Preliminary report upon the sewerage, drainage, & supply of water for the Borough of Leicester / by Thomas Wicksteed. And a Report upon the analysis of the sewage waters, and the water of the stream in the neighbourhood of Leicester by Arthur Aikin and Dr. Alfred Swaine Taylor.

this water with that obtained by pumping in the Town, the cost is 16*l.* 13*s.* 0*d.* per million gallons, more than double the cost of that raised about 110 feet at Liverpool, the height being nearly the same.

4—The Well upon the Common, which has now attained a depth of nearly 1,300 feet from the level of the bed plate of the engine, has been carried through gravel and alluvial soil to a depth of 78 feet; then it traverses the London clay, whose thickness is 304 feet; then the plastic clays, or basement beds, with a thickness of 97 feet; the chalk has been traversed in about a thickness of 820 feet: and Mr. Clark's new contract has not yet expired. The water at present obtained from the well, rises from the chalk, or from the basement beds of the London clay (Appendix B), in a quantity equal to about 21,000 cubic feet per day. The engines could lift much more, but they are often obliged to stop to allow the well to replenish itself. There are two engines which work pumps detached from one another; the first having a lift of 180 feet, the second of 375 feet. From the well, about 8,500 cubic feet rise to the top lift in the 24 hours, independently of the quantity supplied by the bottom lift, which completes the remaining portion of the 21,000 cubic feet.

I leave out of account, in estimating the cost of the water obtained from this well, all the sums paid exclusively for the boring of the shaft. The engines may be assumed to have cost about 1500*l.* of the original outlay, the pumps and pump gear about 1800*l.*; or, together with the buildings they may be assumed to have given rise to, an outlay of 3,500*l.* Taking an average of six years expenditure for raising the water, it has been 480*l.* per annum; to which, adding 5½ per cent. for interest and depreciation, we have a total of 640*l.* per annum as the cost of the 21,000 cubic feet per day. The price per foot cube is then 0.02 of a penny, less, in fact, than the price of the Northam water, notwithstanding the extra lift.

The total actual supply from all sources is only about 250,000 gallons per diem.

Thus it appears, that the existing supply is, upon the average, only about 5-14ths of what the town should really possess. Its quality, according to Professor Way's analysis, is not only far from being what it might be, but also, from what it should be, in many cases.

W. RANGER.

Marshall, Machine Printer, &c., 154, High Street, Southampton.

LEICESTER. Local Board of Health

(13)

PRELIMINARY REPORT

UPON THE

SEWERAGE, DRAINAGE, & SUPPLY OF WATER

FOR THE

BOROUGH OF LEICESTER.

BY

THOMAS WICKSTEED, ESQ.,

ENGINEER TO THE EAST LONDON WATER WORKS,

&c., &c., &c.

AND

A REPORT UPON THE ANALYSIS OF THE SEWAGE WATER, AND THE WATER OF THE STREAMS IN THE NEIGHBOURHOOD OF LEICESTER.

BY

ARTHUR AIKIN, Esq., AND DR. ALFRED SWAINE TAYLOR,

Professors of Chemistry in Guy's Hospital.

Printed by Order of the Local Board.

LONDON, 1850.

REFERENCE TO THE PLANS.

No. 1. Sewage. — Is a lithographed plan of Leicester, showing the Streets through which the three Main Sewers are proposed to be carried tinted red—two lines from the suburbs west and north of the West and North Bridges are also tinted, intending to show that these districts are included in the general plan for the Sewerage of the Borough—but not intended to show the exact line the Sewers may eventually take, nor the points at which they are intended to cross under the river, as these cannot be determined without farther examination and consideration. The plan itself is an imperfect one published as a street guide, and it is only presented to indicate *generally* the direction and localities of the main Sewers. It should also be remarked, that it only represents a small portion of the Streets through which *main* Sewers will be carried.

Nos. 2 & 3 represent Sections of the Streets through which some of the large Main Sewers are intended to pass, and *inclinations* of those from the suburbs, and generally the depth of the Sewer under the surface—these also may have to be varied upon more careful and detailed examination of each separate locality, as in *finally* determining the exact depths of the Main Sewers, accurate levels of *every* street and alley, especially as regards their relative elevation to the Main Sewers, must be taken—and this is absolutely necessary in laying down *before hand,* a scheme for the efficient Sewerage of a town, *the ultimate completion of which may be extended over several years.*

No. 1. Water.—Represents, upon an Ordnance Map of the neighbourhood around Leicester, the various water sheds which supply the tributaries to the River Soar—the sources from which samples of water were taken are indicated by figures corresponding with those given in the Report, and the various areas, showing the extent of water shed supplying the streams at these points, are defined by tints, and the acreage given in figures corresponding with those in the Report.

REMARK.

With the foregoing restrictions the plans may be considered sufficient to explain generally the scheme proposed in the preliminary Report, more accurate or detailed plans could not have been supplied without more accurate information, surveys, levels, &c., having been first obtained, and it was considered that until the principles upon which the works were to be constructed, and the positions of the sources for water supply and outfall for Sewage, were determined, that to incur additional expense would have been inexpedient, and probably unnecessary.

PRELIMINARY REPORT

UPON THE

SEWERAGE, DRAINAGE, & SUPPLY OF WATER,

FOR THE

BOROUGH OF LEICESTER.

TO THE MAYOR, ALDERMEN, AND COUNCILLORS OF THE TOWN COUNCIL OF LEICESTER.

INTRODUCTION.

GENTLEMEN,

Upon the 14th of September, 1849, I received a letter from your Town Clerk, stating that the Town Council of the borough were desirous of receiving a report from me "as to the best mode of draining the town, with a practical plan and estimate, and also my views as to the supply of water," provided the terms upon which I would undertake the business, might be considered to be satisfactory.

On the 17th of the same month, I replied to this communication, stating what my professional charges would be, and having received another letter from the Town Clerk, (dated September 20th), informing me that the Council would avail themselves of my services, upon the 24th September, I commenced a personal survey of the town and neighbourhood, and on the evening of the 25th, attended a meeting of the committee of the Local Board of Health, upon which occasion I received instructions which were afterwards communicated to me by the Town Clerk, in the following words, viz.

"At a meeting of the Sewerage and Highway Committee of the Local Board of Health, held at the Townhall, Leicester, on the 25th September, 1849, it was moved by Mr. Crossley, seconded by Dr. Shaw, and carried:

"That this Committee instruct Mr. Wicksteed to report fully upon the drainage, sewerage, and collecting and disinfecting the produce of the sewers, and also the supply of water to the town, both for the purposes of sanatary cleansing and also for domestic use, either from one or more sources, and also an estimate of each portion."

In explanation of the above resolution, the Committee informed me that the plans and estimates as regarded the sewerage of the town, were to provide for the drainage of every street, court, and alley, but not for the connections with private houses, or other premises, with the street sewers—in other words the *House Drainage*.

This exception, which according to the Public Health Act, belongs to the class of "*private improvement expenses,*" is in my opinion a very proper one, as being connected with details which may spread over a long period, and can be better effected by those intimately acquainted with the localities, than by any party, residing at a distance.

The Superintending Inspector reported to the General Board of Health, April 13th, 1849, that the expense of this portion of the work (the House Drainage) would involve " an Improvement rate of a little less than three farthings per week per house."

Upon the 3rd. of October, I again visited Leicester, and made a personal survey of the district all round the borough, and upon that occasion it was suggested that, as the determining the position for the outfall of the sewerage, and the locality from which a supply of water was to be obtained, were points of great moment, they ought not to be finally determined upon, until the Committee had given the subject their most serious consideration, and that therefore, it would be better that I should make a *preliminary* report, before commencing detailed plans, specifications, and estimates.

It was also considered to be of the greatest importance, that eminent chemists should analyze the waters from the several streams in the neighbourhood of Leicester, and also the sewerage and dye waters, and to ascertain as regarded the latter, whether their mixture with the sewer water would have an injurious, or a beneficial effect, with reference to its future application as a manure; and lastly, to determine whether the admixture of a certain portion of lime with the sewer water, would prevent the evolution of noxious gases and deodorize it.

It is well known to scientific men that the process of chemical analysis, when carefully and properly conducted, is a very slow one, and although the eminent chemists, selected by you to make these analyses (viz., Mr. Arthur Aikin and Dr. Alfred Taylor, Professors of Chemistry in Guy's Hospital), have been most assiduous in their investigations, they were unable to complete them before the latter end of January.

It is but right, however, to observe, that in the course of their investigations, I have had occasion to suggest various experiments (which have appeared to me to be necessary), the carrying out of which, has tended to prevent an earlier completion of their examinations.

I trust, however, that the result, as shewn in the following Report, will prove that the delay has not been detrimental to the interests of the Borough of Leicester.

I can scarcely fail to express the opinion of the Committee of the Local Board, in stating that the principal objects to be attained, are—

1st. The diversion of *all* sewage, dye, and scouring waters, from the River Soar, and the Leicester Canal, and their removal as speedily as possible, from *under* and *near* the Town of Leicester, so as to relieve the Town from noxious exhalations, and to restore the River to the salubrious state in which it was, before it was made the common sewer of the Town.

2nd. The removal of this sewage to such a point in the river *below*, that the process of "collecting and disinfecting" may be carried on without injury or annoyance, either to the inhabitants of the Town itself, or to those of the adjacent Villages; and that the process to be adopted in its disinfection, be such that the water, before it is returned into the River Soar (*below* the town), shall be in a state of at least as great purity, as it was in the River *above* the Town, before any sewage, or dye waters, had contaminated it.

3rd. That the level of the sewers shall be at such a depth that the lowest parts of the Town, shall at all times, be capable of being well and thoroughly drained.

4th. That the fall in each sewer shall be sufficiently great to produce a velocity, that will not only carry off rapidly the liquid filth poured into it, (so as not to allow of stagnation, or of time for decomposition,) but also to produce a sufficient scouring power, to prevent the accumulation of debris, or heavy deposits of road drift.

5th. That there shall be a daily and *nightly* supply of water, abundant in quantity for cleansing the sewers, and neutralizing any bad odours remaining therein, after the bulk of the *daily* sewage shall have ceased to flow.

I am also of opinion, that no scheme for the sewerage of a town, can, at the present time be considered complete, unless it embraces the means for converting the sewage water to useful and profitable purposes; so as to *reduce* as much as possible the expenses of sanatory improvement, if not to merge them altogether, in the receipts arising from the sale of the *manure*.

As regards a supply of water to a town, the Local Board will probably agree with me that it ought (in the terms of the Public Health Act) to be "pure and wholesome;" that it should be abundant, and taken from a source which is not likely to fail, even though the future demand should increase to fourfold the quantity at present required; that there should be the means of delivering it to the top story of the highest house in the town, if required; that it should be *always accessible*, and at a sufficient pressure for the purpose of extinguishing fires; that it should be as soft as it can be procured, (consistently with a due regard to its *wholesomeness and cost);* and that it should be obtained at the smallest possible expense.

If, in fact, the River Soar can be purified, and its waters restored to their original salubrity; if filthy and noxious matters can be removed from the Borough, before time has permitted them to be prejudicial to the health of the inhabitants; if the removal can be effected without injury and annoyance, to the inhabitants of the town, and the adjacent villages; if the refuse can be converted into an article of commerce, yielding a revenue equivalent, or nearly so, to the cost of the sanatory improvements in sewerage and water supply; if also an abundant, and always accessible supply of good and wholesome water, can be afforded to every house in the Town, for baths and washhouses, for street cleansing and watering roads, for washing out sewers, and for the extinction of fires, and, if this water be 100 or 150 per cent. softer, and therefore better adapted for washing, manufacturing, or steam-boiler purposes, than the well water of the Town; and that these desirable objects can be obtained at a moderate cost, then I conceive the Local Board of Health will have obtained that which they seek, and that which the Town expects them to provide.

In the following report it will be my endeavour to prove that these objects may be obtained at a moderate cost, viz.:

	£
For the Water supply	43,000
* For the Sewers and Works for collecting and disinfecting.	55,000
Total	98,000

Supposing this capital to be divided over thirty years, and the interest upon it be calculated at £4 per cent., and £2 per cent. be added annually for the purpose of liquidating the capital, then the annual cost, including the expenses of carrying on and maintaining the several works, will be,

* For about 7 miles of main Sewers, and the Works for disinfecting at the outfall	30,000
For Branch and small lines	25,000
Total	55,000

For the *first* 15 *years ending* 1866, not more than

	Current Expenses.	Interest.	Total.
	£	£	£
For Water supply	2,320	2,580	4,900
For Sewers and disinfecting and collecting	3,200	3,300	6,500
	5,520	5,880	11,400

For the *second* 15 *years ending* 1881, not more than

	Current Expenses.	Interest.	Total.
	£	£	£
For Water supply	3,720	2,580	6,300
For Sewers and disinfecting and collecting	4,700	3,300	8,000
	8,420	5,880	14,300

According to calculations given in detail, in the following report, the average amount of rates per annum, and per week, *for Sewers and Water supply*, will be for each class as follows, viz.:—

	£		s.	d.			d.		
For	5	Houses	5	5½	per annum,	or	1	26-100	per week.
,,	10	,,	10	11	,,	,,	2	52-100	,,
,,	20	,,	21	10	,,	,,	5		,,
,,	30	,,	32	9	,,	,,	7	56-100	,,
,,	40	,,	44	5	,,	,,	10¼		,,
,,	60	,,	67	3	,,	,,	15½		,,
Average charge per House			10	9½			2½		

The quantity of water proposed to be given per week to each class of House, and the average charge per week, will be as follows, viz.:—

	Water per Week.		Charge.
	Average Supply.	Summer Supply.	Per Week.
	Gallons.	Gallons.	d.
For £ 5 Houses......	378	472	0½
,, 10 ,, ...	567	709	1
,, 20 ,, ...	630	787	2
,, 30 ,, ...	756	945	3
,, 40 ,, ...	945	1181	4
,, 60 ,, ...	1260	1575	6
Average	472	590	1

The average charge per House per week for *Sewage* will thus be 1½d., and for *Water* 1d. The charges for manufactories and for public buildings are *not* included in the foregoing, but the water used for sanatory purposes is partly included in these, and partly in the other charges.

		£
The Revenue for the first fifteen years is taken at	....	11,400
Ditto	Second Ditto	14,300

The quantity of *manure* that will be collected in the bottom of the depositing Reservoirs, will be equal to at least 10,000 tons per annum, in the first fifteen years, and 20,000 tons per annum in the second like period—this when fit for removal will contain 33 per cent. of water, and, supposing it when high dried to be worth £2 per ton, in the damp state it will be worth 27s. per ton, and thus deducting 7s. for expenses, will leave 20s. as the net produce per ton.

If, therefore, a market can be found for the sale of the quantity manufactured (of which there is probably but little doubt,) it would give a revenue of £10,000 per annum during the first fifteen years, (a sum which would be nearly equal to the estimated expenses of water supply and sewers for that period,) and during the subsequent fifteen years the income from the same source, would probably amount to £20,000, a sum that would much more than cover these charges.

I have now to request those who are interested in the *details* of the proposed scheme, to favor me with their attention to, and calm consideration of, the statements and facts given, and conclusions arrived at, in the following report.

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REPORT.

THE SEWERAGE.

The objects stated in the introduction to this Report as being essential will be obtained by adopting the following means, viz.

First. That great care be taken that from and after the time the proposed sewers are made, no drain from a dwelling-house or from a manufactory, whether it be for carrying off dye, scouring, and other filthy waters, or condensing water from steam-engines, (which latter will materially assist in diluting, and thus neutralizing the bad effects of the other waters,) should be allowed to communicate with the river or navigation; on the contrary, all drains should be diverted into the new sewers.

Second. That by the mixture of a certain proportion of lime (ascertained to be sufficient for the purpose), with the sewage water, *before* it be exposed to the open air, or discharged into the depositing reservoirs outside the Town, any possible chance of injury or annoyance to the surrounding neighbourhood may be prevented; for, that the water flowing from the reservoirs into the River will be pure, is proved by the fact ascertained by the chemists, that after it has undergone the lime process, it is not only free from noxious gases and bad odours, but the carbonates of lime and organic matter that existed in the water *itself* before it became mixed with the sewage having been precipitated, it becomes *softer* than the natural water of the River into which it will flow, and therefore *chemically* speaking purer.

That the effect of a proper admixture of lime is to render the sewage water inoffensive, I have myself proved by experiments, which can be repeated in the presence of the members of the Local Board and others interested in this important question.

Third. That the level of the main sewers under the streets shall be at least nine or ten feet below the surface, that the cellars and foundations of the houses may be always kept in a dry state; and in some instances the depth must be greater, that the Suburbs in the West and North side of the Navigation and River, and the lower portion of the Town upon the East and South sides of the Navigation may be properly drained.

Fourth. It will be necessary to have the main outlet at a lower level than the surface of the River in its immediate neighbourhood, and as by going farther a-field, than is proposed, no material increase of fall would be obtained, (the rate of fall per mile of the streams not being much greater than would be required for the main sewer, if extended,) so recourse must be had to artificial means, and the required fall must be produced by the use of a steam-engine at the main outlet; and it may be observed, that this in most cases will be found *much more economical* than enlarging the size, or extending the length of the main sewers, more especially in neighbourhoods, like the town of Leicester, where the cost of coals is so small.

Fifth. If an abundant supply of water be afforded to each house during the day, it will, while running through the drain pipes leading from the premises to the main sewers, keep the private drains clear and clean; and if a supply of water be turned into the *main* sewers at *night*, when the inhabitants are not using the water, it will purify and prevent noxious exhalations from them, caused by deposits which might take place at night, after the flow of water from the private houses and manufactories had ceased, unless this means of prevention were resorted to.

And to accomplish this twofold object, no *separate* works (as suggested in my instructions), for the supply of the sewers and for other public uses, would be effective, as the most important point (that of a regular cleansing of the small pipes *from the houses to the sewers*), could not be effected, unless a supply of water were introduced *into* the houses, and therefore the combination of the domestic, and public supply of water, appears to be absolutely necessary; indeed, I consider the laying on of an abundant supply of water to every house, to be as essential (for a perfect system of drainage) as the construction of a drain leading *from* the house; taking for granted, that a real and substantial improvement in the sanatory state of the Borough is the object sought for.

PROPOSED PLAN.

First. *The quantity of water* now passing through the sewers under ordinary circumstances, may be taken as equal to one million of gallons per diem, and I calculate that when the proposed sewers and water works are completed, and the increased supplies of water from private houses, from condensing engines, from manufactories, and from surface water (which now soaks into the ground), are diverted into the new sewers, the quantity will be increased to five millions of gallons per diem. It would be difficult to demonstrate that this would be the exact quantity; but as two-thirds of it will be due to the supply from the new water-works, the condensing engines, and manufactories, (the latter supplies being estimated upon data furnished to me from Leicester,) and as the result of an analysis proves that an addition of four gallons of water from the River Soar, mixed with a gallon of water from the sewers of Leicester, reduces the sewage to the same degree of dilution as the London sewage, I consider that it may be taken as sufficiently near the truth for the present purpose.

It would not, however, be wise to limit the size of the sewers for the passage of so small a quantity; the capacity of the main sewers should unquestionably be sufficient to render the necessity of having to enlarge them hereafter improbable from any future increase in the drainage. To provide against such a contingency, I would, therefore, propose to make the main sewers of sufficient capacity to admit of the free passage of 25,655,540 gallons per twenty-four hours; this would allow for an increase in the present estimated quantity of sewage water (say 5,000,000 gallons per twenty-four hours) of 300 per cent., bringing up the quantity to 20,000,000 gallons per twenty-four hours, and would also provide for the reception of the water flowing off the surface, during heavy, but not excessive, rains; assuming that an area of one-and-a-half miles by one mile, or about 1,000 acres, would probably be the greatest surface from which such water would flow into the proposed sewers and taking a rain fall of three eighths of an inch in twenty-four hours, that would give a sum of 8,483,310 gallons; and supposing that as much as two-thirds of this quantity may find its way into the sewers, that portion would be equal to 5,655,540 gallons, which, being added to the quantity of regular sewage proposed to be provided for, would make up the total of 25,655,540 gallons per twenty-four hours, as before stated.

Second. *The Velocity of the Water in Sewers* is a question of the greatest importance, as upon this their efficiency chiefly depends, and being taken in connection with the quantity of water expected to pass through them, it enables us to determine their dimensions, and consequently the cost of the works; the velocity should be sufficiently great to produce a scouring power that will prevent deposition, and also remove obstructions arising from the accidental introduction of solid matters, for it is when the water is stagnant, or moving at an inconsiderable velocity, that deposition takes place; but still the velocity should not be so great, as to act upon the bottom of the sewer injuriously, by the too rapid passage of stones and bricks, or other heavy bodies. It is often observed by persons unacquainted with the scientific principles which determine the question of velocity, that a given fall is "very great, and quite sufficient for the purpose required." Now, if the *fall* be not sufficient to produce the *required velocity*, however great it may be in feet and inches, it will *not* be sufficient for the purpose required; the larger the quantity of water, and consequently the larger the sewer, the less will be the fall required to produce the necessary velocity; thus to give a velocity of thirty-six inches per second, or one hundred and eighty feet per minute, in a nine-inch drain, the fall must be thirty-six feet in the mile, or one in one hundred and forty-six, while to produce the same velocity in a sewer of four feet six inches diameter, the fall required will only be one-sixth of the above, or six feet in one mile, or one in eight hundred and eighty; it will therefore be advantageous to have the main sewers laid deep in the streets, not only for the purpose of draining the cellars, and keeping the foundations of the houses dry, but also that smaller drainage pipes may be sufficient to carry off the house drainage.

It is stated that the great and rapid river Po has a fall of only six inches in one mile, or one in 10,560; the volume of water passing down is, however, immense, as, in its lowest state, its width is said to be seven hundred feet, and depth ten feet. This affords a good practical illustration of how *small a fall* is required in dealing with *large* volumes of water.

I propose that the mean velocity of the water in the main sewers, shall be at least thirty six inches per second, or 180 feet per minute; this would give a bottom velocity of thirty inches per second, which, according to my experience, would be sufficient to carry off any debris, or heavy materials, such as brick-bats or stones, that may fall into the sewers, and also to prevent permanent deposits.

The rule for calculating the necessary fall to produce a given velocity, has been variously stated by different engineers. Captain Vetch, in his report to the Town Council of the Borough of Leeds, calculates that a fall of one inch in twenty feet will produce a velocity of 36.18 inches per second, or 180 $\frac{9}{10}$ feet per miuute, in a twelve-inch sewer; this gives a fall of twenty-two feet per mile, and a delivery equal to 142 cubic feet per minute.

According to Mr. Hawkesley's table, published by the Health of Towns' Commission, the velocity due to this fall will be 37.43 inches per second, or 187.16 feet per minute; and the delivery will be equal to 147 cubic feet per minute: and, according to my experience, the velocity with this fall and size of sewer, will be 32.6 inches per second, or 163 feet per minute, and the delivery will be 128 cubic feet per minute. The comparative delivery, with the same fall and size of sewer, calculated by each of these formulæ will be as follows : viz.,

		Ratio.
Mr. Hawkesley	147	100
Captain Vetch	142	96·6
Mr. Wicksteed	128	87

I adopt my own data in preference to the others, because I obtained my results from trials upon long lengths of large pipes as ordinarily laid down, with bends and occasional inequalities, and I therefore consider them safer than data obtained from results which are derived from experiments on short lengths of small pipes, laid with great care and in straight lines, or from experiments upon canals or large open water courses ; should the velocity in the proposed sewers be greater than I have calculated upon, the increase will be in favour of the capacity of the sewers, which will be better than if the reverse had happened to be the case.

These velocities are calculated for *circular* sewers when either full or half full, but when the sewers are, as they frequently may be, less than half full, the friction will be increased in an inverse proportion to the volume of water, and the velocity therefore reduced. Now, supposing the sewers are only filled to one-seventh of their depth, then the mean velocity, when full, of thirty-six inches per second, will be reduced to twenty-six inches per second, which will give a bottom velocity of twenty-one inches per second. From experiments made by me, (with great care,) I find that with a bottom velocity of sixteen inches per second only, heavy pieces of brick, angular granite stones, and sand will be removed ; and with a velocity of twenty-one and three-quarter inches, even iron borings and heavy slag, will be carried along and scoured out. The above minimum velocity will therefore be sufficient.

As regards the form of the sewers, I prefer that having a *circular* section, not only on account of its presenting the least resistance to the flow of the water when full or half full, but because it is the strongest form to resist pressure, supposing the earth in which it is laid to be good, and also because it requires the least quantity of material in its construction ; there may, however, be circumstances which might render a different form not only better—but necessary—but such I do not consider to be the case in the present instance.

The next point, namely, the *materials* of which the sewer should be formed, is also of very great importance, and has lately received considerable attention ; I do not think it can be summarily disposed of by saying that either brick sewers or glazed earthenware pipes are the most eligible in every situation, as either may be, and no doubt are, preferable under certain circumstances.

The difference between the friction in a well-constructed brick sewer and of a glazed earthenware drain, or even of a cast-iron pipe, being unappreciable for all practical purposes, the real question, in choosing between them, is the *cost;* and in considering the thorough drainage of a town, I should recommend that the *large* sewers which are laid deep in the principal streets, should be constructed of brick-work, which if permeable, will assist in draining the ground on either side of them, and in keeping the foundations of the houses dry; but for all sewers of twelve inches in diameter, and under, if the cost of glazed earthenware be the same as good brick-work in cement, the former I consider would be the most suitable; for those that are laid nearer the surface of the ground in the small streets, alleys, and courts, it might be well to adopt the glazed earthenware, even should the cost be somewhat greater, because these smaller drains (as they cannot be available the same way as the larger and deeper laid sewers) if permeable, or imperfectly constructed, would probably be the source of much annoyance to the comfort, and injury to the health, of the inhabitants; but for all drains immediately connected with dwelling-houses, they should undoubtedly be used in preference, and will I have no doubt be found cheaper than any other.

DIRECTION AND SIZE OF THE PRINCIPAL SEWERS.

I propose that the outfall shall be into the River Soar, under and beyond the aquaduct which conveys the water from the Old Abbey Mill into the Leicester Canal, near the Belgrave Mill Head, at the extreme end of the Abbey Meadows, not far from what is called on the plans, " Swan's Nest," the level will be the same as the Belgrave Mill Tail, from thence it will pass under the Leicester Canal into the Belgrave Mill Meadows. I propose to construct two Depositing Reservoirs of about three and-a-half acres area in the aggregate on either side of the canal, as may be found best, and I also propose to erect two steam-engines of about fifty horses power each, one only to be used under ordinary circumstances for the purpose of raising the sewage water into the lime, or deoderizing *covered* tanks, from whence it will flow into the open reservoirs when freed from all offensive odour; under ordinary circumstances *all* the water will undergo this process, and be delivered into the reservoirs where the deposition of the manure will take place—but, in case of storms, or heavy rains, and floods, the water, after all *sewage* has been washed out of the sewers, will flow past the reservoirs to the outfall; the engines being then used for the purpose of relieving the sewers. Under ordinary circumstances one engine will be employed to lift 5,000,000 of gallons per diem, at an average power of thirty horses, but in cases of heavy rains or floods, the auxiliary engine may be used if required, and the two worked to their full power to relieve the sewers in the town, and together they will be capable of lifting 15,000,000 gallons in twenty-four hours, if working night and day; in general the engine, at night and on Sundays, need not be worked up to more than one-third of its powers, as the bulk of the ordinary sewer water will be discharged in the *day-time* during six days per week.

From the outfall to the Pack-Horse Inn, near Belgrave Gate, it is proposed to make the sewer four feet six inches in diameter; from this point, or near it, three main sewers will branch.

First. The West Main Sewer, thirty-nine inches in diameter, up Belgrave Gate, through Foundry-square, Archdeacon-lane, Harcourt-street, Luke-street, Saint John-street, Canning-street, Margaret-street, Sanvy-gate, North Gate-street, North Gate-lane, Friars-road, Charlotte-street, Alexander-street, Friars Causeway, Bath-lane, across Bridge-street, through the Hollow, Castle View, Castle-yard, the Newark, across Mill-lane, or Bonner's Lane, through Green-street to Infirmary-square, at which place it will be at a sufficient depth to carry off the sewage from the locality lying between the high ground, where the Race Course, Leicester Asylum, and New Cemetery are situated, and the Gaol, and which district, I am informed, is well provided for by a sewer passing down Knighton Street into Cow Lane; and at this point it will have to be diverted into the proposed new Sewer. This Sewer follows the course of the navigation and the lower levels of the town, without crossing private property, which it is generally very objectionable to do, seldom paying for the expenses incurred, and it is also inconvenient for the junctions of future branch sewers; some deviations may, however, in this as in other cases, be found advisable hereafter.

Second. The East Main Sewer. Twenty-seven inches diameter, from the Pack Horse Inn, Belgrave Gate, through Bridle-lane, Russell-square, Wharf-street, Brook-street, Lead-street, Benford-street, Curzon-street, to Humberston-road, at its lowest level, nearly opposite Kent-street.

Third. The Central Main Sewer. Twenty-seven inches diameter, from the West Main Sewer in Belgrave Gate, opposite Woodboy-street, through the Haymarket, Gallowtree Gate, Granby-street, or London-road, to the present sewer under the Midland Counties Railway, and thence to Conduit-street.

I also propose to have sewers, varying in size according to circumstances, embracing the suburbs of Braunstone, Frog Island, &c., the whole length included in my estimate being about forty miles, exclusive of existing drains. The depths will differ according to the variation in the surface, and as may be found necessary for obtaining the required falls; generally speaking, however, they will be laid about twelve feet below the surface, excepting the principle main sewers.

I have made some sections of the proposed sewers (which I now present); they will shew generally the depths and inclinations of these sewers; but before the Plans can be finally determined upon, it will be requisite for me to make myself better acquainted with the localities than I am at present, and to be provided with more sections and surveys than I have hitherto required. I have, however, had sufficient information afforded to me (in addition to the personal surveys I have already taken of the Borough) to enable me to say with confidence, that the cost of executing in a perfect manner the works herein generally described, will not exceed the sum of £55,000.

SEWAGE MANURE.

That sewer water contains salts which are of very great value as a manure, is a fact that is now, I believe, very generally admitted; it is, however, still a question as to the best form in which this can be made available; some maintaining that the liquid form is the best—that the mode of conveying it by means of a system of pipage is the cheapest, and that in any other form it is very inferior; while on the other hand it is advanced, that by the admixture of a small proportion of lime, *all* the *valuable* salts and organic matter are precipitated, together with the lime used in the process, and that the whole becomes a valuable solid manure; that in this state it may be partially dried so as to allow of its being removed by water, or rail, or that it may be high dried at a low temperature, so as to prevent the loss of the volatile salts, and then packed in casks in the same manner as is practised with guano, or Roman cement, and sent in this state to any part of the United Kingdom, or exported to the Colonies, so that on its arrival at its destination, it may, if required, be diluted with a moderate proportion of water (instead of the superabundant quantity with which it is mixed in its original state of sewage water), and thus be used as a liquid manure for the crops to which it is suited, and it is a fact that when so rediluted, it will possess all the valuable fertilizing properties of the original sewer water, without the inconvenience of an enormous excess of water; it is also advanced on this side of the question, that if the sewage water be destributed by means of hose and pipes in the state in which it is when taken directly from the sewers—and before the sulphuretted hydrogen then contained in it be fixed by the lime process—this noxious gas will be evolved in large quantities, and diffused through the surrounding atmosphere, poisoning it, and rendering the neighbourhood where such an operation may be carried on most unhealthy.

In the plan I propose to you, there is nothing however, to *prevent* your pumping up the sewage water in its natural state, and forcing it through a system of pipes to any locality, where the use of it in the liquid form may be deemed most advantageous, but if, upon a careful estimate of the cost of carrying out this plan, it should appear to be excessive (in this especial locality), its adoption would, of course be rejected.

Now, although there *may* be localities favourable for a limited adoption of such a plan, nevertheless, to provide for the distribution of the *whole* of the sewage water of a large town by such means would, in my opinion, be a most imprudent speculation; when it is considered, that for every ton of manure in the sewage water of London (in the state of dilution in which it was five years ago), there were 266 tons of water; and supposing the statements made by the advocates of this plan to the Health of Towns Commission to be correct, viz., that carting manure five miles costs 4s. per ton, and that distributing sewage water costs 2½d. per ton only, this will give us the cost of carrying one ton of manure *without water* 4s., and that of one ton of manure *with* 266 *tons of water*, at 2½d., £2. 15s. 7d. per ton of manure; and again, taking the cost of the sewer water at 3d. per ton, the cost of a ton of the manure would be £4, while the cost of high dried manure would not exceed £2 per ton. It is also stated, that 100 tons of the water is required for one acre of ground, which would be equal to 25s. per acre, or 7½ cwt. of manure, while the cost of the high dried would be but 15s. for 7½ cwt., and taking the sewage water of Leicester to amount to 5,000,000 gallons per diem, or 8,168,528 tons per annum, at 100 tons per acre, it would require an area of 81,685 acres to consume it, or about 127 square miles, which is equal to nearly one-sixth of the whole area of the county of Leicester, cultivated and uncultivated; and when the expense of covering such an area (more than eighty times greater in extent than the town) with a system of water-pipes is considered, I think it will appear very evident that the distribution of the *whole* of the sewage water could never be *profitably* effected by such means.

At the same time, it is but right to observe, that the distribution of a *portion* of it over the Abbey Meadow, and the lands in the immediate neighbourhood, would not involve so great an expense, and in a *commercial* point of view this might be worthy of consideration, were there no objection on the score of *health*; perhaps the Inhabitants of the Borough would be able to arrive at a very fair conclusion as to the effect of such a distribution of the sewage water, by comparing it with the effluvia arising from the sewage and dye-water that is *at present* poured into the Canal and River. I am fearful that it would be merely removing the nuisance from the River to diffuse it more widely.

The foregoing observations are intended to apply to two points only; first, to the disposal of the *whole* of the sewage by one system; and, secondly, to the disposal of a *portion* of it in the *neighbourhood* of the town; it is not intended to be stated that there may not be cases in which sewage water might be used profitably and without injurious effects, but it then implies a reasonable distance from the source—a sufficient distance from dwelling-houses, and (under these restrictions) a market capable of taking the whole supply.

Before proceeding to report more particularly upon the value of the Leicester sewer waters, as a manure, I should wish the following statement to be well considered.

There can I think be little doubt, that it is desirable to give as plentiful a supply of water to a town as possible, and that after having provided the subterranean water courses for carrying the sewage away, the surface cannot be too frequently cleansed from all filth, and this will be best effected by the use of large quantities of water, and the greater the extent of the dilution, the more salubrious the surrounding atmosphere will be. This is now becoming a very prevalent feeling, and much credit is due to those who have persevered in keeping such a sanatory proposition constantly in public view. Now, presuming this principle to be acted upon, the sewage water of every town will (as increased supplies of water are given) contain less manure in proportion to the quantities of the water passing through the sewers, and consequently from this larger quantity of fluid having to be dealt with, the distribution of it through pipes would be rendered a continually augmenting source of expense.

On the other hand, however great the state of dilution in which the sewer water may be, by the adoption of the *lime process* all the valuable salts which it contains, may be concentrated, and the principal increase in expense would be in engine-power at the reservoirs, a very insignificant charge when compared with that of the extensive enlargement of a system of pipage.

The plan *proposed* is similar to one suggested (for the first time) by me, in 1841, for the sewerage of the City of Berlin, where according to the statement of Major Baeyer (the Royal Commissioner sent over by the King of Prussia, to inquire as to the best means of supplying His capital with water, and for providing for its drainage,) the greatest elevation above the surface of the River Spree, was eleven feet only. Under such circumstances, *underground* drainage by natural means would have been impracticable, I therefore recommended that an artificial outlet, or deep reservoir, should be constructed outside the city, into which the sewers should deliver their contents, and that the low level should be constantly preserved by employing pumping-engines sufficiently powerful to raise all the sewer water, and that it should be distributed over the barren and arid land in the neighbourhood of the city. The idea of such a plan for creating an artificial fall was suggested to me by the system of drainage carried on for above a century in the Marsh and Fen Lands of Great Britain, and from the fact that late improvements in steam-engines, (having effected a great diminution in the quantity of coals required in their employment,) had made the adoption of such a plan both economical and practical.

The use of the steam-engine for pumping has now become general, and when it is known that during the last eleven years the *average* quantity of coals consumed by the improved engines at the East London Water Works, has been one ton for every 1,406,988 imperial gallons raised one hundred feet high, it will at once appear that it is not an expensive operation. The power of the engine and the consumption of coals, being directly in proportion to the quantity of water and the height to which it is raised, if a ton of coals will raise 1,406,988 gallons to a height of one hundred feet it will raise 4,689,960 gallons thirty feet high; or to raise the quantity of 5,000,000 gallons of water, calculated for the Leicester Sewage, thirty feet high, will require 21⅓ cwt. of coals of similar quality to those used at the East London Water Works, viz.:—the best small Newcastle Coals—being slack or the screenings of large coals; and assuming that the Leicestershire slack produces 15 per cent. less effect than the Newcastle, then it will require 24½ cwt. of coals of the latter description, which at 5*s.* per ton will amount to 6*s.* 1½*d.* per diem. or £112 per annum, In 1845, I proposed a similar plan (as far as relates to the artificial fall,) for the drainage of the Metropolis, *and after mature consideration, I am still of opinion that it will be found to be not only the best, as regards the cost of the works,* *and the entire removal of all filthy and noxious water from the River Thames, but the only one practicable.* To this arrangement of an artificial fall, I added not only that of deodorizing and softening the water before it was discharged into the Thames, at Barking, but also that of using the preci- pitate obtained by the process of deodorizing, as a *manure*, the sale of which at a very moderate price would have afforded a most ample return for the capital invested; this plan has been approved of and recommended by some of the first engineers in this kingdom, and will I have no doubt, be ultimately adopted. The fact, that so many of the competitors who have sent in proposals for disposing of the Sewage of London, in compliance with the requisition of the late Commissioners of Sewers, having adopted this principle (as published by me in 1845,) as the basis of their schemes, proves it is very generally approved of.

I have, perhaps, entered more at large upon this subject than may be considered to be necessary, but I have been induced to do this from the feeling that *at present* the question is one of the greatest importance, and that the more it is investigated and understood, the more important it will appear to be.*—The point is this—for perfect sewerage, there must be an abundant supply of water, and a sufficient fall to insure a velocity of current capable of speedily removing the filth poured into the sewers. Now it seldom happens that a town is so situated that all parts of it can be well drained into a river or natural outfall, in its immediate neighbourhood; and hitherto recourse has been had to the expedient of taking a shorter line than the course of the river, into which the sewers are intended to empty themselves, to a point below the town, but while by these means an additional fall has been obtained, the size and length of the sewers, and their consequent cost have not been considered, and hence most costly works have been executed, because a less expensive means of effecting the same object was not known. As previously mentioned, the use of steam (and prior to that, of wind and water,) power for draining lands has been long known, and draining or carrying off the sewage of a town is in effect but a similar operation—but formerly the cost and imperfections of mechanical

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* From a report published in the *Times* upon the 18th instant, it would appear that the present Commissioners of Sewers for the metropolis have not made up their minds whether the Thames is, or is not, still to be the receptacle of all the *unpurified* filthy sewage of the metropolis. They also appear to be in doubt whether the experience of more than half a century of the economy of steam power, and the certainty of its regular action, is sufficient, I say *in doubt*, because it would appear that they do not object to the use of steam power altogether, bnt to its *extensive use*, not to *one* pumping engine, but to *two* or *three*; and again while they appear to object, and I think very properly, to the construction of two lines of sewers, one for house drainage and another for surface drainage, they seem to consider that it might be advisable to construct two lines of sewers, one for the *high* and another for the *low* levels, and that, in the latter case, machinery *might* be used. If honest estimates of the cost of the two systems (the natural and artificial drainage) were published, this tedious question might be brought nearer to a solution.

power prevented the adoption of it in towns—now, however, the cost of improved steam power for raising water is, as I have shewn so small, that it becomes essential to estimate the difference between the expense of a large and costly sewer (with the interest upon the outlay for its construction), and the cost of steam power, before determining upon the plan to be adopted. Again, the process of purifying the sewer water by means of lime, is at once so simple and so complete in its effects, that the water, after having been submitted to its action, may be returned into the river, with a certainty that it will be as pure as it was in its previously uncontaminated state; and if the manure obtained by this means (of the value of which there can now be no doubt) be considered, the operation, so far from proving a source of expense, will, in effect, be productive of a large profit. If recourse be had to steam power, any amount of fall required for the drainage of particular localities may be obtained, and, as has been already stated, the greater the fall the less will be the size of the sewer required. The question, then, resolves itself into a mere matter of estimate, viz :—What is the proportionate cost of a large sewer, and of that of raising water a few feet high by pumping? and that which can be done at the least cost will (in this instance) be preferable.

As regards the particular case now before us, although many parts of the borough, are sufficiently elevated to command *any* required fall, other localities lie so low that artificial means must be adopted for their effectual drainage; for to extend the sewers until a sufficiently low outfall could be obtained below the town, would require an outlay the interest of which would far exceed the amount of expenses which would be incurred by the adoption of steam power.

But in no case could I recommend the adoption of *two* lines of Sewers, one for the high levels, and another for the lower ones; nor can I for an instant suppose that any such proposition could ever have been made, either for Leicester or London, if those propounding it had taken the precaution to estimate the cost of such a scheme.

PARTICULARS RELATING TO THE

LEICESTER SEWER WATERS.

In consequence of instructions received from the Committee, I had samples of water taken from the following localities, viz. :—

1st. From the navigation near the North Bridge, where a drain flows in from Messrs. Brewin and Whetstone's manufactory.

2nd. From the mouth of the sewer at Bay Street Wharf.

3rd. From the sewer in Mill-lane, a continuation of Bonner Lane.

4th. From the sewer crossing the Belgrave Road, near Willow Brook, taken fifty yards from the road in Mr. Millican's close.

5th. From the last mentioned sewer at its confluence with the Leicester Canal.

6th. From a sewer passing through Mr. Brown's garden, near the Castle.

7th. From the navigation where it was discoloured with black dye.

Four gallons of water from each of the above localities were forwarded to the Chemical Laboratory, Guy's Hospital, to be examined by Mr. Aikin and Dr. Taylor ; and I also gave instructions, the principal of which related to the effect that an admixture of dye-water would have upon the sewer waters, having been informed at Leeds that it reduced its value as a manure (that this was a very erroneous notion is fully proved by your chemists), and also as to the effect of lime upon the sewage water, as a disinfectant and deodorizer—the answers of the chemists will sufficiently explain the intent of the questions without repeating them in this Report.

They state that there are no saline or other substances contained in the dye waters which will so affect the sewage water as to lessen its value as a manure ; on the contrary, the organic matters and phosphoric and ammoniacal salts contained in these waters will *greatly improve* the sewage water, and render it better-fitted for manure, and for this reason the dye waters may be safely turned into the common sewers of the town.

That Dye water contains very offensive and *noxious* gases, and is continually evolving sulphuretted hydrogen, which is a *pernicious gas, even in small quantity, and becomes rapidly diffused*, so as to *contaminate the air of* *a locality*; so far therefore as regards the *public health*, it would be advisable to turn it into the *sewers* of the town, and not allow it to be turned into the *canal* to become there stagnant. That the exposure of a large surface of this water in a stagnant state during a summer temperature, would tend to render the atmosphere of the place *noxious*, and to *produce injury to public health*.

That a mixture of the first samples, after being allowed to subside, deposited 60·9 grains for every imperial gallon—the sediments consisted chiefly of organic matter, which was found to contain *nitrogen and sulphur;* in a dry state, it would therefore be *highly valuable as manure*. The portion available as manure is that which is described as combustible, and is equal to 47 grains; the fixed residue being also useful as a manure. That the *greater* portion of the deposit took place in a few hours.

That the effect of 30 or 40 grains of lime upon an imperial gallon of water was to render the most turbid sample clear in about twenty minutes. The lime precipitates the whole of the mechanically diffused organic matters, and probably the whole of those which are dissolved.

It throws down the free carbonic acid as carbonate of lime, and *combines with the sulphur so as to fix that most offensive gas, sulphuretted hydrogen* It causes a very speedy deposit, and renders the liquid clear.

The weight of the sediment after the lime process, minus the lime, was for the imperial gallon, organic matter, 56.9 grains; fixed, 30,03 grains; total, 86·93 grains. The lime added is also precipitated, and is in close combination with the organic matter, mixed with the carbonates of lime and magnesia, and phosphate of lime, making an addition of 30 grains, or more.

That the value of the deposit as manure is, generally speaking, in direct ratio to the quantity of organic or combustible matter thrown down by the lime—this matter consists *chiefly* of substances containing *nitrogen* and *sulphur*, hence it contains the elements of *good manure*. The phosphate of lime which is precipitated together with the surplus lime, may be considered as useful adjuncts—the value of the former is well known. Hence the value of the deposit as a manure may be taken at a higher proportion than that indicated by the quantity of the combustible matters.

The analysis having so far proved satisfactory, I considered it desirable to procure an *average* sample of the contents of the sewers. Samples therefore were procured from each sewer, taken every hour in the day, and mixed together, this it was presumed would be a fair specimen of the *average* quality of the *present* Leicester sewer waters.

Upon this mixture of waters the chemists report that—

The water had neither an acid nor an alkaline reaction. It had a highly offensive odour, in which suphuretted hydrogen was perceptible.

It was of a deep blue black colour, but became quite clear and colourless by filtration, shewing that this colour and appearance were owing to undissolved matters diffused through the water.

The offensive odour was entirely removed in a few minutes by a small quantity of lime, but not by chloride of zinc, even when used in large quantities; and they subsequently found, that this fluid had less power of removing the offensive effluvia than a *small quantity of lime.*

The weight of the dry deposit calculated for the imperial gallon, was thus constituted :—

	Grains.
Combustible or organic matter, containing nitrogen and sulphur	94.3
Fixed residue chiefly saline and earthy matter	45.4
	139·7 Grains.

The weight of the Deposit after an addition of lime, was, minus the lime, as follows :—

	Grains.
Combustible or organic matter, as before..................	139
Fixed saline residue..	89·66
	228·66 Grains.

As regards the deodorizing effect of the lime, the Chemists observe,

That most noxious gas, the *sulphuretted hydrogen, is entirely removed from it,* and it may be fairly asserted, that ⅘ths of the *offensive* effluvia of the water are entirely removed by the employment of *lime.* It should be observed, that these experiments were carried on in a *laboratory, and not in the open air.*

From the foregoing statement the following comparison may be made between the Deposit obtained from a mixture of the first set of samples of sewer water, taken at one time only, and the second set being a mixture of samples taken every hour of the day from each sewer.

	Combustible or organic matter.	Fixed Residue.	TOTAL.
1st set of samples	56·9	30.03	86·93
2nd set of samples..................	139·	89·66	228·66
Excess of 2nd set over 1st set	82·1	59·63	141·73

This shews that the obtaining a 2nd set of samples was a prudent proceeding.

Although the result of the last analysis afforded every information as regarded the state of the sewer waters at the *present time*, nevertheless it would not be a criterion of the value of these waters as a manure, at a *future time*, when they will be much more diluted than at present, I therefore considered that it would be prudent to obtain an analysis of the mixed sewer waters with an addition of 4 measures of water from the River Soar, considering that this would be the extent to which the sewer water would be diluted, when the town was properly supplied with water, and the condensing water from the Steam Engines was diverted into the new sewers.

The result of the analysis of the Chemists of this sample of the diluted water, after undergoing the lime process, was as follows:

	Grains.
Combustible or organic matter	54·
Fixed saline residue	70·
Total..	124·

This shews that instead of the combustible matter being reduced to $\frac{1}{5}$th, or 28 grains, by the process of dilution, it was only reduced to half that extent, while the fixed saline residue was only reduced $\frac{2}{9}$ths.

It is upon these latter proportions that I calculate the amount of *manure* that may at a future day be obtained from the sewer water of Leicester, adding to it the lime used in the process.

It appeared to me that any calculation founded upon the amount of manure from a given quantity of water based upon an analysis of the sewer waters in their *present concentrated state*, would lead to very erroneous results—At the same time, to calculate that the quantity of deposit after its admixture with four times its volume of river water would only be $\frac{1}{5}$th, would be equally erroneous, as the effect of the lime process would be, to precipitate both the earthy salts *and organic matter*, contained in the river water, as well as in that of the sewer water to which it was added, and the result shews this opinion to have been well founded.

SUPPLY OF WATER TO THE BOROUGH.

So much has of late years been said upon the subject of the *purity* of water, and such extravagant schemes have been proposed for bringing pure water from distant localities (although it appears to me the *wholesomeness* of water has not had equal attention paid to it), that I requested your Chemists to make some remarks upon this subject in their Report to you, considering that the opinions of men so well qualified to speak on the subject would have great weight with the Town Council; and I believe I may, without impropriety, add that other very eminent Chemists have lately expressed similar opinions in reporting upon the water supply of the metropolis.

They state that absolutely *pure* water is that which has been procured by distillation, and which evaporated to dryness, leaves no solid residue. The only *natural* water that approaches to this character is *rain* water, which is caught in clean glass or porcelain vessels, before it comes in contact with anything upon the earth.

That if the objects in supplying a town, were merely to furnish water for manufacturing, and washing, or culinary purposes, then in this view of the case, the only *pure* water would be *distilled* water, but *the use of water for the diet of men and animals is so important a part of this question, as to justify its being made the first consideration.*

That distilled water, though absolutely pure, would not be proper for a *diet water*—it wants that freshness which all good spring water possesses by reason of the carbonate of lime, and carbonic acid contained in it.

That in the course of a few hours it becomes so completely poisoned by contact with lead in a leaden pipe or cistern as to render it quite unsafe for domestic use.

That the exact weight of solid residue obtained by evaporation is not of itself a criterion of the *wholesomeness* of a water, and that the term *purity* cannot be appropriately employed in reference to *dietetic use.*

That waters which leave a *dry residue*, of from 12 to 40 grains, by the evaporation of an imperial gallon, may be considered as comprising the *most wholesome varieties*, and those which are *best adapted for the diet of men and animals.*

To justify this inference, however, it must be proved that the residue obtained by evaporation contains but little organic, or combustible matter, and that the salts are chiefly calcareous.

That laying aside the use of the term *purity* as indefinite, the *wholesomeness* of any given water depends—

1. On freedom from colour, taste, and smell.

2. On its holding a proportion of saline matter, *not under* 12, *or above* 40 *grains to the imperial gallon.*

3. The organic matter should not be in a greater proportion than from one to three grains in the imperial gallon.

4. The saline matter should consist chiefly of carbonate of lime, with small quantities of chloride of sodium (common salt), and sulphate of lime (plaster of paris.)

5. It should not acquire a poisonous impregnation by contact with lead.

Water which is thus constituted, whether taken from lake, river, canal, or well, will comprise all that is necessary to render it wholesome and fit for the use of man and animals. Such a water would not be *pure*, but it would be decidedly *wholesome*, the best for *dietetic purposes, and well adapted for other uses.*

It is not intended to be said that waters containing a greater portion of saline matter are, therefore, necessarily unwholesome, sometimes the salts contained are carbonate of soda and common salt, which are not injurious to health. It is where the magnesian salts predominate, that injury is likely to arise. If we go below 12 grains there is the liability to poisoning under the common mode of distribution through lead.

That Clarke's test for hardness throws no light upon the *wholesomeness* of water, as judged by it the water which would be the most dangerous to health (from impregnation by lead) would be the softest, and in one sense the purest for the supply of a town.

The evaporated residue might contain 50 per cent. of organic matter, and be liable to become putrid in summer, but this soap test would indicate that it was a remarkably pure water. On the contrary a most wholesome water might be condemned by it as hard and unfit for domestic use. It can, therefore, neither point out the good nor the bad varieties of water.

That if the whole object of a water supply to a town was that of furnishing washerwomen with the water that would economize soap, then the test would have some value, but a few pounds of soap, more or less, must not be set against the health of a community. There are numerous domestic ways of *softening* water for washing where it marks 20° or 30° of hardness, but there is no process known by which a water abounding in organic matter, and marking a few degress of hardness, can be converted into a wholesome diet drink for man and animals. Your chemists also observe, that it is not easy to find a water which will suit *all* purposes *equally* well; that which is wholesome for drinking may be unfit for washing, or steam-engine use, and that which will suit the latter may be unfit for manufactures.

For further and most important observations upon this subject, I must refer you to the excellent remarks of your chemists, accompanying this report—the question has become one of the greatest importance in a pecuniary point of view, for while all must allow that a good and wholesome water is essential for the supply of a town, nevertheless, it is not absolutely necessary to incur a very heavy expenditure for the purpose of obtaining such a quality of water as shall render it best suited for *manufacturing* purposes, especially as it may thereby be rendered less wholesome for the community at large—the arguments so frequently used during the last few years in favour of bringmg supplies from a great distance, because a sufficient elevation may thereby be obtained to render the use of steam power unnecessary, have generally been fallacious—it certainly requires a little more experience in machinery to supply a town by means of steam power, than merely to lay a main *large enough*, from the top of a hill to the bottom—and it is also certain that the cost of pumping water was much greater a few years ago than it is now—and hence perhaps the frequent objection to using steam power; but in this, as in all other cases, the cost of the two systems should be calculated for the present time, and, *cæteris paribus*, the cheapest should be adopted. When the *cost* of bringing water from a great distance, including not only the cost of the pipes, but of compensation for damage to landowners and millowners, to increased parliamentary opposition, and its consequent expense—and of large storing reservoirs, and the land they will occupy, is considered—and the interest upon this outlay be compared with the cost of coals and other items of expense attendant upon the use of steam power, I believe there will be found very few instances where the latter will not produce that, which next to quality and quantity, is the most important desideratum, viz., cheapness.

This question is, as I have before remarked, one for serious consideration at the present time, when such schemes as those for bringing water from *Bala Lake*, in *North Wales*, for the supply of *Liverpool*, and even for the *Metropolis*, are seriously proposed; when many towns have incurred an enormous expenditure—others are incurring it, and others contemplating it, to obtain soft water and avoid using steam power; it is high time that the question of *cost*, which after all is the one that affects most the supply of an article which should be good and as abundant as it is good, should have more attention paid to it than it has had of late years; and to arrive at a right conclusion, the question of a *chemically* pure water must not be allowed to take precedence of that of wholesomeness and cheapness. I believe that the town of Liverpool might at this time have been supplied with a most abundant quantity of good, wholesome, and beautifully clear water, for less cost than has been already incurred during the last few years in preliminary measures, for obtaining water from a distance of 20 or 30 miles, and endeavouring to determine, without trial, whether water can be obtained from a source which has never failed for the last half century, when proper means have been resorted to for obtaining it. And whether the scheme which has already proved so costly should be carried out or abandoned. I trust, however, that the opinions now published, of the most eminent and most experienced chemists of the day, will tend to remove the impressions that have of late years been so prevalent, and that common-sense experience will take their place.

Many different opinions having been given as to the quality of water in the various streams in the neighbourhood of Leicester, and it appearing to me that the examinations hitherto made had not been so thorough as the importance of the question seemed to demand, and as I trusted the investigation, which I was called upon to make, might be the last that would be required to enable the Council to determine upon a plan for carrying into effect the supply of water to the Borough, so I felt that every source in the neighbourhood, from which it had been even suggested a supply could be obtained, should be examined, hoping that by this means the question might be set at rest. Having stated this opinion, instructions were given to me to have an examination of the following waters made by the chemists, viz. ;—

No. 1 W from Willow Brook at Humberstone Bridge.

No. 2 W from ditto at Saltersford Bridge.

No. 3 W from Belgrave Brook, on the Thurmaston Road.

No. 4 W from Brook between Barkby and Beeby.

No. 5 W from Brook leading from Grooby Pool.

No. 6 W from Grooby Pool by Mill Sluice.

No. 7 W from Brook ¾ mile beyond Bocheston, where the road crosses it.

No. 8 W from the United Brooks at Thornton, near the Guage at Lockey Bridge.

No. 9 W from Glenfield Mill-pond.

No. 10 W from the United Brooks below Great Glen.

No. 11 W from Knighton Brook where it crosses the Lutterworth Road.

No. 12 W from the Brook between Blaby and the Mill, near the Narborough Road.

Upon a general examination of these waters, your chemists report, that their opinion is, judging by colour, taste, and smell, by the action of the soap-test, the proportions of saline matter contained in each, as well as the proportion of organic matter, the waters which are best adapted for selection for domestic, dietetic, and manufacturing purposes, are in the respective order as follows :—

No. 10 W (from the United Brooks below Glen Magna.)
No. 3 W (from Belgrave Brook on the Thurmaston Road.)
No. 2 W (from Willow Brook at Saltersford Bridge.)
No. 12 W (from the Brook between Blaby and the Mill near the Narborough Road.)
} æquales
No. 8 W (from the United Brooks at Thornton near the Guage at Lockey Bridge.)

All, the samples were afterwards submitted to the lime process, and your chemists reported that the only object of this experiment will be to determine what proportion of saline matter is likely to be deposited in steam boilers, or under other circumstances, in which the carbonic acid of the water is likely to escape. Taking this as a criterion of the properties of the water, they stand in the following order, *i. e.* that water which comes first is the best, under Clark's process, or will produce the least sediment by mere boiling or by loss of carbonic acid.

No. 6 From Grooby Pool.
No. 11 From Knighton Brook.
No. 5 From Brook leading from Grooby Pool.
E No. 8 From United Brooks at Thornton near Lockey Bridge.
No. 4 From Barkby and Beeby Brook.
} æquales
No. 7 From Brook ¾ mile above Bocheston.
B No. 3 From Belgrave Brook.
C No. 2 From Willow Brook at Saltersford Bridge.
} æquales
A No. 10 From the united brooks below Glen Magna.
D No. 12 From brook between Blaby and the mill near the Narborough Road.
No. 11 From Willow brook at Humberstone Bridge.
No. 9 From Glenfield-mill pond.

Cæteris paribus, No. 6 will produce the least deposit by the loss of its carbonic acid, either in boiling or by spontaneous evaporation, and No. 9, will produce the greatest deposit under the same circumstances.

We see no reason to alter our opinion with regard to the selection of the waters, as, in taking dietetic and general domestic use into consideration those marked with the letters of the alphabet, beginning with A, are the best in order. No. 6, the best under this process, would be decidedly objectionable for any purposes except washing, steam boilers, and some manufactering uses. Finding from these reports of the chemists that No. 12 was as good water as No. 8, the first from the Glen Magna stream, as low down as the Narborough road, and the other from Thornton, I was desirous of following the same stream farther down, and approaching nearer to the town, I therefore obtained samples of water from above and below St. Mary's Mill, and labelled them No. 13 W from the mill head, and No. 14 W from the mill tail; and as No. 12 had been reported as having an objectionable colour, I requested the chemists to filter through *sand*, instead of blotting paper; and they reported that No. 13, after filtration through a column of clean sand, eighteen inches deep, becomes *qaite clear*, *colourless* and *tasteless*. In respect to saline contents, it resembles No, 7 (brook, three quarters of a mile above Bocheston, and below Lockey Bridge, after Bagworth Brook has joined it), but contains less organic matter, and may be considered on the whole as equal to No. 2 (Willow Brook, at Saltersford Bridge), marked C, in the former list.

No. 14 contains somewhat less organic matter than No. 13 does, but the results of the lime process shew scarcely a perceptible difference between the two waters; it may be remarked that this was likely to be the case, as water in the mill head would be more stagnant than that in the mill tail.

Both samples, when filtered, are very good potable waters, very much resembling C, or the water from Willow Brook, at Saltersford Bridge.

The chemists were now requested to analyse No. 8 and No. 14; they report that the process of filtration through sand did not produce any change in the quantity or quality of the saline contents, calling for particular notice, in No. 8, but that No. 14 was improved by filtration, as, upon analysis, it was found to have lost both mineral and organic matter, the same having separated, during the process of filtration. about one-fifth part of the total weight of its solid contents. They state, that No. 14 contained less mechanical impurity than is found in most kinds of river and spring water. In its physical properties, it has all the character of a good water for dietetic use, but may be considered as a hard water as regards washing and steam boilers. In conclusion, they observe, these waters may be regarded as good and wholesome; No. 8 (which consisted of a mixture of two samples of water from the Thornton Guage, one when the brook was clear, and the other after rain, but not during a flood), with the exception of being somewhat coloured, may be considered as the best for domestic and dietetic use. Both are greatly improved by the lime water process, but No. 8 is most improved, as its hardness chiefly depends on the presence of carbonate of lime, the separation of this salt by lime water, causes it to become remarkably soft. No. 14 is not softened in an equal degree, because its hardness chiefly depends on the presence of sulphate of lime, a salt which is not precipitated by lime water.

After communicating with the chemists upon the subject, I considered it advisable, to enable a comparison to be made between No. 14 and the spring water now generally used in Leicester, that a sample should be obtained from a well which would represent the average quality of well water in Leicester; a sample was, in consequence, obtained from Messrs. Brewin and Whetstone's well, and was labelled No. 21 W.

The chemists reported that this water, although well shaken, was quite clear and free from any mechanical impurity. It had neither colour, taste, nor odour, and presented every appearance of a good spring water. (It should be observed that the chemists were not informed where any of the waters were taken from until they had completed and recorded their analyses.)

The salts contained in this water are in unusually large proportions, but it is remarkably free from organic matter, it may be considered as very hard, and as wastefully consuming a large quantity of soap. The water was rendered somewhat softer by the lime process, but it was still much harder than most varieties of spring and river waters, which we have examined. This water cannot be recommended either for domestic use, or for dietetic and manufacturing purposes. The sulphate of lime is in such large proportion as to render it unfit for *constant* use as a diet drink. The large proportion of saline matter contained in it, would cause it to fur boilers more than a good water should do.

For the purpose of seeing at one view the proportion of salts in the three waters, No. 8, No. 14, and No. 21, before and after the lime process (or before and after long boiling), the following Table is presented :—

—	No. 8 W.		No. 14 W.		No. 21 W.	
	Before.	After.	Before.	After.	Before.	After.
Carbonate of Lime, and traces of Carbonate of Magnesia	7	2	13		31	
Sulphate of Lime	2	2	6	6	52	52
Chloride of Sodium, with traces of Chloride of Calcium and Magnesium.................	2	2	5	5	Com salt. 14	14
Combustible organic matter..................	5	1	6	2	Chl. cal & mag. 3	3
Silica and oxide of iron....			3	3		
	16	7	33	16	100	69

The Reports of the chemists, from which the foregoing extracts are taken are very elaborate, and enter into very great detail; and it would appear *(cæteris paribus)* that No. 8 (the water from Thornton) is the most suitable *before* exposure to the lime process, or before boiling; but that *afterwards* it would be liable to act upon lead; there are, however, other questions to be determined, before it can be decided, whether this is the water that should be selected for Leicester. First, whether there be a sufficiently abundant quantity of it at its source to supply the present, and *future* wants of the town? and next, whether the expense of bringing it to the town will not be greater than the advantage of superior softness would justify? These points are only second in importance to that of *wholesomeness.*

The quantity of water supplied to the Borough of Hull for 17,884 houses, or about 100,000 inhabitants, was in the year 1849, epual to 15 gallons per diem per individual. At Nottingham and other towns, it is stated to be 18 gallons per diem. In the East London District it was in 1849, equal to 23½ gallons per diem for all purposes of trade or public supplies, and for private supplies only, 21 gallons per diem. The superintending inspectors generally estimate an average of 20 gallons per diem for all purposes, and I think, when calculating for the probable *future* wants, this quantity will be the safest upon which to form an estimate.

If therefore provision be made for the next thirty years, when the population (as shown hereafter) may amount to 145,466, the daily supply should be equal to 2,909,320 gallons.

Suppose this supply is to be obtained by collecting rain, and flood waters into a store reservoir; then it becomes a question what the fall of rain in the locality of the proposed reservoir is likely to be in a year, when there is the *least* fall, and what proportion of the rain so falling is likely to flow off the ground into the reservoir; and it should be observed that in the years when there is the least fall of rain, the earth must be drier than in wet years, and of course being more absorbent a less proportion of the rain falling will find its way into the store reservoir.

It appears that out of 12 years, viz. 1835, 36, 37, 38, 39, 40, 41, 42, 45, 46, 47, and 48, from rain guages registered by Mr. Burgess, at Great Wigston, the year 1838 was the shortest water year, when 22 inches only of rain fell; the greatest fall was in 1848, when 36¾ inches of rain fell; and that the average of the 12 years was equal to 27⅓ inches; bnt it may be assumed that 22 inches is likely to be the *smallest* annual fall of rain. From experiments made by me in one of the Lancashire valleys, to determine the quantity of water flowing off the ground, as compared with the rain fall, I found that although the proportion varied very much, yet that half of the fall might be taken as the average flow, and the country in the neighbourhood of Leicester, not being dissimilar in its contour to that in which the experiment was made, it is quite reasonable to assume that the same proportions may be taken as an approximation for this locality.

The quantity of rain water, therefore, that may be stored in the neighbourhood of Leicester should not be estimated at more than 11 inches per annum. Mr. Hawkesley in his evidence before the surveying officers at Leicester, in 1847, stated that he had no sufficient data from which to calculate the rain fall in the neighbourhood of Thornton, but from what it was found to be at Nottingham, he thought it might be from 28 to 30 inches, and that allowing 16 inches for evaporation, he could not reckon that more than 12 inches, or about 43 per cent. of the whole rain fall would flow into the proposed reservoir. According to the guages taken at Thornton, from February, 1848, to September, 1849, or for 20 months, it appears that the whole fall of rain was equal to 45.48 inches, or at the rate of 27.28 inches per annum. The fall at Great Wigston during the same period was 59.21 inches, or at the rate of 35.52 inches per annum. The difference between the falls of rain at the two places is 23 per cent. and as the first is on higher ground than the latter, this confirms, not only my own experience (obtained in Lancashire and Derbyshire), but is in accordance with that of the great Dr. Dalton's, who, in his observations upon the fall of rain at the pass on Mount St. Bernard (vol. 5, new series of Manchester Phil. Trans. page 236), remarks, that from observations made in Great Britain, it appears to be an established fact, that more rain falls in the hilly parts of the country than in the plain. *But it also appears that the quantity of rain in* a low situation *is greater than that in an elevated situation in the* vicinity.

Taking the shortest rain fall at Great Wigston to be twenty-two inches per annum, then the fall at Thornton would be 23 per cent. less, or seventeen inches.

The quantity of rain that flowed off the ground at Thornton during the twenty months before named, was equal to 51 per cent., or say half of the rain fall—the quantity of rain therefore that could be calculated upon in short water years at Thornton should not be estimated at more than 8½ inches, although the *average* rain fall would, upon the same data, amount to 21 inches, and the *average* flow to 10½ inches; these calculations are made upon the assumption, that the store reservoirs are sufficiently capacious to collect the *whole* of the rain flowing off the ground *in the year.*

The area of the water shed at Thornton is stated to be equal to 2890 acres, which I shall assume to be correct, (although, according to the Ordnance plans, it would appear to be about 10 per cent. less,) the quantity therefore that could be collected in short water years from this extent of water-shed would be equal to 89,170,950 cubic feet per annum, or 244,304 cubic feet per diem, equal to 1,522,502 imperial gallons, and this divided by 20 gallons per diem, the quantity, which I agree with Mr Hawkesley in recommending as a proper supply, will amount to 76,125, representing the amount of population that could be supplied from this source, and even though the expense of bringing the water a distance of nine or ten miles were put out of the question, I could not, under such circumstances, recommend the establishment of works at a source so limited in its capabilities for the supply of a large and increasing town like Leicester, which, if the increase of population be as great during the next, as it has been for the last thirty years, would require not less than twice this quantity of water for the proper service of the inhabitants. I have shewn upon the accompanying Ordnance map, the extent of water-shed supplying each of the sources from whence the samples of water sent to me were taken. In taking the extent described upon the plans and in the tables, it is assumed that reservoirs of sufficient size *could* be constructed at these sources, but in most of the cases this would be found practically unattainable, on account of the great expense that would have to be incurred; the plan and tables referred to will, however, show the comparative capabilities of each shed or valley for supplying water. I have made a table shewing the area as measured from the Ordnance map, the distance of the source from the Grand Stand on the Race-course, and the number of inhabitants that could be supplied, supposing the whole of the water flowing out of the valleys during the twelve months of the *shortest* rain year could be collected at the point represented on the map. I have placed those above the line in the order given by your chemists, as representing the best waters, and those rejected by them as inferior are given afterwards below the line.

The sources on the south are calculated according to the Great Wigston Register, and are distinguished by the letter "a," the others according to the Thornton Register.

	Area of WaterShed Acres.	Distance from the Grand Stand on Race Course, Miles.	No. of Inhabitants that can be supplied with 20 Gallons per Day in short water seasons.
A No. 10, Glen Magna	8,686	$5\frac{1}{2}$	228,789
B No. 3, Belgrave Brook	5,312	3	139,918
C No. 2, Willow Brook, Saltersford Bridge.	3,927	$2\frac{3}{4}$	103,437
,, Nos. 13 and 14, St Mary's Mill, River Soar	91,000	$1\frac{5}{8}$	3,102,000 (a)
D No. 12, Lower down Glen Magna, near Narborough Road......................	23,239	$4\frac{5}{8}$	792,168 (a)
E No. 8, Thornton and Lockey Bridge	2,670	$9\frac{3}{4}$	70,238
No. 6, Grooby Pool	2,022	$6\frac{1}{2}$	53,259
No. 11, Knighton Brook	4,642	$1\frac{1}{2}$	158,236 (a)
No. 5, Brook leading from Grooby Pool ..	2,768	$5\frac{1}{4}$	72,909
No. 4, Barkby and Beeby Brook	3,905	$6\frac{1}{2}$	102,857
No. 7, Brook $\frac{3}{4}$ mile above Bocheston	4,406	$9\frac{1}{4}$	116,054
No. 1, Willow Brook at Humberston Bridge	7,852	$1\frac{7}{8}$	206,821
No. 9, Glenfield Mill-pond..............	11,580	$5\frac{1}{2}$	305,417

In selecting the best source for the supply of a large town, due regard must be paid to the probable future increase of population, and if choice be allowed, that one which will afford the largest quantity should (cœteris paribus) be chosen. And it becomes the more desirable to select a site which would afford a supply sufficient to meet any increased demand that may arise, at least for sixty years to come, so that there may be no occasion to erect new works at any other point, because the extension of works which may be necessary from time to time, to meet an increasing consumption, will be a much less expensive operation, if the same source can be resorted to, for the whole of the additional quantity that may be required.

Now, should the population of the borough continue to increase in the same ratio that it has done for the last thirty years, namely, thirty per cent. in every ten years, at the end of sixty years it would amount to 319,586; and an examination of the foregoing tables will shew that there are only two sources from which a sufficient quantity of water could be obtained, for the efficient supply of so large a number of inhabitants; namely, the Glen Magna stream, between Blaby and the mill, near the Narborough road, and the river Soar, at St. Mary's mill.

By the report of the chemists, it would appear that the water from the Soar is of better quality; and, as the point at which it is proposed to take it from that river is only about a distance of one mile five furlongs from the grand stand, on the race course, while that on the Glen Magna stream is about four miles five furlongs, it is unquestionable that, in an engineering point of view, the river Soar offers, by far, the most eligible source of the two; as regards the other sources referred to in the tables, it will be only necessary for me to remark, that, with the exception of the Thornton scheme, the adoption of either of them would involve a heavy expenditure, not only in the construction of large store reservoirs, but also in the employment of steam power.

It may be as well to add, that the chemists report the water from the Willow Brook, at Saltersford Bridge, as being better than the water from the same brook, lower down, at the Humberstone Road Bridge, and the Soar water, at St. Mary's Mill, as being equal in quality to the water from the Willow Brook, at Saltersford Bridge; those, therefore, who have been in the habit of using the water from this brook will be able to form a very correct idea of the quality of the proposed supply; at the same time, it must be borne in mind that it is proposed to filter the Soar water before it is delivered into the town, and the improvement in its quality, to be obtained by that process, is shewn by the chemists to be very great,

The water taken from Messrs. Brewin and Co's well, is represented to be considered as an average specimen of the well waters used in Leicester; taking for granted that this is the case, it may be interesting to draw some comparisons between that, and the water from the Soar, which latter it is proposed to filter before distribution.

The saline contents of the two waters, before and after the lime process (or before and after boiling), appear to be as follows :—

		Grains.			Grains.	
Well water	Before,	100	per gallon.	After,	69	per gallon.
Soar water	„	33	„	„	16	„
Well water in excess		67	or 103 per cent.		53	or 231 per cent.

It is shewn, by the chemical experiments, that the weight of soap required to soften an imperial gallon of each of the foregoing waters, so as to produce the same economical effect for washing purposes, is —

		Grains.			Grains.	
For well water	Before,	533	per gallon.	After,	426.4	per gallon.
For Soar water	„	213	„	„	106.6	„
Well water in excess		320	or 50 per cent.		319.8	or 201 per cent.

A very essential difference: for, from a return made to me by Mr. S. S. Harris, it appears, that the consumption of soap in the manufactories *alone* amounts to 312 tons per annum; this, at £50 per ton, is equal to £15,600 per annum. The same return also shews that 56lbs of soap are required for every 264 gallons of water consumed.

There can be no doubt, from the analyses of the sewer and navigation waters, where contaminated by the dye waters, and that of filtered Soar water uncontaminated, that a great saving will be produced to the manufacturers by the substitution of the proposed water for that which is not unfrequently used, but, as before remarked, those who have used the Willow Brook water for manufacturing purposes, will be well able to appreciate the difference.

As regards the diminution of incrustation in Steam Boilers, it will be in the proportion of 33 to 100 which numbers represent the quantity of Salts in each water. The time that a Boiler will last without cleansing, depends (cæteris paribus) upon the quantity of water evaporated in it in a given period, so that if equal quantities of well water and Soar water be evaporated in two boilers of the same size, the incrustation at the end of any stated time would be three times as great in that supplied with well water, as in the other in which Soar water was used, and therefore a Boiler working with well water, would require to be cleansed three times as often as if the Soar water were used in it; assuming that with every 56lbs of soap there be used 264 gallons of water, then taking the same proportions, 312 tons will give a result of 3,294,721 gallons, representing the total quantity of water with which soap is used by the Manufacturers in Leicester in the course of a year, therefore as it was found by the chemists that to soften the Soar water, it required 9 grains of lime to every gallon, it follows that less than 2 tons of lime would soften the whole of the above quantity.

If these statements be correct, the adoption of this inexpensive process would appear to be well worthy of the consideration of Manufacturers who require soft water, and the more so, that it has been already used for this purpose (for a long period) although not generally; as an instance of this on a small scale, one of your chemists, Mr. A. Aikin, informs me, that he has employed it for many years to soften the water supplied to his residence by the New River Company.

If, however, it were proposed to soften in this way the whole of the water supplied to the Town, to effect that, 609 tons of Lime per annum would be required, which would alone cost £335, and if to this be added the expense of labour and interest upon Capital for the works required for carryiug on the process upon so large a scale, the charge would be increased to £500 per annum, which sum being capitalised at 4 per cent. would amount to £12,500, an expenditure that I should have much hesitation in recommending; this however being a commercial question, will be best decided upon by the Committee.

DESCRIPTION OF WORKS.

It is proposed to take the water from the River Soar, somewhere in the neighbourhood of St. Mary's Mills, from whence it will run into a reservoir, where the coarser particles suspended in it will be deposited previous to its being permitted to flow on to the filter bed : and from thence it will pass directly into the pump wells of the engines. The filter bed will be made of sufficient size to filter the whole of the water that it is calculated may be required, in any period, during the next 30 years. It is proposed to make a small summit reservoir upon the Race Course or in its neighbourhood, and to erect two engines of about 60 horse power each, with two pumps to each ; one pump to raise eleven-twelfths of the whole quantity of water into the above mentioned reservoir, the other pump to raise the remaining one-twelfth over a standpipe about 50 feet in height at the summit reservoir, to supply Stoney Gate, the Lunatic Asylum, and the neighbourhood of the Race Course *above* the level of the reservoir. It is calculated that one engine will be sufficient for the first 15 years, and that the second will only be required as an auxiliary in case of accident or stoppage for necessary repairs, but during the second 15 years it will be required to work the second engine, and a third engine will then have to be erected, the size of which, however, will be best determined when the period arrives for the necessity of its erection.

It is proposed to lay about 40 miles of pipes varying from 20 inches to 3 inches in diameter. The estimated cost for the whole of these works is £43,000, for the supply of 145,466 persons with an average quantity of 20 gallons per diem each.

This quantity however includes supplies for manufactories and for sanitary purposes.

This estimate is equal to less than 6s. per individual, and it may be observed that £1 per individual is not an uncommon amount calculated as the average cost of water works.

As regards the mode of distribution, I take for granted that the council, under existing circumstances, will consider it necessary that it should be upon the system of what is termed constant supply, and if the meaning of that term be a supply equally constant, equally abundant, and under a pressure equal to that afforded to Nottingham, and some other towns, I can see no difficulty in their undertaking to adopt a similar arrangement. As regards the poorer classes of houses, I consider that the arguments urged by the sanitary Commissioners must be considered as convincing.

Although I still see great commercial difficulties in a *private company's* undertaking to give such a supply; these do not appear to me to be the same in the case of a *Municipal Body*, where in fact every member of the council, and every officer employed by them, becomes an inspector to prevent waste, who will have a personal interest in taking care that this does not occur, since, by allowing it to do so, a penalty would be inflicted on himself in the shape of additional rates. The position too of the Town Officers will have a moral effect upon the poorer classes, which no Directors of a Company could expect to produce, for as in the first case, the parties would be presumed to act for the public benefit only, in the latter, it might be supposed that they were merely studying their own profits.

I should not, however, recommend the Town Council of Leicester to impose such restrictions as have been promulgated by the Town Council of Coventry; if they intend giving an abundant supply of water to the poor, they should take care that the restrictions are for unnecessary waste only, and not by extending them beyond this point to give a less abundant supply, under a system where the water is supposed to be continually accessible, than would have been afforded by an ordinary daily supply. I have not entered into the details of connecting pipes, and internal fittings for the houses, as ample provision is made for this portion of the work in Acts passed in late years by the Legislature.

POPULATION AND RATES.

	Number.	Increase in 10 years.	Per Centage of increase.
In 1801 the population amounted to	16953		
In 1811 ditto ditto	23146	6193	36½ per Cent.
In 1821 ditto ditto	30125	6979	30 1-10 ,,
In 1831 ditto ditto	39306	9181	30 4-10 ,,
In 1841 ditto ditto	50932	11626	29½ ,,

These returns shew an average increase in the population for the last 30 years, at the rate of 30 per cent. in every ten years, and calculating upon the same rate of increase, the population for the next 30 years will be as follows :—

In 1851	66212	15284	30 per Cent.
In 1861	86075	19863	30
In 1871	111897	25822	30
In 1881	145466	33569	30

Assessed Rental.— It appears from a return from the Town Clerk's Office, dated Oct. 16th, 1849, That it amounted to £93,533. 1s. 5d. upon 12,962 private houses, or an average of £7 4s. 3¾d. per house ; according to the census of 1841, the number of uninhabited houses was 10,552, and the population 50,932 or 4.82 inhabitants per house ; adopting this ratio, 12,962 houses will represent a population of 62,477 and the assessed rental will be nearly equal to 30s. per individual per annum.

The assessed rental upon " *other buildings*," *&c.* amounted according to the said return to £13,632. 15s. 5d.

The assessed rental upon " *land, &c. not included elsewhere*," amounted according to the said return to £11,087. 6s. 7d.

According to clause 88 of the Public Health Act, the property in the last item can, it appears, be rated at 1-4th part only of the net annual value thereof, or £2772.

I cannot positively say that all the particulars in the last items, given in the return before me, are affected by this clause, it is in fact a question belonging to your legal adviser, I have, however, to suit my present purpose assumed that such is the case. As regards the second item for " *other buildings*," *&c.*, I also assume no increase.

In the following calculations I have assumed that the assessed rental upon private houses will increase in proportion to the increase of population, at the rate of 30s. per annum per individual, adding to this amount £16,000 per annum for the two last items; should this amount be increased in future years, the amount of rates hereinafter specified will be reduced, pro tanto.

Calculating upon the foregoing data, the population in 1851 will amount to 66,212, and the assessed rental at 30s. per head to £99,318, to which £16,000 are to be added, making a total of £115,318.

In 1881 the population will amount to 145,466, the assessed rental upon private houses to £218,199, to which must be added £16,000, making a total of £234,199.

The annual quantity of water proposed to be supplied in the first instance (in the year 1851), will amount to 483,347,600 gallons, of which 15 per cent., or 72,502,140 gallons, is supposed to be required for public sanitary purposes, which leaves 410,845,460 gallons, the sale of which should produce a revenue of £4,900, the cost therefore of every 1000 gallons will amount to 2d.86-100 or say for Manufacturers, 3d. per 1000 gallons.

The annual quantity supposed to be taken by the manufacturers is calculated at 15 per cent. also, or 72,502,140 gallons, which, at 3*d.* per 1000 gallons, will produce a nett revenue of £906. 5*s.* 6*d.* or, say £900 per annum; this amount deducted from the £4,900, leaves £4,000 to be raised by rates upon houses and other buildings, and deducting £560 as the proportionate rate upon £16,000 assessed rental upon "*other buildings, &c.*" will leave £3,476 as the total annual rate upon private houses.

According to the document before referred to, the number of houses at each amount of rent, appears to be according to the following proportions, viz.,—

Out of 1000 houses there are	675 the assessed rental of which is £5 per annum.	
Do.	161	10
Do.	94	20
Do.	34	30
Do.	14	40
Do.	22	above
	1000	

The following table will represent the number of houses at each amount of assessed rental, the rate per house, at per annum, and per week, and the total annual amount produced by each class,

1851.

Class of Houses.	Number.	Rate per Annum.	Rate per Week.	Amount per Annum.
		s. d.	d.	£ s. d.
Houses at £ 5 Assessed Rental	2739	2 7	0 6-10	1197 15 3
Do. 10 "	2212	5 2	1 2-10	571 8 8
Do. 20 "	1292	10 4	2 4-10	667 10 8
Do. 30 "	467	15 6	3 6-10	361 18 6
Do. 40 "	192	21 0	4 8-10	201 12 0
Do. 60 "	302	31 6	7 1-4	475 13 0
Total amount and average Rates ..	13738	5 0¾	1 16-100	3475 18 1

The total amount which is supposed to be the annual cost of water at the commencement of the thirty years, is equal to $3\frac{1}{2}$ per cent. upon £99,318, the assessed rental of the private houses.

SUMMARY.

		£
Annual charge for houses	....	3,476
Do.	for "other buildings," &c.	560
Do.	for manufacturers	900
	Total	£4,936

The following statements show the quantity of water, the rates, &c., for the year 1881.

The whole quantity of water supplied per annum, will amount to 1,061,901,800 gallons, and deducting 15 per cent., or 159,285,270 gallons, for sanitary purposes, there will remain 902,616,530 gallons to be supplied for £6,300, which is at the rate of $1\frac{675}{1000}d.$ per 1,000 gallons.

The annual quantity proposed to be supplied to manufacturers will be equal to 159,285,276 gallons, which, at $1\frac{675}{1000}d.$ per 1,000 gallons, will amount to £1,111 13*s.* 6*d.*, say £1,112 per annum, and this deducted from £6,300, leaves £5,188 to be raised by rates upon houses and "*other buildings*," &c.

The assessed rental will amount to £234,199, from which deducting £16,000 for "*other buildings*," &c., leaves £218,199 for private houses.

A rate of $2\frac{1}{4}$ per cent, upon £234,199 will produce £5,269. 10*s.* per annum, and, deducting £300 as the proportion for "*other buildings*," &c., it leaves £4,910 for the amount of annual rates upon private houses.

The number of private houses, in 1881, will, it is calculated, amount to 30,180.

The following table is constructed upon the same principle as the last.

1881.

Class of Houses.	Number.	Rate per Annum.	Rate per Week.	AMOUNT.
		s. d.	d	£. s. d.
Houses at £ 5 Assessed Rental......	20,372	1 8	0 4-10	1697 13 4
Do. 10 "	4,859	3 4	0 3-4	809 16 8
Do. 20 "	2,837	6 8	1 ½	945 13 4
Do. 30 "	1,026	10 0	2 3-10	513 0 0
Do. 40 "	442	13 4	3 0	281 6 8
Do. 60 "	664	20 0	4 6-10	664 0 0
Total amounts and average rates....	30,180	3 3	0 3-4	4,911 10 0

SEWER RATES.

Adopting the same principle of calculation for Sewers, as I have done for the water supply, the following results are obtained.

In 1851, the annual cost for the Sewers will be as before stated, £6,500, and a rate of 5 65-100 per cent. upon £115,318 will produce this amount, hen deducting £900 the proportion due to £16,000 the assessed rental for "*Other buildings, &c.*" £5,600 will remain as the Annual amount of rate to be charged to private houses.

In 1881, the annual cost will be £8000, and a rate of 3 41-100 per cent. upon £234,119, will produce this amount, and deducting £545, the proportion due to £16,000, the Assessed rental for "*Other buildings, &c.*' leaves £7455, to be charged for private houses.

TABLE FOR SEWERS.

1851.

Class of Houses.	Number.	Rate per Annum.	Rate Per week	Amount Per Annum
		s. d.	d,	£ s. d.
Houses at £ 5 Assessed Rental....	9273	4 2	0 97-100	1931 17 6
Do. 10 "	2212	8 4	1 94-100	921 13 4
Do. 20 "	1292	16 8	3 38-100	1076 13 4
Do. 30 "	467	25 0	5 82-100	583 15 0
Do. 40 "	192	33 6	7 73-100	326 12 0
Do. 60 "	302	51 0	11 77-100	770 0 0
Total amounts and average rates......	13738	8 2	1 9-10	5606 0 2
1881				
Houses at £ 5 Assessed Rental....	20372	2 6	0 57-100	2546 10 0
Do. 10 "	4859	5 0	1 15-100	1214 15 0
Do. 20 "	2837	10 0	2 3- 10	1418 10 0
Do. 30 "	1026	15 0	3 46-100	762 10 0
Do. 40 "	422	21 0	5	443 2 0
Do. 60 "	644	32 0	7 38-100	1062 8 0
Total amounts and average rates....	30180	5 0	1 15-100	7454 15 0

Table of Charges per Annum, and per Week, for Water supply and Sewage together, for the years 1851 and 1881, and also the mean or average charge between the two years.

Class of Houses.	1851.		1881.		Mean or Average between 1851 and 1881.	
	Rent per Annum.	Rent per Week.	Rent per Annum.	Rent per Week.	Rent per Annum.	Rent per Week.
For £5 Houses ...	6/9	1 56-100	4/2	0 96-100	5/5½	1 26-100
10 " ..	13/6	3 12-100	8/4	1 92-100	10/11	2 52-100
20 " ..	27/	6 24-100	16/8	3 34-100	21/10	5
30 " ..	40/6	9 34-100	25/	5 76-100	32/9	7 56-100
40 " ..	54/6	12 57-100	34/4	7 92-100	44/5	10 1-4
60 " ..	82/6	19	52/	12	67/3	15 1-2
Average per House	13/2	3d.	8/3	1d. 9-10	9½	2½d.

From the foregoing, it appears, that the average expenditure for the first fifteen years for sewers and water supply will amount to £11,400 per annum, or deducting £900 paid for water for manufacturing purposes, it will amount to £10,500 per annum; and for the second fifteen years it will amount to £14,300 per annum, or deducting £1,112 paid for water for manufacturing purposes, it will amount to £13,188 per annum.

The average for the thirty years (exclusive of manufactories) will amount to £11,844, this, it must be recollected, includes interest upon capital and for its liquidation.

The average charge during the thirty years for a £5 house will be equal to 1¼d. per week, and the average charge upon all classes of private houses will be 2½d. per week.

The foregoing estimates, however, are made upon the supposition of there being no returns from the sale of manure; so satisfied, however, am I of the value of the manure, that I have but little doubt that responsible parties might be found who would supply the necessary capital for constructing the works, both for sewage and the supply of water, (to the extent described in the foregoing report,) upon the following terms:—

1st. To construct the works; to maintain them for 30 years, and deliver them to the Corporation at the end of that period, in a state of good repair and good working order.

2nd. To supply filtered water for all private houses and public buildings, and for sanitary purposes, to the extent both in quantity and elevation that is hereinbefore stated; but the distribution and apportionment of the water to be made by, and be under the directionof the Town Council, the Contractors only undertaking to afford the stipulated quantity.

3rd. To construct works for the manufacture and sale of the manure, as on as the present sewage is diverted into the new sewers, which works they will also deliver up to the Town Council in a state of good repair, and good working order, at the expiration of 30 years from their establishment.

4th. The Contractors to undertake that any *profits* arising from the sale of the manure, after deducting 5 per cent. interest for capital expended, and an annual amount to liquidate the capital in 30 years, be divided *equally* between the Contractors and the Town Council.

5th. The Town Council undertake to pay to the Contractors £9,500 per annum for 30 years, from the establishment of the works, upon the security of the Borough rates, and to provide the land required, leasing it to the Contractors at per acre—to secure to them sufficient Parliamentary powers, and to afford them all the facilities in carrying out the works that their position and powers as a Corporation, enable them to do.

Calculating upon the same principles by which the former tables have been constructed, the charge per week for the £9,500 would be, upon an average of 30 years, 2*d.* per week upon the average of all classes of houses (exclusive of manufactories). These charges would be about 20 per cent. less than those hereinbefore quoted. I have made the foregoing statement with a view to show distinctly my opinion of the value of the manure to be obtained from the Leicester sewer water; but while stating what I believe contractors would be willing to undertake, I do not mean to say that if the Town Council felt authorized to undertake the work themselves, the profits would not be much larger, but the risk would also be greater. At the same time the share of the profits (if any) would go in reduction of rates, and should there be no profits, the town would, nevertheless, sustain no loss.

The following Table will show what proportion of water is intended to be supplied to each class of houses, at the rates hereinbefore stated.

	Average supply per House per diem.		Average supply per House per week.		Summer supply.	
	Barrels.	Gallons.	Barrels.	Gallons.	Per diem Gallons.	Per week Gallons.
£5	1½	54	10½	378	67½	472½
10	2¼	81	15¾	567	101¼	708¾
20	2½	90	17½	630	112½	787
30	3	108	21	756	135	945
40	3¾	135	26¼	945	168¾	1181
60	5	180	35	1260	225	1575

These quantities will, I presume, be considered sufficient for domestic purposes, including water closets, baths, &c.

Compensation to Mill Owners on River Soar.

I consider that no compensation will be due toMill-owners belowBelgrave Mill, as all the water that will be raised by the works at a higher point, will flow through the sewers, and be returned into the river immediately below that mill. The greatest average quantity of water, that will be abstracted during the first 15 years, will be 1,354,240 gallons per diem, or 147½ cubic feet per minute.

And during the second fifteen years it will be 2,909,320 gallons per diem, or 324 cubic feet per minute.

The falls of the mills to be compensated are as follows :—

	Feet.
Swan Mill	2·63
Castle Mill	3·03
North and Abbey Mills	7·32
Belgrave Mill	7·
Total	19·98 say 20 feet.

In calculating the power of these mills, the *effective* power cannot be taken as more than 60 per cent. of the water falling; and supposing that this loss should take place on every day throughout the year, which will not actually be the case, as it is most probable that for at least one-third of the time there will be more water passing the mills than can be used by them, then the loss in horse power for the two periods named will be as follows :—

	Loss in horse power for the first 15 years.	Loss in horse power for the second 15 years.
Swans Mill	0 44-100	0 97-100
Castle Mill	0 5-10	1 11-100
North and Abbey Mills	1 23-100	2 7-10
Belgrave Mill	1 17-100	2 57-100
Total	3 34-100	7 35-100

The amount to be allowed annually to the mill owners for the loss of power to the above extent, is included in the estimate for annual expenditure, but it would evidently be inexpedient to express in this Report any opinion as to what that amount should be.

I believe I have now reported upon all matters referred to me; and should the general principles enunciated in the foregoing Report, be approved of by the Town Council, I should be prepared (if called upon) to provide the necessary plans, specifications, and estimates, for carrying the proposed works into execution for the amount stated.

I cannot conclude this Report without offering my thanks to the Committee, and to the Officers of the Town Council for the valuable assistance they have so kindly and promptly afforded me during the progress of these investigations.

I have the honour to be Gentlemen,

Your most obedient Servant,

THOS. WICKSTEED, *Civil Engineer.*

Since writing the foregoing Report, I have submitted it to Mr. Aikin and Dr. Taylor, who have expressed their full concurrence in all the statements and opinions offered therein upon chemical matters.

REPORT OF ANALYSIS

OF

THE LEICESTER SEWER WATERS.

The First Series of Waters

WAS MARKED RESPECTIVELY No. 1, 2A, 3, 4, AND 5.

No. 1.

THIS water had a blueish grey colour, and deposited rapidly a considerable sediment. The greater part of the solids mechanically diffused through it were deposited in four hours, but it was remarked that the liquid was turbid after the lapse of six days; and this turbidness was found to be owing to the presence of a quantity o soapy matter dissolved in it.

SPONTANEOUS DEPOSIT. The quantity of sediment deposited spontaneously from a measured portion of the liquid, amounted in the imperial gallon to 56·6 grains. The dried sediment had a deep blue black colour and a soapy feel. It burnt with a yellow smoky flame like grease, and yielded on distillation nitrogen and sulphur. The blue colour was owing to the presence of minute particles of indigo. The *dry deposit* was found to be thus constituted :—

Combustible or organic matter, containing nitrogen and sulphur	46.47 grains
Fixed saline residue, consisting chiefly of carbonate of soda and earthy matter	10.13
Total deposit from Imperial gallon	56.6

The residuary liquid was found to contain sulphuretted hydrogen and carbonic acid. Its offensiveness was partly due to organic matter in a state of putrefaction. It had a slightly acid reaction.

Deposit by Lime Water. When the water was mixed with one-third of its volume of a saturated solution of lime, it lost much of its offensive odour, and became speedily curdled. In a quarter of an hour there was deposited a thick flocculent precipitate, consisting of lime in combination with the organic matter contained in the water. The weight of dried sediment thus obtained amounted in the imperial gallon to 149·33 grains.

Combustible or organic matter	121.33
Fixed saline residue..........................	28.
	149.33 grains

The residuary water of the lime process was rendered so clear by filtration through paper as to look like common spring water. It still had an offensive odour, partly due to the presence of some sulphuretted hydrogen, and partly to some organic matter in a state of decomposition.

The entire liquid (*i. e.* the sewer water) became clearer by filtration, but not so clear as by the lime-process. The filtered liquid was found to contain in the Imperial gallon 50·5 grains of saline matter, consisting of the chlorides of sodium and magnesium, phosphate of soda, sulphate and carbonate of lime, with traces of the oxide of iron.

No. 2 A.

This liquid was turbid and of a brownish colour. It had a highly offensive odour, partly due to sulphuretted hydrogen and partly to decomposed organic matter. Of sulphuretted hydrogen, it was found to contain 2·027 cubic inches in the imperial gallon.

Spontaneous Deposit. After four days, a greyish black sediment was procured by subsidence, the supernatant liquid being still turbid and muddy-looking. The dried sediment was in the proportion of 58·6 grains to the Imperial gallon. This was found to consist entirely of combustible matter, abounding in nitrogen and sulphur.

Deposit by Lime Water. The lime water process was employed as in No. 1, with similar results. The deposit took place rapidly—the offensive odour was in great part removed, and the supernatant liquid was rendered nearly clear.

The amount of deposit for the Imperial gallon was—

Combustible or organic matter....................	51.50
Fixed saline residue	35.43
Total deposit in Imperial gallon	86.93 grains

The entire water was rendered clear by double filtration, but was slightly coloured. The saline residue in the Imperial gallon amounted to 113·3 grains; it was constituted of salts similar to those found in No. 1.

No. 3.

This water was turbid, had a green colour, apparently from some dye liquid, and an offensive odour, but less so than 2 A. It had a slightly acid reaction; it was rendered clear by filtration, but still retained a greenish tint.

Spontaneous Deposit. The dried sediment obtained by spontaneous subsidence had a greenish brown colour, and was mixed with woollen fibres. The quantity of deposit calculated for the Imperial gallon amounted to 32 grains. It contained nitrogen and sulphur, and was thus constituted :—

Combustible or organic matter....................	23.47
Fixed saline residue	8.53
Total deposit from Imperial gallon	32. grains

Deposit by Lime Water. The water, as in the previous cases, became clearer and less offensive after it had been submitted to the lime process.

The amount of deposit for the Imperial gallon was—

Combustible or organic matter	55·46
Fixed saline residue	5·34
Total deposit in Imperial gallon	60·8 grains

The entire water became clear after two filtrations, but it was still coloured, and evidently contained much organic matter dissolved. Hence it was evaporated; and the filtered liquid then left a dark brown residue, amounting in the Imperial gallon to 140 grains. It was thus constituted:—

Organic matter, containing nitrogen and sulphur	24·6
Fixed saline residue	115·4
Total contents of filtered liquid	140· grains

The total quantity of organic and saline matter obtained from this water by spontaneous subsidence and evaporation, calculated for the Imperial gallon, will stand as follows:—

	Organic.	Grains.
Spontaneous deposit	23.47	
By evaporation	24·6	48·07
	Saline matter.	
Spontaneous deposit	8·53	
By evaporation	115·4	123·93
Total organic and fixed in Imperial gallon		172· grains

The lime process separates the whole of the organic matter, the slight difference in weight probably depending on the fact that some carbonic acid is thrown down by the lime, and subsequently driven off by exposing the precipitate to heat.

The salts chiefly contained in the water were the chlorides of sodium and magnesium, the sulphates of potash, lime and ammonia, carbonate of lime, carbonate of magnesia and oxide of iron. No phosphates were found.

No. 4.

The water was turbid, of a brownish green colour, and had an offensive odour. In four days a slight deposit had taken place, and the liquid became clearer, although still coloured.

Spontaneous Deposit. The quantity of dried sediment, calculated for the Imperial gallon, amounted to only 5·6 grains. It consisted chiefly of organic matter containing nitrogen and sulphur.

Deposit by Lime Water. The dried sediment obtained by lime water weighed 22.93 grains, and it was thus constituted :—

Organic matter	7·82
Fixed saline residue	15·11
Total deposit by lime in Imperial gallon	22·93 grains.

The lime had, therefore, slightly increased the quantity of organic deposit.

The entire water was rendered clear by two filtrations. On evaporation, the filtered liquids yielded, in the Imperial gallon, a residue consisting of

Combustible or organic matter	14·6
Fixed ash containing salts	77·4
	92 grains.

The combustible matter contained nitrogen and sulphur. The salts were similar to those found in the other waters. There was a small quantity of phosphate of lime. The filtered water contained carbonic acid and sulphuretted hydrogen. It could not be entirely deprived of the latter by lime, and still retained an offensive odour from animal matter, which the lime did not remove. It will thus be perceived that the lime water removed only one half of the organic matter contained in this water.

No. 5.

This water was black, turbid and highly offensive, owing to the presence of sulphuretted hydrogen and putrescent animal matter.

It became clear by filtration, but its offensive odour was not removed.

Spontaneous Deposit. This deposit had completely taken place in four days—the supernatant liquid being then almost colourless. The dry deposit was thus constituted :—

Combustible or organic matter	4·86
Fixed residue, carb. (lime and oxide iron)	2·6
Total deposit from Imperial gallon	7·46

Deposit by Lime Water. The weight of the dry deposit was 17·6 grains. It consisted entirely of combustible matter, deducting the weight of lime, and left no saline residue. The lime had, therefore, considerably augmented the amount of organic deposit in this instance. It had also rendered the liquid clearer and less offensive.

The entire liquid, when filtered and evaporated, left a dark-coloured saline residue, which was thus constituted in the Imperial gallon :—

Combustible or organic matter	13·3
Fixed saline residue....................................	30·7
In Imperial gallon of filtered water	44 grains.

The combustible matter contained nitrogen and sulphur. The salts in the water were similar to those found in No 4, including a small quantity of phosphate of lime.

It will be perceived, that in this water, the quantity of organic matter which is deposited spontaneously, is small. It is increased four-fold by the use of lime water.

Question 1. Are there any salts contained in these waters which will affect the sewage water of the town, so as to lessen its value as a manure?

Answer. No—on the contrary, the organic matters and phosphoric and ammoniacal salts contained in these waters, will greatly improve the sewage water and render it better fitted for manure. For this reason, the dye-water may be safely turned into the common sewers of the town.

Question 2. Can the dye-water be turned into the canal, without injury to health ?

Answer. The dye-water contains very offensive and noxious gases, and is continually evolving sulphuretted hydrogen, which is a poisonous gas, and is liable to become rapidly diffused and contaminate the air of a locality. It is, therefore, our opinion, that, so far as regards the public health, it would be advisable to turn the dye-water into the sewers of the town, and not allow it to be discharged into the canal, to become there stagnant. The exposure of a large surface of this water in a stagnant state, during a summer temperature, would tend to render the atmosphere of a place noxious, and to produce injury to public health.

Question 3. The quantity and nature of the solids held in mechanical suspension in the five specimens of water ?

QUANTITY OF SOLIDS. The quantity of solids deposited from the waters by *spontaneous subsidence,* when exposed under similar circumstances, may be thus stated in grains—the quantity of each water being estimated at an Imperial gallon :—

No. 1	56·6
No. 2	58·6
No. 3	32
No. 4	5·6
No. 5	7·46
Deposit from the mixed waters	60·9

Nos. 1, 2 A, 3, and the mixture of waters yield the largest proportion of sediment as a result of mechanical subsidence. They appear to owe this large proportion to the refuse of the dye-waters. No. 4 is represented as sewage water unmixed with dye-refuse, and this will probably account for the small proportion of solids deposited from it.

NATURE OF THE SOLIDS. In the whole of the five specimens, the sediment consisted chiefly of *organic matter*—in Nos. 1, 3, and 5, apparently derived from the dye-refuse. This organic matter was found, in each case, to contain nitrogen and sulphur:—in a dry state it would, therefore, be highly valuable as manure.

The proportion of organic matter available as manure, and calculated for an Imperial gallon of each water, is as follows :—

	Organic.	Fixed.	Total.
No. 1	46·47	10·13	56·6
No. 2	58·6	nil.	58·6
No. 3	23·47	8·53	32.
No. 4	4.	1·6	5·6
No. 5	4·86	2·6	7·46
Mixed waters	47·04	13·86	60·9

The fixed residue is also useful as manure. This observation applies particularly to those waters in which phosphate of lime was found. From the above table, it will be perceived that Nos. 2 and 1 are the richest in manuring qualities.

Question 4. The time required for the deposit to take place, when the water is at rest?

Answer. The subsidence was as complete as it was likely to be in all the specimens, in a space occupying from two to four days.

Question 5. The proportion of lime required to cause the substances held in suspension to be entirely deposited; the quantity thus precipitated,—nature of the deposit,—its value as manure, —and the time required for such deposition to take place?

Answer. Lime water was used in these experiments, and the proportion employed amounted to from thirty to forty grains of lime to the Imperial gallon of sewer water. This was found to be not more than was sufficient in the case of Nos. 1, 2 A, and 3; but it was more than was required for the waters marked 4 and 5. The surplus lime, however, has the advantage of removing the smell, and any excess is speedily taken away by exposure to air, owing to its combination with carbonic acid and its precipitation as chalk.

The effect produced by lime upon all the waters was very similar. The lime appears to precipitate the whole of the mechanically diffused organic matters, and probably those which are dissolved. It combines with them and produces a coloured sediment. It throws down the free carbonic acid as carbonate of lime, and combines with the sulphur, so as to destroy the most offensive gas, sulphuretted hydrogen. It causes a very speedy deposit and renders the liquid clear.

Quantity of Deposit by Lime. In the following Table the weight of each deposit is calculated, less the weight of lime employed. The quantity of Sewer water is an Imperial gallon, and the weights are in grains.

	Organic Matter.	Fixed.	Total.
No. 1	121·33	28·	149·3
No. 2 A	51·5	35·43	86·93
No. 3	55·46	5·34	60·8
No. 4	7·82	15·11	22·93
No. 5	17·6	Nil.	17·6
Mixed Waters	56·9	30·03	86·93

It will be perceived by this Table that the effect of the lime is to augment considerably the total amount of deposit, and in some instances to increase the proportion of organic matter which is contained in it.

Nature of the Dfposit. The deposit consists of the lime added in close combination with organic matter, mixed with the carbonates of lime and magnesia and phosphate of lime.

Value of Deposit as Manure. This is, generally speaking, in a direct ratio to the quantity of organic or combustible matter thrown down by the lime. This matter consists chiefly of substances containing nitrogen and sulphur—hence it contains the elements of good manure. The phosphate of lime which is precipitated and the surplus lime may also be considered as useful adjuncts. The value of the former is well known; hence the value of the deposit as manure may be taken at rather a higher proportion than that indicated by the quantity of combustible matter because some portion of the fixed residue consists of phosphate of lime.

Time required for Deposition. The deposit takes place with great rapidity when the lime is dissolved. The liquid acquires in a few minutes a curdled appearance, and the solid matters subside in great part in about a quarter of an hour. Agitation of the liquid after the addition of the lime, tends greatly to favour the separation.

Question 6. The appearance, nature, and value of the waters after having been submitted to the lime process?

Answer. The water becomes much clearer, and on filtration is almost colourless: some of the specimens, however, still retain an offensive odour, which disappears by free exposure to the air.

The Second Series of Sewer Waters,

MARKED NO. 1 TO NO. 7 S.

A COMPOUND WATER was prepared from a mixture of equal quantities of each of these waters.

This represents the *Leicester Sewage Water as it is at present.*

The mixture had a highly offensive odour, in which sulphuretted hydrogen was perceptible. It was of a deep blue black colour, but became quite clear and colourless by filtration, shewing that the colour and appearance were owing to undissolved matters diffused through the water. The offensive odour was entirely removed in a few minutes by a small quantity of chloride of lime, *but not by chloride of zinc, even when used in large quantity, and the mixture was preserved for a month.* It was subsequently found that this so-called Deodorizing Fluid had less power of removing the offensive effluvia *than a small quantity of lime.*

SPONTANEOUS DEPOSIT. The greater part of the solids contained in the water were deposited in the course of a few hours, but the deposition was not complete until after the lapse of forty-eight hours.

THE DEPOSIT was collected, dried, and weighed. It had a dark greenish colour, and was of a greasy, soapy nature. When heated, it evolved nitrogen and sulphur; and at a high temperature it gave off a white vapour, which burnt with a yellow smoky flame.

The dry deposit, calculated for the Imperial gallon, was thus constituted: —

	Grains.
Combustible or organic matter, containing nitrogen and sulphur	94.3
Fixed residue, chiefly saline and earthy matter	45.4
Total weight of deposit	139.7

THE WATER, after filtration,was colourless and tolerably clear. It was very offensive, but less so than before filtration. It contained no sulphuretted hydrogen in a free state, but it held dissolved carbonic acid as well as the salts usually found in land-spring water. It also contained salts of ammonia. When evaporated it left a brownish coloured residue; and this, when calculated for the imperial gallon, weighed 98 grains, of which 32 were combustible or organic matter, and 66 fixed saline residue.

The fixed saline residue of this water was found to consist of sulphate of lime, the carbonates of lime and magnesia, phosphate of lime, with traces of common salt, oxide of iron, and silica. The volatile or combustible portion, including ammonia from the ammoniacal salts, consisted of nitrogenous and sulphurous organic compounds.

DEPOSIT BY LIME WATER. The mixed water was treated with one third of its volume of a saturated solution of lime in water. The solid matters began to be precipitated in five minutes, and the precipitation was complete in half an hour. The weight of dried sediment thus obtained, amounted, in the Imperial gallon, to 228.66 grains, and it was thus constituted :—

	Grains.
Combustible or organic matter containing nitrogen and sulphur . .	139.
Fixed saline residue containing the salts above mentioned.	89·66
Total weight of deposit by lime process.	228·66

From this it will be perceived that lime separates more organic matter than can be procured either by spontaneous subsidence or by filtration.

THE RESIDUARY WATER of the lime process retains a fishy and disagreeable odour. Itcontains ammonia and sulphur (the latter combined with the lime as sulphuret of calcium):—*that most noxious gas, the sulphuretted hydrogen is entirely removed from it ;* and perhaps it may be fairly asserted that seven eighths of the offensive effluvia of the water, are entirely removed by the employment of lime in the proportion advised.

COMPARISON OF THE MIXED WATER OF THE FIRST SERIES, NOS. 1 TO 5, WITH THAT OF THE SECOND SERIES, NO. 1 TO NO. 7 S. The quantities are here calculated for the Imperial gallon.

SPONTANEOUS DEPOSIT.

	Combustible.	Fixed.	Total Weight.
1st Series	47·04	13·86	60·9 Grains.
2nd Series	108·5	49·2	157·7

Deposit by Lime Water.

	Combustible.	Fixed.	Total Weights.
1st Series	56·9	30·03	86·93
2nd Series	139.	89·66	228·66

Relative Amount of Deposit from the two series of Mixed Waters.

	Spontaneous subsidence.	Deposit by lime.
1st Series	60·9	86·93
2nd Series	157·7 Grains.	228·66 Grains.

It will thus be perceived that lime increased the deposit in the first series of mixed waters by 42 per cent., and in the second series by 45 per cent.

Residuary Waters. All the liquids of the second series (No. 1 to 7 S) after having been treated with lime, were rendered nearly colourless. All excepting 7 S contained sulphur as sulphuret of calcium: but *no sulphuretted hydrogen gas was evolved.*

Amount of Solids precipitated by the Lime Water Process, less the weight of lime employed.

The following table is similar to that given in page 13 of the first Report on the waters, Nos. 1 to 5. It therefore allows a comparison to be instituted between the two series.

	Organic (Combustible).	Fixed.	Total.
No. 1 S	66	27	93
No. 2 S	440	166	606
No. 3 S	33	40	73
No. 4 S	43	36	79
No. 5 S	13	10	23
No. 6 S	174	170	344
No. 7 S	60	nil.	60
Mixed waters	139	896	228.6

The great difference in weight observed in Nos. 2 and 6 S appears to have been in great part due to the very large proportion of fixed ash found in the deposits, probably arising from the soapy matter mixed with the water marked No. 2 S. The organic or combustible portion of the deposit was found in each case to contain much nitrogen and sulphur.

The fixed Ash obtained from these waters consisted of carbonate of lime, phosphate of lime, carbonate of soda, chloride of sodium, oxide of iron and silica, varying in proportion in the different specimens. While some of these salts, *e. g.* phosphate of lime, have valuable manuring properties, there are none of them which are injurious. The phosphate of lime was most abundant in those waters which yielded the largest proportion of organic deposit, hence the manuring value of each specimen will be determined by the relative weight of organic or combustible matter obtained in each case from the Imperial gallon, for which the weights in the above table have been calculated. It is to be observed, however, that the weight given under the head of organic or combustible matter includes the *ammonia* contained in all the specimens excepting Nos. 1 and 7, which scarcely contained any of this alkali. The fact that ammonia is included in this weight, does not at all interfere with the conclusion above drawn, because this alkali is a valuable product and adds to the manuring properties of the deposit.

A Compound Water was now made by mixing equal portions of each sewage water No. 1 to 7 S with four measures of 13 W taken from the River Soar, thus representing the *Leicester sewage water as it will be.*

The Compound Liquid had a black appearance and a very offensive odour, which was partly due to the presence of sulphuretted hydrogen; but in other respects it presented the characters of sewage water much diluted.

The offensive odour had, to a great extent, disappeared after the water had been exposed to the air twenty-four hours.

Spontaneous Deposit. The greater part of the diffused solids subsided in about an hour in the form of a thin black sediment. The deposit when dry, had a dark greenish black colour, evidently from a large admixture of organic matter. When heated, it evolved ammonia and sulphur, a fact which proved that it contained some nitrogenous organic compound. It burnt on exposure to the air, and left as a residue a brownish coloured ash. It was thus constituted :—

	Grains.
Combustible matter containing nitrogen and sulphur	24
Fixed residue containing carbonate and phosphate of lime, with traces of magnesia, oxide of iron, and silica	10
Total weight of deposit in Imperial gallon	34

It was found by a parallel experiment that the solid deposit was obtained as completely by spontaneous subsidence as by filtration; hence filtration for the purpose of separating the deposit, need not be resorted to.

The Filtered Water was clear, but it had a slightly yellowish colour, and an offensive smell. The saline residue left by evaporation, calculated for the Imperial gallon, was thus constituted.

	Grains.
Salts consisting of carbonate and sulphate of lime, with chloride of sodium	13
Combustible or organic matters (dissolved)	27
Total saline contents in Imperial gallon of Filtered Water..	40

Deposit by Lime Water. The sewage water was mixed with one-third of its volume of lime-water. The offensive smell was in great part removed. There was no trace of sulphuretted hydrogen, and the residuary water contained no sulphuret of calcium.

The deposit was dried and weighed.

Calculating for the Imperial gallon, this deposit was found to be thus constituted:—

	Grains.
Combustible or organic matter	54
Fixed residue—carbonate, sulphate and phosphate of lime, with insoluble matters, less the weight of lime used	70
Total weight in the Imperial gallon	124

According to these experiments, the total weight of organic matter in the Imperial gallon including the dissolved and undissolved portions, stands thus:—

	Grains.
As obtained by spontaneous deposit	24
,, from residue of Filtered Water	27
Total weight of organic matter	51

The quantity separated by the action of lime-water in the above-mentioned experiment amounted to 54 grains. It may, therefore, be inferred, that in the proportion suggested, the lime-water operates by throwing down the *whole* of the organic matter which admits of precipitation. The quantity of organic deposit, obtained by the use of lime-water, is more than twice as great as that which is procured by spontaneous subsidence.

COMPARISON OF COMPOUND SEWAGE WATERS.

(Imperial Gallon).

A. Sewage water as at present (Mixed S. series).

B. Sewage water as it will be (compound mixture here analysed).

1. Spontaneous Deposit.

	Combustible.	Fixed.	Total weight.
A.	94·3 grs.	45·4 grs.	139·7 grs.
B.	24·	10·	34·

2. Deposit by Lime Water.

	Combustible.	Fixed.	Total weight.
A.	139 grs.	89·66 grs.	228·66 grs.
B.	54·	70·	124.

From this table it will be perceived that if lime be used for the purpose of precipitation, then the quantity of deposit obtained from the same quantity of sewer water is more than doubled. It is certainly desirable that lime should be employed for aiding the separation of the deposit, not only because the quantity is thereby greatly increased and the solid portion is more rapidly precipitated, but because the offensive odour of the sewer water is at the same time almost entirely removed. The results prove that no injury is done to the deposit by the use of lime; and it is not thereby rendered less valuable for the purposes of manure.

A. Aikin.

Alfred S. Taylor.

REPORT OF ANALYSIS

OF SOME

SPECIMENS OF WATER MARKED W.

A Preliminary Examination was made of the waters marked from No. 1 to No. 14, W.

This examination included—1. The determination of the weight of saline contents and proportion of organic matter in an Imperial gallon of each water. 2. The physical properties as to colour, taste, and smell. 3. The comparative effects produced in each by an equal quantity of a standard solution of soap. 4. The action of a solution of lime on an equal quantity of each water, and the weight of the matters thereby precipitated. A report of these results was forwarded with the conclusion, that, considering the domestic, manufacturing, and dietetic uses to which these waters were likely to be put, the following were considered to be the best, in the order in which they are given—Nos. 10, 3, 2, 12, and 8.

From instructions subsequently received, a further analysis of the following waters was made, namely, Nos. 1, 3, 4, 7, 8, 10, 12, 14, and No. 8 W F W, the latter being a compound water prepared from a mixture of equal quantities of No. 8 W, and No. 20. W.

EFFECT OF FILTRATION THROUGH SAND.

The whole of the specimens were submitted to very slow filtration through a thick stratum of well washed sand. The water of each specimen came through very clear, and in the greater number it was colourless. The only water of the whole series which appeared to have become much improved by filtration was No. 14 W. This, upon analysis, was found to have lost both mineral and organic matter; the sand having separated, during the process of filtration, about one-fifth part of the total weight of its solid con tents. In Nos. 4 and 12, filtration through sand was found to have produced no alteration whatever in the quantity of matters contained in the waters. The results obtained by careful analysis were precisely the same both before and after the process of filtration. In all the other specimens, including the selected specimen 8 W F W, the process of filtration through sand did not produce any change in the quantity or quality of the saline contents, calling for particular notice. It is our opinion, however, that the effects of filtration through sand can only be properly estimated where the experiment is conducted on a very large scale.

These effects are in general limited to the separation of mechanically diffused impurities; but in some instances, owing to the loss of carbonic acid by evaporation, some carbonate of lime (the chief constituent of these waters) may become deposited, and with it some organic matter, The waters were found to contain but a very small proportion of mechanically diffused impurities, and to this may be ascribed the very slight effects produced upon them by slow filtration through sand.

ANALYSIS OF 14 W WATER.

This water contained less mechanical impurity than is found in most kinds of River and Spring water. It became quite clear on standing, was nearly colourless, and free from any taste or smell. In its physical properties it has all the characters of a good water for dietetic use. When evaporated it leaves a light brownish colored residue, which, when calculated for the Imperial gallon, weighs 33 grains. The saline matter in this water forms a proportion of 1-2121 parts by weight. The residue obtained from the evaporation of the water consisted of:—

	Grains.
Combustible (organic matter)	6.
Ash fixed at a high temperature	27.
	33.

By the application of various tests and re-agents the ash was found to be thus constituted.

	Grains.
Carbonate of lime, with traces of carbonate of magnesia	13
Sulphate of lime	6
Common salt (chloride of sodium) with traces of chlorides of magnesium and calcium	5
Silica and oxide of iron	3
Organic matter (combustible.)	6
Total weight of residue in Imperial gallon	33

The carbonate and sulphate of lime are in about the same proportions as those commonly found in River water.

THE LIME WATER PROCESS.

It was found by experiment that one measure of a saturated solution of lime was required, in order to produce a full chemical effect with from seven to eight measures of this water. The water became speedily turbid, and a thick sediment fell down, consisting of carbonate of lime, slightly tinted brown by the presence of organic matter. When filtered, the water was obtained quite clear and colourless. It was found to have been rendered somewbat softer by the deposit of carbonate of lime. The lime had rendered the water purer, as far as physical properties are concerned, and at the same time had not imparted to it any unpleasant taste. The filtered water was neutral; and owing to the separation of the carbonate of lime, the chemical tests shewed that there was much less of this alkali in the water which had been submitted to this process, than in the entire water. The proportion of lime-water required for an Imperial gallon of this water would be about 22 ounces, containing from 8 to 10 grains of lime.

When the water which had been submitted to the lime process was filtered and evaporated, it left as a residue in the Imperial gallon 16 grains, of which 2 consisted of combustible or organic matter, and 14 grains of fixed salts. The lime had thus caused the water to lose two-thirds of its organic matter, and about one half of its fixed saline constituents (carbonate of lime). The whole of the carbonate of lime, previously held dissolved in the water by carbonic acid, had been removed.

ANALYSIS OF No. 8 W F W.

This water was artificially made by mixing together equal measures of No. 8 W, and No. 20 W.

The mixed water was clear but had a distinctly yellowish colour; there was no particular taste or smell. On evaporation it was found to leave a residue, which when calculated for the Imperial gallon was thus constituted :—

	Grains.
Combustible (organic) matter	5
Fixed saline residue	11
Total weight of residue	16

The fixed residue by the application of the usual processes, was found to consist of various salts in the proportions mentioned in the following table (viz.) :—

	Grains.
Carbonate of lime, and traces of carbonate magnesia	7
Sulphate of lime	2
Chloride of sodium, with traces of chlorides of calcium, & magnesium	2
Combustible or organic matter	5
Total contents in Imperial gallon	16

The proportion of saline matter in this water was equal to 1-4375th part by weight, *i. e.* it was in less than half the quantity of that contained in the water marked 14 W.

THE LIME WATER PROCESS.

When mixed with one-fourth of its volume of a saturated solution of lime in water it became very cloudy, and an abundant deposit of carbonate of lime, slightly coloured by organic matter, speedily subsided.

The water filtered from this deposit was remarkably clear. On evaporation it yielded in the Imperial gallon only seven grains of dry residue, consisting of six grains of fixed salts (chiefly common salt and sulphate of lime) and one grain of combustible or organic matter. The lime-water had therefore removed four-fifths of the organic matter, and nearly one-half of the mineral constituents, chiefly carbonate of lime; no free lime could be detected in the water on filtration.

These two waters may be regarded as good and wholesome: No. 8 W F W, with the exception of being somewhat coloured, may be considered as the better adapted for domestic and dietetic use. Both are greatly improved by the lime-water process, but 8 W F W is most improved. As its hardness chiefly depends on the presence of carbonate of lime, the separation of this salt by lime-water causes it to become remarkably soft; No. 14 W is not softened in an equal degree, because its hardness depends in part upon the presence of sulphate of lime, a salt which is not precipitated by lime water. Nevertheless, it may be regarded as a good and wholesome water.

ANALYSIS OF 21 W.

This water, although well shaken, was quite clear and free from any mechanical impurity. It had neither colour, taste, nor odour, and presented every appearance of a good spring water. It was found to contain in the Imperial gallon—

	Grains.
Carbonate of Lime	31
Sulphate of Lime	52
Common Salt	14
Chlorides of Calcium and Magnesium—organic matter, traces	3
Total weight of dry saline residue	100

The salts contained in this water are in unusually large proportion, as they form 1-700th part of it by weight; but the water is remarkably free from organic matter, so that the saline residue obtained by evaporation is nearly white, and is not deliquescent, showing that the chlorides of magnesium and calcium were in small proportions. The water may be considered as very hard; it has a great tendency to fur boilers, and will wastefully consume a large quantity of soap.

The effect of the lime-water process, used as in the other waters of the W series, was simply to cause the precipitation of the carbonate of lime, and to reduce the dry saline residue to about 66 grains in the Imperial gallon, a result which was obtained by experiment. The water was thereby rendered somewhat softer, but it was still much harder than most varieties of Spring and River water which we have examined.

When a quantity of the water was placed in contact with a polished surface of metallic lead, and allowed to remain four days, it was found, although still clear, that there had been a slight chemical action on the metal. The surface of metal was coated with a thin film of sulphate of lead, and a small portion of a salt of lead had become dissolved, or diffused in a finely divided state through the water. It has about the same tendency to act upon lead as some of the other W specimens which we have examined; but 14 W and 8 W F W did not give such well-marked indications of a chemical action on lead as 21 W.

This water cannot be recommended, either for domestic use or for dietetic and manufacturing purposes; the sulphate of lime is in such large proportion as to render it unfit for constant use as a diet drink.

In consequence of its freedom from colour, taste, and smell, and of the absence of any notable portion of organic matter, this might be pronounced a good potable water. Chemical analysis, however, shews that there are such strong objections to its use, that it should be rejected when a better quality of water can be obtained.

THE SOAP TEST APPLIED TO THE THREE WATERS.

THE WATER NO. 1.

Before the lime process, it was found that this water required four measures of a standard solution of soap to take away the hardening effect of the salts, and render the water soft for domestic use or manufactures.

After the lime process, two measures of the same standard solution of soap sufficed to render the water as soft as the original water was rendered by four measures.

THE WATER No 8. W F W.

Before the lime process, it was found that three measures of the standard solution of soap rendered this water as soft as No. 14 was rendered by four measures. In a second experiment the water was rendered decidedly soft by two and a half measures of the standard solution, but this quantity of soap solution did not suffice to soften an equal quantity of No. 14.

After the lime process one measure of standard solution of soap sufficed to render this water quite soft.

THE WATER 21 W.

Before the lime process this water required *ten* measures of standard soap solution in order to soften it to the same degree as the other waters were softened. *Nine* measures softened it only partially, and *nine and a half* measures did not so effectually soften it as *ten*. We consider, therefore, that in practice it requires ten measures of standard solution to put 21 W in the same condition of softness as the other waters.

After the lime process *eight* measures produced on this water the same effect as ten measures produced on that which had not been submitted to the lime process. The lime process removed, therefore, about one fourth of its hardness.

SUMMARY OF RESULTS AS TO HARDNESS.

An Imperial gallon of each water before and after the lime process would consume the following weights of soap before the soap would be available for ordinary domestic use. These calculations are based on experiments made on water which has not been boiled

The weight of the soap is in grains, of which there are seven thousand to the Imperial pound.

BEFORE THE LIME PROCESS.

	14 W.	8 W F W.	21 W.
	Grains.	Grains.	Grains.
Weight of soap to soften an Imperial gallon	213.2.	133.25 to 159.9.	533.

AFTER THE LIME PROCESS.

	14 W.	8 W F W.	21 W.
	Grains.	Grains.	Grains.
Weight of soap in grains to soften an Imperial gallon	106.6.	53.3.	426.4.

A. AIKIN.

ALFRED S. TAYLOR.

APPENDIX

TO THE

REPORT ON THE ANALYSIS

OF THE

LEICESTER WATERS.

REMARKS ON THE PURITY OF WATER.

In the Report to the General Board of Health on the water supply to Leicester, by W. Ranger, Esq., 1849, we find, at page 31, the following passsage :—

" By the terms of the Act, the supply of water must be 'pure and wholesome,' *i.e.* free from vegetable, animal, or mineral matter, and at the same time not flat, but well aerated; it must be 'proper,' a word to be taken in its fullest sense. It must also be sufficient for all the purposes comprehended in the Public Health Act."

As we have been entrusted by the Corporation of Leicester with the duty of making a chemical examination of the waters for the supply of this large town, we take leave to offer a few remarks on the above statement.

What is meant by '*pure*' water? There are probably no two persons, unacquainted with chemistry, who would agree in assigning a meaning to the word "*purity*," as applied to water. Absolutely *pure* water is that which has been procured by *distillation*, and which, when evaporated in any quantity to dryness, would leave no solid residue whatever. The only *natural* water that approaches to this character, is *rain water*, which has been collected in clean glass or porcelain vessels, before it has been allowed to come in contact with any substance upon the earth. The rain water thus collected in towns, generally holds dissolved, numerous impurities floating in the atmosphere of towns.

In the Parliamentary inquiry on the water supply of the metropolis, instituted by the House of Lords, in the year 1840, their Lordships appear to have considered water to be *impure* just in proportion to the quantity of saline or mineral matter contained in it; and some of the chemists examined on that occasion as witnesses, appear to have led them into this error, by speaking of certain waters being *purer* than others, merely because there was a smaller proportion of saline matter contained in them. In fact, "purity," as in the extract which we have quoted from your Leicester Report, was made to depend on freedom from vegetable, animal, or mineral matter.

If the object of water-supply to a town were merely to furnish water for manufacturing, washing and culinary purposes, then, in this view of the case, the only *pure* water would be *distilled* or *rain* water; and their Lordships, as well as the Board of Health, would be correct in setting up *this* as the *standard of purity ;* but the use of water for the *diet of men and animals* is a very important part of this inquiry; and, in our view, this should be made the first consideration.

Distilled or rain water, collected in the manner described, although *absolutely pure*, would not be proper for a diet water. This is very well known to all professional men. It wants that freshness or aeration which good and wholesome spring water always possesses, by reason of the carbonate of lime and carbonic acid contained in it. In the extract from the Leicester Report, two incompatible conditions are assumed for determining the quality of water. Water which is entirely "free from vegetable, animal, or mineral matter," *i. e.* distilled water, must necessarily be "*flat*," and cannot be "*well aerated*." The carbonate of lime constituting the greater part of the mineral matter in wholesome spring water, acts as a basis for fixing carbonic acid, and it therefore serves to aerate the water, and deprive it of that flatness which it would otherwise possess; but, according to the statement in the Report, the water selected must be well *aerated—not flat*, and yet free from mineral matter. It may be safely asserted, that no such water exists on the surface of the globe, and that to seek for it would be a needless waste of time.

There is another most serious consideration connected with the use of distilled or rain water, namely, that in a *direct ratio* to its *purity*, or its freedom from vegetable, animal, or mineral matter, it is liable to become *poisoned* by contact with lead, as by circulation through leaden pipes or by being collected in leaden cisterns. With absolutely *pure* water, the production of poisonous compounds of lead (carbonate and hydrated oxide) takes place in the course of a few hours; we have known it to occur by mere contact with the metal in a few minutes. These facts are demonstrable by experiment, and they show that the *standard of purity* assumed by their Lordships' Committee, in 1840, and in the Leicester Report, is altogether distinct from the *standard of wholesomeness.* Many years since, an epidemic colic prevailed at Amsterdam, which was ultimately traced to the general use of *rain water (pure water)* which had been collected from the leaden roofs of the houses. The rain water thus collected was used for culinary purposes, and it gave rise to an alarming number of accidents. A large number of persons suffered severely from lead-colic. On a recent occasion, the Ex-Royal Family of France suffered from lead-poisoning at Claremont. The water which supplied the mansion was found, on analysis, to be remarkably free from vegetable, animal, and mineral matter, and it had, *therefore*, become strongly impregnated with a poisonous salt of lead. The members of the family were only saved by immediate removal, and the substitution of slate for leaden cisterns.* Hence, even if it be doubted whether *distilled or rain water* be less wholesome as a constant diet drink than good spring water, the fact, that under the common mode of supply it would become infallibly *poisoned*, is a complete answer to such water being taken as the *standard of purity* for the supply of towns.

The impregnation with lead would not interfere with the use of

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* A similar case occurred a few years ago at the Dowager Marchioness of Westminster's, at Moor Park—by the advice and under the direction of Mr. Wicksteed, the leaden pipes were removed, and cast iron pipes and galvanised iron tubing were substituted by order of Lord Robert Grosvenor, and upon an examination of the water taken from the spring-head, and also from the leaden pipes in the house, Mr. Aikin found that the first was remarkably pure, but that the latter was strongly impregnated with lead.

such water for manufacturing and washing purposes: but it is clear that it could not be employed for dietetic or culinary use. The objection, moreover, would not exist if slate, iron, earthenware, or glass were used for cisterns or pipes; but from the very general employment of lead, it is a fact which cannot be overlooked in the water supply of a town. We must also here take leave to remark that that water which would be pronounced the *purest or the most free from hardness* by the use of *Dr. Clark's soap test*, would be the most dangerous for selection, if the health and lives of men and animals are to be regarded as well as washing and manufactures.

The freedom from saline or mineral matter, although a proof of (chemical) *purity* is no proof of *wholesomeness.* On the contrary wholesome water wherever found, will always contain more or less saline or mineral matter.

To take the other side of the question, it may be observed, that water which contains a *large proportion* of saline or *mineral* matter i. e. from above 50 to 120 grains in the Imperial gallon, or even more than this (we have found 440, and such water led to the death of many of our troops at Aden on the Red Sea, until the cause was discovered by chemical analysis) is unwholesome for a continued diet drink; and according to the nature of the salts contained therein, it may or may not prove injurious to health. Sulphate of magnesia (Epsom salts) and chloride of magnesium (bittern) if abundant in any water, invariably derange health by giving a tendency to relaxation of the bowels and ultimately leading to ulceration of the mucous membrane. Sulphate of lime (plaster of Paris) if unusually abundant, acts in another way, and may tend to produce costiveness. The Leicester well water marked 21 W., of which we have given an analysis in our report, contains a very large and unusual proportion of sulphate of lime, and is in this respect objectionable as a continued diet drink. From the very large quantity of saline matter contained in it (100 grains to the Imperial gallon) it would also greatly tend to fur boilers, and it would be objectionable for culinary or washing purposes. Natural waters which thus contain an unusual proportion of saline or mineral matter, may be very clear, quite colourless, sparkling, inodorous, and have no well-marked saline taste, unless magnesian salts happen to predominate, when they are bitter. The abundance of fixed air contained in them may altogether conceal their mineral character, and thus give rise to the impression that the water is *very pure* and *wholesome.* To take the words of the Leicester report on water supply, such a water would not be *flat but well aerated ;* it would not, however, answer any of the other conditions therein assigned to a pure and wholesome water, and it certainly would not be a " proper " water for selection in any sense of the word. We have recently examined for a Soda water establishment in this metropolis, a spring water which we found to contain in the Imperial gallon 117 grains of saline matter,—of this, 31 grains were found to be sulphate of lime, or plaster of Paris. Until this chemical examination had been made it had been pronounced to be a remarkably *pure* water. To those who fix their standard of purity in water, by the mere absence of colour, taste and smell, by perfect aeration and absence of flatness, this water would appear to be *absolutely pure* and *wholesome,* the carbonic acid contained in it giving to it a sparkling freshness, which to a certain extent conceals the very large quantity of saline matter dissolved in it. The greater number of persons take their standard by these three criteria, i. e. that pure water is without *colour*, *taste*, and *smell*; but although a water which has a decided colour, taste or smell, cannot be regarded as wholesome, the converse of this proposition is not true. A water may be colourless, tasteless, and inodorous, and yet not be fitted for dietetic, domestic, or manufacturing purposes. The spring water above referred to, and the Leicester well water 21 W, are objectionable on account of the very large *quantity* of saline matter contained in them, as well as the *nature* of that saline matter. The sulphate of lime (plaster of Paris) forms 52 per cent of the dry saline residue obtained from the Leicester well water, and this renders it not only exceedingly hard, but unfit for use in steam boilers by giving rise to a large amount of fur: it is also unwholesome as a continued diet drink.

We must not, however, fall into the error of supposing that the *exact weight* of *solid residue* obtained by the evaporation of an Imperial gallon of any water will indicate whether it be or be not *wholesome.* The term *purity* we discard as being vague and quite inappropriate, in reference to the application of water to dietetic use.

Waters which leave a *dry residue* of from 12 to 40 grains by the evaporation of an Imperial gallon, may be considered as comprising the *most wholesome varieties*, and those which are *best adapted for the diet of men and animals.* In this respect the standard of wholesomeness assumed in the extract from the Leicester report, which heads this paper, is quite at variance with facts. In order to justify the above inference, however, it must be proved :—First, that the dry *saline residue* obtained by evaporation contains but a small proportion of combustible or *organic* matter ; and second, that the salts of which the residue is constituted are chiefly *calcareous*, the lime being principally combined with *carbonic acid.* The water marked No. 6 W in the series received for analysis, yielded 18 grains of dry residue in the Imperial gallon; but of this, *eight grains* only were found to consist of fixed saline matter. There is therefore a very large proportion of combustible or organic matter contained in this water, which, when the water was stagnant under a warm temperature, would give rise to putrescency, and form a nidus for the growth of confervæ and infusorial animalcula.

It may be stated generally, that in the most *wholesome* waters found on the earth, the predominant ingredient is carbonate of lime held dissolved by carbonic acid, then common salt and sulphate of lime. The quantity of saline matter in the Imperial gallon generally varies from *twenty* to *thirty* grains, of which carbonate of lime forms from two-thirds to three-fourths. The proportion of organic matter may be from one to three grains in a gallon, and the remainder will be constituted of common salt and sulphate of lime. The proportion of saline matter, especially of sulphate of lime, is sufficient to protect the water from acquiring a poisonous impregnation of lead in its distribution through leaden pipes and cisterns; and such water may therefore be drunk with safety, by men and animals. These salts, although in one sense they render the water *impure*, undoubtedly render it safe and wholesome as a diet drink. Waters which yield in dry saline residue more than thirty grains to the Imperial gallon, are generally *hard*, especially if sulphate of lime predominates ; while those which contain from twelve to fifteen grains are cæteris paribus *soft*; but a water may contain forty or fifty grains to the Imperial gallon, and yet, if carbonate of soda be a predominant ingredient, it will be *soft.* This is the case with the water supplied by an Artesian well to the Royal Mint, and with the water supplied to the fountains in Trafalgar Square in this metropolis. The softness is here owing entirely to the *chemical properties* of the water, *i. e.* to the chemical nature of the salts contained in it, and is therefore no indication of *purity*; for so far from being free from mineral matter, such water may yield 60, 70, or 100 grains in the gallon. The water of the Royal Mint yields 37·8 grains in the Imperial gallon; that of the Trafalgar Square fountains 68·9 grains.

Dr Clark's soap-test assumes to determine the *purity* of water by the qualities of *hardness* and *softness;* but such a test can never determine the *wholesomeness* of water. Thus, water may be quite undrinkable and very unwholesome from the large quantity of carbonate of soda contained it, and yet, upon Dr Clarke's process, it will mark the highest degree of *softness* or *purity*. Again, a water like 6 W of the Leicester series may contain no carbonate of soda, but a small proportion of saline matter and a large proportion of organic matter; such a water, according to Dr Clark's test, would be pre-eminently *soft* or *pure*; but it would be in the highest degree objectionable, as its tendency to putrefaction would render it most unwholesome. The soap test, upon which unfortunately so much reliance has been placed by the Commissioners of Woods and Forests and the Board of Health, is therefore quite inadequate to solve the important question of water supply to a town.

Hard water may, it is well known, be rendered soft by the addition of lime water, or a certain proportion of carbonate of soda; but, however useful either process may be for manufactures or washing purposes, it is hardly applicable to waters intended for the diet drink of a large town population.

From the preceding observations, it may be inferred that it is by no means an easy matter to find a water which will suit all purposes equally well — *that* which is wholesome for drinking may be unfit for washing or steam-engine use; and that which will suit the latter may be altogether unfit for manufacturing purposes. A water containing about 14 grains of dry saline residue in the Imperial gallon, and which holds chiefly carbonate of lime, with a small quantity of sulphate, would come the nearest to these desiderata. In going below 12 grains to the Imperial gallon, there is always the liability of the water acquiring a poisonous impregnation by contact with lead, and thus giving rise to paralysis and colic.

As a summary it may be stated that the *wholesomeness* (not the *purity*) of any given water depends—

1. On freedom from colour, taste, and smell.
2. On its holding a proportion of saline matter not under twelve nor above forty grains to the Imperial gallon.
3. The organic matter should not be in a greater proportion than from one to three grains in the Imperial gallon.
4. The saline matter should consist chiefly of carbonate of lime, associated with small quantities of chloride of sodium (common salt) and sulphate of lime.
5. The water should not acquire a poisonous impregnation by contact with lead.

A water thus constituted, would not come up to the requisites of *purity*, as laid down in the Leicester Report; but we undertake to affirm that such a water would comprise all that is necessary to render it wholesome and fit for the use of man and animals. It matters not whence it may have been taken, whether from lake, river, spring, canal or well,—it would contain all that was necessary for the supply of a large town population with a wholesome and necessary article of diet. It would be a "proper" water in the "fullest sense of the term."

In giving this summary it is not intended to be implied that waters containing a greater proportion of saline matter to the Imperial gallon than 40 grains, are therefore necessarily unwholesome. The salts may be of an innocent kind, such as common salt, or carbonate of soda, and not prejudicial to health, unless the salts happened to be in very considerable proportion. It is chiefly where the *magnesian* salts predominate that injury to health is likely to arise from the daily use of water, as a diet drink. On the other hand, if we go below the proportion of twelve grains to the Imperial gallon, although cæteris paribus, the water may not be therefore unwholesome, it may become poisoned by the common mode of distribution through lead.

ON Dr. CLARK'S SOAP TEST.

From some results obtained by this test and published in Mr. Ranger's report on the town of Leicester, we feel called upon to advert to it, as the results in question have a close bearing upon the wholesomeness of the water supply to a town. We have already remarked that the test merely proposes to distinguish *hardness* from *softness*, and not *wholesomeness* from *unwholesomeness*. It cannot, therefore, distinguish a good from a bad water. On the one hand, the evaporated residue of an Imperial gallon, may contain 50 per cent. of organic matter, and be liable to become putrid in summer; but this soap test as applied by Dr. Clark, would indicate that it was a remarkably *pure* water, merely because it was *soft*. On the other hand, it cannot shew the amount of saline matter contained in water, which is rather important in reference to steam engine use; for as it has been already remarked, the presence of carbonate of soda would give to the water an artificial softness, thus causing it to resemble distilled or rain water of absolute purity. Professor Brande informs us that the well water of the Royal Mint contains 38 grains of saline matter in the Imperial gallon, and on Dr. Clark's scale it marks only 10 degrees of hardness; while Thames water containing only 21 grains of saline matter in the gallon marks 16° of hardness. Thus, if any reliance were placed on this test, a most wholesome water might be condemned by it as hard and unfit for use, while a very unwholesome water, i.e. one containing a large proportion of organic matter or carbonate of soda, might be selected as the best water for the supply of a town! It is very true that these conflicting results may be corrected by chemical analysis, but then the test is not only unnecessary, but absolutely deceptive. It can neither point out the good nor the bad varieties of water. If the sole object of a water supply to a populous town, were that of simply furnishing washerwomen with a kind of water that would economize the use of soap, then Dr. Clark's mode of testing waters would have some value; but a few pounds of soap more or less must not be set against the health of a community. There are numerous domestic ways of softening water for washing, when it marks 30° or 40° of hardness; but there is no process known to us, wherebya water abounding in organic matter or carbonate of soda, and marking only a few degrees of hardness can be converted into a wholesome diet drink for man and animals.

As this test has received a sort of Parliamentary sanction, and we believe it to be most unsound and unsafe in its usual mode of application, we beg to offer a few additional remarks in respect to it.

1. The curd soap employed is directed to be taken by weight. We have found by experiment that this kind of soap is constantly losing weight by evaporation even in damp weather. Hence a test solution made with a certain weight of such soap is always liable to vary in strength, and therefore to present great uncertainty in its application.

2. The alcoholic solution of soap sold by Messrs. Griffin, and prepared according to Dr. Clark's formula, varies in strength; thus a fall of temperature gives rise to a deposit of altered soap in cold weather. By watching the standard solution for six weeks, we have found such variations in the proportions of soap held dissolved by it, as to render its application impossible for any practical purpose. The same number of measures of this solution, taken at different times, would have apparently made the hardness of the water vary, when the variation was really due to the imperfection of the test.

3. The presence of free carbonic acid is an insurmountable objection to the safe application of this test. This gas is contained in variable proportions in all natural waters, and as Dr. Clark himself admits, it decomposes soap and offers an obstacle to the employment of the test. Thus a water containing much free carbonic acid and but little calcareous matter (a really soft water) might be pronounced by the soap test to have the same or even a greater numerical degree of hardness, than another water which contained but little free carbonic acid and much calcareous matter (a really hard water.) Dr. Clark recommends for the removal of this difficulty that the water should be shaken in a bottle and the carbonic acid, thus mechanically set free, continually sucked out by a tube. Such a plan as this can never give fair *numerical results in degrees*; there is no fixing a limit for shaking and sucking, and if these operations be carried too far, some of the carbonate of lime may be precipitated, and the water then pronounced unduly soft on the scale of degrees; if not carried

far enough, some carbonic acid will remain, and the water then pronounced unduly hard. It must be remembered that it is *not* the *carbonic acid* which gives hardness to water, or leads to the furring of boilers; it is the quantity of *carbonate of lime*. Clark's test taken alone cannot distinguish whether the hardness be due to one or the other, i. e. whether it be real or apparent.

4. A salt of *lime* is taken as a standard solution for comparing the hardness of a water which may really abound in *magnesia*. This is wholly unchemical, because very different weights of these two alkaline bodies consume the same quantity of soap. Thus 20 parts of magnesia have the same effect as 28 parts of lime, and yet the standard of comparison taken is a fixed solution of a salt of *lime*. Dr. Clark admits in his letter (see Leicester Report, page 21) that the kind of acid in the salts in no way affects the hardness; hence it requires all the more care in distinguishing between the effects produced by different weights of the alkalies which decompose soap.

With circumstances thus so strongly opposed to accuracy of results, it is, in our judgment, impossible to rely upon the numerical scale fixed by Dr. Clark. The degrees are based on pure hypothesis, and are as liable to be erroneous as correct. The same waters examined at different times may give very different results, and be marked, therefore, in very different degrees. This appears to explain two alleged difficulties in your Report, referred to at page 21, by Dr. Clark, and at page 30, by Dr. Lyon Playfair. In the latter case, the waters may, it is true, have undergone a change; but, in the former case, we have a clear and distinct proof of the inadequacy of the soap test to give any definite or certain results. It is well known to all chemists, that soap is readily soluble in distilled water without chemical change; hence, if any hard water be diluted with half its volume of distilled water, its hardness will of course be proportionably reduced one half. To adopt any other view, is to assume either that the hardness does not depend on the proportion of saline (calcareous) matter in the water, in which case the soap test is useless, or that water which is already soft gives hardness to hard water, which is absurd. Dr. Clark states, (page 21) that a mixture of equal parts of distilled water and hard water consumes, by the application of his mode of testing, as much soap as if the *whole* were hard water, and he vouches for the fact. Hence it follows, that his own mode of applying the soap test is liable to a great fallacy, because it cannot enable him to distinguish between the quantity of saline matter contained in two waters, one of which holds only *half as much* as the other. A chemical analysis would of course immediately show the difference. Dr. Clark refers this result to some peculiarity in the Leicester waters. We are inclined to regard it as one of those necessary fallacies which must arise where we endeavour to obtain numerical results by processes which are incapable of affording them. We do not know any stronger condemnation of this mode of testing waters, than this statement of results in the letter published in the Leicester Report.

You will now be able to appreciate our reasons for not applying Dr Clark's mode of testing to the Leicester waters. We have applied the old soap test, as it has been long known to chemists to determine the relative hardness of three waters, which it was desirable to compare; but we have not marked this hardness in degrees, for the simple reason that it cannot be done with any practical utility. The only standard with which the hardness of water can be fairly compared as unity is *Distilled water ;* but, except for particular purposes, it is not required to take this unity for comparison.

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Professors of Chemistry in Guy's Hospital.

GUY'S HOSPITAL,
March 6, 1850.

LEICESTER. Local Board of Health

REPORT

OF THE HIGHWAY AND SEWERAGE COMMITTEE

OF THE

LOCAL BOARD OF HEALTH.

In presenting to the Local Board a letter from the General Board of Health, on the subject of the proposed scheme of sewerage for this borough, together with the Report of Mr. Lee, one of their Superintending Inspectors, on which such letter is founded, and the observations of Mr. Wicksteed in reply, the Highway and Sewerage Committee feel it to be their duty to address to the Local Board a few preliminary remarks.

The Act of Parliament constituting the Town Council the Local Board of Health, received the royal assent and came into operation on the 1st August, 1849, and one of the first questions which occupied the attention of the Board, was the appointment of a competent Engineer, to devise an efficient system of sewerage; it being well-known from the low level of several densely-populated districts in this town, that the accomplishment of this important object would require more than ordinary skill and consideration.

At a Meeting of the Board, held on the 5th September, 1849, it was moved by Mr. Whetstone, seconded by Mr. Thos. Macaulay, and carried unanimously, in pursuance of a unanimous recommendation from this Committee, moved by Dr. Shaw, and seconded by Mr. Moore,—"That Thomas Wicksteed, Esq., of London, should be appointed Engineer, for the purpose of reporting as to the best mode of draining and sewering the borough, and of presenting a plan with an estimate of the expense." Mr. Wicksteed was personally unknown to every member of the Board, and he was selected solely on account of his high