuriant growth, the quantity of liquid could be so regulated—increased, diminished, or withdrawn altogether—as to prevent, at least to some extent, the injuries to which crops are in such cases liable. And in case of a continued heavy rain, by which the grounds were likely to be rendered injuriously wet, the irrigation pipes would be available for draining off a great portion of the superfluous moisture. For this purpose an outfall would have to be provided, into which the contents of the pipes could at any time be discharged by means of a penstock in the outfall pipe.

The application of manure by this method to any extent of land, in any number of fields, is so easy and so completely under the control of the market gardener himself, who by the mere turning of a tap can apply just what quantity he sees fit, that every objection that has been urged against the *modus operandi* of applying liquid manure appears completely obviated.

The main pipes through which the liquid is conveyed to the farms or gardens being kept constantly charged under pressure, the quantity served to each purchaser could either be *ad libitum*, or might be delivered by turncocks, as is now done with water for household purposes by the present Water Companies; each gardener having one or more cisterns for receiving daily such quantity as he requires.

These hints are thrown out more for the consideration of those interested than with a view to pointing out the best mode of its application, and any one may easily satisfy himself by an experiment on a small scale as to the practicability and efficacy of the plan.

G. DONALDSON.

	Feet Apart.	No. of Plants.	Feet Apart.	No. of Plants.	Feet Apart.	No. of Plants.
The number of Plants which may be planted on a Statute Acre=160 Rods, or Poles = 4,840 yards = 43,560 feet, is as follows:—	1	43,560	6	1,210	15	193
	1½	19,360	7	889	16	170
	2	10,890	8	680	17	150
	2½	6,969	9	537	18	134
	3	4,840	10	435	19	120
	3½	3,556	11	360	20	108
	4	2,722	12	302	21	98
	4½	2,151	13	257	25	69
(*Loudon's Encyclopedia of Gardening*, Ed. 1835, p. 1121.)	5	1,742	14	222	30	48

No. II.—Paper on the Application of Liquid Manures, by De Candolle.*

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.

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; 2nd, 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 are to be distinguished of using liquid manures: 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 render 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

* 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.

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 applicable generally.

ON THE MODE OF COLLECTING LIQUID MANURES.

The liquid manures used in agriculture are—first, the 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. They give the name of "lizier" (in German, Gülle) 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 recommended by the agriculturists of Zurich of collecting this manure 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 overnight, 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.

2nd. They give the name of manure water (in German, Jauche) 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 carbon (*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 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 washhouses may be collected either into the vessel of "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 dung-hill 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 into 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.

No. III.—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 night-soil 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 cess-pool 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 night-soil, 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 farther 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 2½d. for a measure containing 22 gallons. In Flanders, it is held that this quantity, which will weigh hard upon 2 cwt., is equal to about 5 cwt. of farm-yard dung.

No. IV.—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 to 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.*)

No. V.—Account of the Irrigations with the Town Manure from Milan, forwarded to E. Chadwick, Esq., 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 brick-work, 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 water-closets 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 Seves, 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. The 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 same 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. *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 authorised 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.

No. VI.—Account of the Irrigations with the Town Manure from Edinburgh, given by Dr James Stark.

I now come to your queries as to the irrigated meadows—a difficult subject on which to give you such information as is applicable to all cases—seeing that the practice of different irrigators varies according to their command of water, and the extent of the meadow when watered. To enable you to have some guess as to what number of acres may be advantageously watered by a certain amount of sewer water, I have taken much trouble to ascertain the existing number of acres, Scots measurement, watered by the foul burn, or sewerage water of drains, shortly described in the second and third paragraphs of p. 2 of 'Inquiry,' beginning "The drainage," and ending "open channels to the sea." This drainage, proceeding chiefly from the Old Town, is not half so great in amount as it would be had these old tenements a supply of water and of water-closets; yet it waters abundantly at the present moment one hundred and seventy-two Scots acres of land, and it is proposed to bring in fifty more acres this year—the utmost the present supply could irrigate.

The first thing done is to level and thorough-drain the land, and divide it by proper ditches into small portions of about half-an-acre each. The land being all ready or the last cutting being taken the 30th or so of October, the watering for the next season's crop commences the first week of November; the water is laid on a fresh portion of the divided meadow every other or every third day, so that some portions are always watering while the others are drying. The whole sewer water is thus constantly used—none being allowed to run waste. Those who have a small extent of meadow to water, and more than an abundant supply, continue the watering of each portion for several days at a time, then intermit for a fortnight, and lay on the water again. Those who have a larger extent of meadow to irrigate, and of course a smaller proportional supply of sewer water, only irrigate each lot, or division, *once every fortnight*, the watering being continued to each division during the space of one day—and night also, if practicable. That no water may ever be allowed to run waste, the small half-acre divisions are classed into fourteen or sixteen larger divisions, and the whole supply of sewer water is laid on each of these larger portions *seriatim*, once every fourteen or fifteen days, so that by the time the whole divisions have been once watered it is time to bring back the water to the first watered lot. The more water each portion receives, the larger is the crop raised on it, and the higher the price got for that crop in the market, so that while the lots which are watered only once in the fortnight in general bring only from 23*l.* to 30*l.* per acre, annually, those which receive a larger supply let for from 28*l.* to 50*l.* each per acre. The above watering is continued uninterruptedly at the same intervals of time to each portion *during the whole year*, so that it will be apparent that though the whole meadow is not under water at the same moment, but only its 14th or 16th part, still the whole sewer water is used for watering one or other portion of the divided meadow. This water is never kept in tanks or ponds for the purposes of irrigation, as it is found to deposit a considerable proportion of solid matters, which are worth from 2s. 6d. to 5s. per ton, as a manure for gardens. But such tanks and ponds are a constant source of sickness, and ought never to be allowed in any circumstances. During heavy falls of rain, when thick mud is carried down with the sewer water, the whole is allowed to flow direct into the sea—experience having shown that such water cannot be used for the purposes of irrigation, excepting during the winter season, when there is no growth. If by chance used during summer, it destroys the next cutting, rendering it so sandy and tainted that the cattle refuse to eat it.

The best meadows yield from four to five cuttings annually, the poorest three cuttings only. If allowed to stand too long on the ground, the crop rots at the root—its excessive weight causing it to fall over and heat—just like laid white crop.

To come to exact particulars—Craigentinny meadows, consisting of 144 acres, 1 rood, 9½ falls, Scots measurement, are divided into 249 lots or divisions: with a few exceptions, averaging about half an acre each. About 15 of these lots are watered on the self-same day,—a fresh number being every successive day irrigated till the whole number is gone over. This is continued uninterruptedly during the whole year—but it sometimes happens that a day or two longer elapses between one watering and another from the crop being ready for cutting, or other causes. The following is extracted from the "Meadow Book," kindly furnished me for this purpose by the Messrs Stewart, agents for W. H. Miller, Esq., of Craigentinny—showing the exact days on which the *same series of lots* was watered during a period of 18 months.

Lot 1 *of Craigentinny meadow* was watered May 3, 1845; May 14; June 3; June 20; June 7; July 24; Aug. 15; Aug. 31; Oct. 8; Oct. 29; Nov. 24; Dec. 31; Jan. 30, 1846; Feb. 18; March 5; March 22; April 2; April 13; May 10; May 28; Juae 14; June 30; July 14; Aug. 5; Aug. 19; Sept. 17; Oct. 12; Nov. 1 In 1845, only *day waterings* were given, and three cuttings obtained; in 1846, the waterings were continued *day and night*, and four cuttings were obtained. During frost the waterings are discontinued. The first cutting is usually taken the last week in March.

I hope the above statement has made the subject intelligible—if not, I should be happy to furnish you with whatever further knowledge you may desire.

Having long known these facts, it appeared to me that the Sewerage Company in London committed a grand mistake in proposing to form tanks for the reception of the sewer water. If such companies are to be formed, certain proportions of the supply of sewer water ought to be *permanently farmed* by certain proprietors or tenants of land, and the whole supply be deposited on the land as soon as it reaches its destination, the meadows being divided into 15 to 18 portions, each of which would in succession receive one day's supply till all are gone over, when the irrigation would re-commence at the first watered division.

I forgot to mention that if the drains get out of order, and the sewer water is allowed to form pools on the land, the crop is destroyed, or the yield is small in quantity and bad in quality. In fact, sewer water putrifying on the land kills the grass, as it would do the human race if exposed to its emanations. In very dry seasons, however, as last June, the exits of the drains require to be plugged up in order to retain a sufficient degree of moisture in the land to produce the required rank vegetation.

VII.—Experiments on the Distribution and Use of Sewer Water to Agriculture, made on the Grounds of James Thomson, Esq., of Primrose, 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, 2½ 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 mouth-piece 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 Yard.	Gallons per Minute.	Gallons per Hour.
50	15	7½	21½	1290
,,	24	12	33½	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 fifteen yards. It was about the same with 800 yards of hose and eighty feet of fall. Now there is very little of the land where there is less than twenty-five feet of fall, to the larger portion of it there is above fifty. In the calculations which are to follow, it will be quite fair to take the jet at fifteen 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—

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It is marked off by putting down a few sticks into stretches of forty 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 length, 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 AG; 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 ten acres per day; the labourers are paid 2s. per day each, which makes the cost of the application 5d. per acre. The hose, at 1s. 2d. per yard, and 2d. per yard for kyanizing 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 five per cent. on the capital and ten per cent. for wear and tear, together fifteen per cent., amounting on 53*l.* to 7*l.* 19s. to be charged on eighty acres, being 2s. 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 4½d. per acre. As it is, however, the cost is 2s. per acre and 6d. for the labour, making 2s. 6d. 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 journies, 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 20s. for the five acres, or 4s. 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 no 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.

Table of Experiments on the Friction through House 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 long experiment, 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, and area of ditto.		Length of small hose in feet.	Diameter and area of hose.		Velocity of feet per second through		Weight on pump valves in lb.	Discharge in gallons pr second.	Remarks.
					Diameter.	Area.		Diameter.	Area.	Large hose.	Small hose.			
	min. sec.											lb		
1. Hose had a sharp bend	1 5	11	37	60	4½	15 9				0.83		1.6	0.57	
2. Hose kept straight	50	11	37	60	4½	15 9				1.0		1.6	0.74	
3. Velocity increased	20	10	37	60	4½	15 9				2.7		3.3	1.85	
4. Ditto	15	10	37	60	4½	15 9				3.63		3.3	2.47	
5. Double length of hose	55	11	37	120	4½	15 9				1.0		2.5	0.67	
6. Ditto ditto	15	10	37	120	4½	15 9				3.63		5.5	2.47	
7. Two small hose jet pipes, with flat spreaders	1 0	11	37	120	4½	15 9				0.91		4.1	.62	
8. Ditto ditto	20	10	37	120	4½	15 9				2.7		12 5	1.85	
9. Ditto ditto	16	11	37	120	4½	15 9				3.38		16.0	2.3	
10. Three lengths of hose	55	11	37	180	4½	15 9				1.0		4.5	0.67	
11. Ditto	17	11	37	180	4½	15 9				3.2		12.5	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	3.3	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	7 3	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	17.6	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	3.5	0.51	
16. Ditto	17	11	37	180	4½	15 9	120 / 120	2¼ / 2¼	3.9 / 3.9	3.2	6.4	21.0	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	25.0	1.7	
18. Without jets	40	13	37	180	4½	15 9	300 / 300	2¼ / 2¼	3.9 / 3.9	1.3	2.6	9.1	0.92	
19. Ditto	25½	12	37	180	4½	15 9	300 / 300	2¼ / 2¼	3.9 / 3.9	2.2	4.4	16.0	1.5	Hose much distressed with the action of pumps.
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	5.8	0.57	Larger air-vessels required
	35	13	37	180	4½	15 9	300 / 300	2¼ / 2¼	3 9 / 3.9	1.6	3.2	16.0	1.10	