XI.—*On the Composition, Value, and Utilization of Town Sewage.**

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Position of the Sewage Question.

IT is no less true than strange that, after so many centuries of advance in regard to almost every other requirement of civilised life, the lesson should not yet have been learnt of how to dispose of the excretal matters of large populations, in such a manner as to secure both their collection and removal without nuisance and injury to

* The substance of this paper was given as a discourse before the Chemical Society, February 1, 1866, by Dr. Gilbert.

health, and their economical utilization for the reproduction of food. But it is undoubtedly the fact that, hitherto, where utilization has been the most complete, comfort and health have generally been in the greatest degree sacrificed, and where, on the other hand, the refuse matters of town populations have been the most rapidly and perfectly removed from their dwellings, there has been either no utilization at all, or it has been most imperfectly attained.

Sewage, the foul stream which flows through the underground veins and arteries of our great cities, carrying with it the excretal and other refuse matters of large populations, hitherto to little better purpose than to be wasted, and to be a source of pollution to our rivers—to destroy their fish, injure their channels, and render them unfit as a water-supply to other towns—is the product of the, to us, modern, but in the history of the world only resuscitated and elaborated, water-system of town purification. There is no doubt that excretal and other refuse matters are removed from habitations more rapidly, with less nuisance to the occupants, and with less injury to their health, by means of water, than in any other way hitherto practised on a large scale. But such is the dilemma into which the progress of modern civilisation in this direction has brought us in this country, so far as utilization and the condition of our rivers are concerned, that some authorities, especially on the Continent, incline to the reactionary conclusion that a return to the cesspool system, or rather the adoption of some improved barrel, tank, or cesspool system, of collection and removal without admixture with extraneous water, is inevitable.

Before, therefore, entering upon the question of the composition, value, and modes and results of the utilization of dilute town sewage, it will be well to call attention, though very briefly, to some of the results of experience hitherto attained, under other systems of town purification, and other modes of utilization of the products, than the modern ones by means of water.

China and Japan are frequently cited as affording examples of very perfect utilization of human excretal matters, and, as a consequence, of great productiveness of the soil and great concentration of population on a given area of land. The manner of collecting, removing, and transporting human excretal matters in those countries is, however, such as to be quite inadmissible with our modern notions of cleanliness, decency, comfort, and health.

It is frequently stated that in Belgium human excretal matters are very perfectly utilized, and realise considerable money return to the town populations. Indeed, in one of the applications made only last year to the Metropolitan Board of Works for the concession of the Southern sewage of the Metropolis, and still under the consideration of that body, it is stated that the excretal matters sell in Belgium for something over £1 per person per annum.

There is no doubt that in some parts of Belgium the solid, and a portion of the fluid excrements of the town populations are collected, as free as possible from extraneous water, in receptacles of more or less perfect construction, and periodically removed for application to the land, and that the land so fertilised is very productive. From observation and inquiry made in some of the towns in question, it may, however, be safely affirmed, that the practices adopted are attended with, at any rate, so much of nuisance and discomfort as would not now be permitted in this country; whilst it would appear that a considerable proportion of the urine of the populations escapes collection and utilization. As the result of the same inquiries, it was concluded that, in no case, did the town population realise by the disposal of their excretal matters as much as averaged one franc per head per annum.

The conclusion that, as a rule but little, and frequently nothing, is realised by town populations when their excretal matters are collected under more or less modified cesspool or tank systems, as free as possible from extraneous water, and so removed for application to the land, is fully confirmed by the results of an inquiry conducted by a Commission sent out by the Prussian Government in 1864, to investigate the modes of collection, removal, and utilization, in various localities, with a view to the adoption of improved plans for the city of Berlin.

The Prussian Commissioners, Herren C. v. Salviati, O. Röder, and Dr. Eichhorn, visited and reported upon, not only the Belgium towns of Ghent, Ostend, and Antwerp, but likewise Hanover, Cologne, Metz, Carlsruhe, Strasburg, Basle, Lyons, Zurich, Munich, Nuremberg, Dresden, and Leipzig; and their report shows not only that the householders seldom realised anything like a franc per head per annum for their excretal matters, but that in the majority of cases it cost them something for the removal. Nevertheless, looking to the position and local circumstances of Berlin, and especially to the results of the water-system in this country hitherto, the Commissioners deprecate the adoption of that system for that city, and recommend more perfect arrangements and more stringent regulations for the emptying and removal of the contents of existing cesspools, and, where practicable, the adoption of a system under which the excretal matters of each house are to be collected in a barrel placed at the bottom of the shaft leading from the closets, which, when removed, is covered with a closely fitting lid, and is of such dimensions that two men can carry it by means of handles attached for that purpose. They seem to anticipate little, if any, pecuniary profit to the town from these arrangements, but consider that they will be attended with scarcely any, or even no, nuisance or discomfort, and that by their means a large amount of valuable manure will be provided in a convenient form for transport and utilization. There can, however, we think, be little doubt that under such a system the collection and removal must be attended with considerable nuisance, that the greater part of the urine will be lost, and that the cost of the collection, removal, and transport will be such as to render the utilization unprofitable beyond a comparatively limited distance from the city.

There is little probability that the difficulties of the water-system will lead us in this country to have recourse again in our large towns to any system of cess-pools, tanks, or barrels, however improved; but it may be well here to notice one or two attempts that have been made within the last few years to obviate the use of water, and thereby to avoid the pollution of rivers, and to secure the collection of the manurial matters in a form more readily transportable by ordinary means, and, therefore, more applicable for general agricultural use : for there cannot be a doubt that if any system could be devised by which human excretal matters could be collected and removed from dwellings, without either nuisance or injury to health, and obtained economically in a concentrated, dry, and portable condition, their utilization would be much more perfectly attained by such means than is at all likely, or even possible, under the water-system.

Perhaps the most noticeable attempt of the kind in question is that which has been made at Hyde, in Lancashire, a manufacturing town of more than 20,000 inhabitants. Some few years ago a company contracted to carry out what they call the "Eureka system." They provided boxes to fit in at the back of the privy or closet of nearly every house, leaving scarcely a water-closet in the place. Some disinfecting or deodorising mixture is put into the box before it is placed in its position, and the box is exchanged for a fresh one after a certain number of days, according to the number of individuals frequenting the place; and it is stipulated that neither extraneous water, nor any other than human excretal matters, should be accumulated in these receptacles. The boxes, when removed, are covered with closely fitting lids, and so transported in closed vans to a manure manufactory close to the town. Here the matters are first well mixed, and then strained to remove rags, which are washed and sold for paper-making. More disinfectant is then added, and the matter concentrated by distillation, the distilled water being sold to dyers and bleachers. The residue thus thickened is then mixed with coal-ashes, which are collected in the houses in casks left for the purpose, and before being used are re-burnt in a reverberatory furnace, and finely ground.

On visiting Hyde in 1863, it certainly appeared that the mode of collection and preparation adopted was attended with, at any rate, very little unpleasant odour, and it was maintained by the advocates of the system, that its adoption had been successful in a sanitary point of view; though even at that time some difference of opinion existed, and a controversy on the subject was in progress. The system is still in operation; but we are informed that the feeling of the inhabitants is very strong against the maintenance of the works in the neighbourhood; indeed, that an injunction against them has been sought, though unsuccessfully, and that proceedings by indictment are now being taken. This opposition has reference not to the mode of collection, but to the conducting of the manufacture so near to the town, But, whether or not, the plan of collection and removal may have proved successful, so far as the avoidance of nuisance and injury to health are concerned, the process of manufacture seems, unfortunately, to offer but little prospect of successful utilization, so far at least as can be judged from the results of an analysis made at Rothamsted, of a sample of the manure obtained direct from the works. It was found to contain only between 1 and 2 per cent. of ammonia. Such a manure, although it might be useful enough when applied in quantities of many tons to the acre, would obviously be not worth more than its carriage beyond the distance of a very few miles. Besides the great dilution of the more valuable manurial matters by the admixture with ashes, a little consideration of the habits of the people is sufficient to account for the small quantity of ammonia found in the manure; for it is obvious that little of the urine beyond that passed once a day with the fæces would reach the boxes, and so find its way into a manure thus collected and prepared.

One more dry system, the offspring of the difficulties of the wet one, should be briefly noticed, namely, that of the Rev. Mr. Moule. Mr. Moule has invented and patented an arrangement for the use of dry sifted earth, instead of water. He states that by the use of about 4lbs. per head per day of finely sifted clay, deposited by means of a mechanical arrangement upon the fæcal matters as soon as passed, they are at once entirely deodorised, and in a few weeks are so entirely disintegrated that neither excretal matters nor paper can be detected in the mass, which, he says, looks and smells like fresh earth, and may, after resifting, be re-used, until it has done duty four times over, by which, of course, there is not only a great saving of material, but the value of the manure is considerably increased.

Very obvious objections to such a system are—the difficulties of the supply and preparation of the soil in the case of towns, or even in the country in wet seasons; the fact that but little of the urine, containing as it does so large a proportion of the valuable manurial constituents of human excretal matters, would reach the compost so prepared; and that, in the manure produced, the more valuable matters would be diluted with so large a proportion of comparatively useless material, that beyond a very short distance the cost of carriage would be all that the manure was worth. On the other hand, that the adoption of such a system would be a great improvement in a sanitary point of view, in the cases of sick rooms, detached houses, or even villages, where the water-system is not available, and that it might be even economical where the earth for preparation and absorption, and the land for utilization, are in close proximity, may, perhaps, be readily granted. But we are certainly not so sanguine as the Rev. Mr. Moule, who seems to think that with the aid of Earth-closet Companies, his plan is as practicable for large towns as is the supply of water, gas, and coal, at present, and much more so than the removal and utilization of dilute town sewage.

Whilst it must be admitted that the agricultural utilization of human excretal matters has, hitherto, been much more completely attained under the system of collection without water than under our new one with it, it must not be forgotten that neither on the continent of Europe nor in this country has such utilization resulted in any substantial profit to the towns; and that it is, with the recorded results of China and Japan before us, and after so many centuries of experience nearer home, of at least comparatively successful utilization, that the old systems have been abandoned, as utterly inconsistent with advance in habits and notions of cleanliness, and with the maintenance of the comfort and health of large populations. Nor do the modifications of the dry systems, to which brief reference has been made, seem to hold out any hope of general and permanent applicability to large populations, looking, as we must, to the combined requirements of convenience, comfort, health, and utilization. Our water-system of house defecation and town cleansing is, on the other hand, scarcely more than a generation old. By its means excretal and other refuse matters are more rapidly removed from dwellings than is possible by any other; and, independently of the increased comfort and freedom from nuisance obvious to all, sanitary statistics have abundantly shown increased immunity from zymotic diseases, and increased longevity, as the result of the adoption of that system. True it is that these advantages have, hitherto, been attained at the cost of the almost universal sacrifice of the manure, and of great injury to our rivers.

This, then, is admittedly the existing dilemma of our modern practices. But public attention is now so thoroughly directed to the subject, that little fear need be entertained that either the systematic non-utilization of the sewage, or the pollution of our rivers by it, will long be permitted. Least of all is it reasonable to find discouragement in the fact, that the system which has done so much for some of our town populations in so short a time, should not, at this early stage of its trial, have accomplished all that might be desired, or to conclude that the nuisances and difficulties incident to the old plans, which have remained unremedied through so many centuries, have much better chance now than formerly of being successfully obviated.

Assuming that there is more likelihood of the general applicability, success, and permanence of the water, than of any other system of urban defecation, it becomes important to consider the composition, the value, and the modes and results of the utilization of the product of that system, namely, *dilute town sewage.*

Many plans have been proposed for the separation of the valuable constituents from sewer-water, and the manufacture of them into dry and easily portable manure. But whilst several of these plans have been successful in separating the whole of the insoluble or sedimentary matter, and even some small portion of the soluble constituents, leaving the fluid to a great extent, or at any rate temporarily, purified, and in a much less objectionable condition for turning into rivers, none have succeeded in either adequate or permanent purification, or in the separation of the more valuable manurial matters, and the production of a concentrated solid sewage-manure, having a sufficient value to be remunerative, and to bear the cost of transport more than a very few miles;* nor when we consider the great solubility of some of the more active manurial constituents of sewage, and the great dilution of them in the sewage, can any hope be held out of so desirable a consummation;—desirable, indeed, for if human excretal matters, the residue of the constituents consumed as food, cannot be recovered in the form of a concentrated, dry and easily transportable manure, little hope can be entertained of their re-distribution over anything like the area from which they came, or of their general use for the direct reproduction of the varied descriptions of food which were their source.

The questions arise: What is the amount, and what approximately the money value for the purposes of manure, of the constituents contributed to sewage by a given population? What their state of dilution in sewer-water? To what soils and crops is dilute sewage the most applicable? What is the money-value realisable in practice by sewage utilization? What are the conditions of profit or loss to towns of such utilization?

Composition and Value of Town Sewage.

It is one thing to determine the amount of constituents contained in sewage, or contributed to it by a given population, and to estimate their value accordingly, as if they existed in the dry and portable condition of the various concentrated manures of known value in the market; but it is obviously quite another to settle the really available or realisable value of the same consti-

* For information in regard to some of the plans proposed for the partial purification of sewage-water, or for the separation of a solid manure from it, see—"On the Application of Sewage to Agriculture," by Dugald Campbell, Esq., F.C.S., Chem. Soc. Qu. J. vol. x, p. 272. "Report of Chemical Investigations relating to Metropolitan Main Drainage Question," by A. W. Hofmann, LL.D., F.R.S., and Henry M. Witt, F.C.S., Report on Metropolitan Drainage, 1857. Deodorization of Sewage, Second Report of the Royal Sewage Commission, 1862., Appendix No. 6, p. 64.

tuents when they are distributed through an enormous volume of water, and if they must be transported and utilized in that condition. Let us first consider what may be called the theoretical value of the constituents of sewage, or their estimated value, taking as the measure the value of the same constituents in dry and portable manures.

Numerous authorities have undertaken the consideration of this question, and two chief methods have been adopted. One of these has been to take samples of sewage and determine its composition by analysis, to adopt such estimates as are at command relating to the amount of sewage available within a given time or from a given population, and so to reckon the amount and value of the constituents in a given quantity of sewage, or per head, or for a given number of persons, per annum. Another is to base the calculation upon the amounts of fæces and urine, or of the various constituents of these, which have been recorded as voided by individuals of different sexes and ages—sometimes making allowance, and sometimes not doing so, for other than human excretal matters reaching the sewers.

First, as to the results attained when the calculation is based upon the analysis of sewage, and estimates of the amount of it yielded by a given population.

In estimates of the value of the constituents of sewage, about three-fourths of the total value has generally been attributed to the ammonia (or nitrogen reckoned as ammonia); and it so happens that if a value of 8d. be put upon every lb. of ammonia shown by analysis to be contained in sewage, or if for each grain of ammonia per gallon, a value of one farthing be given to the total constituents in 1 ton of the sewage, the result will, in either case, agree almost exactly with that obtained by the elaborate method of giving the currently adopted market values to the several constituents, taking dry and portable manures as the standard.

One or two illustrations may be given of the applicability of the latter mode of reckoning. In the summer of 1863, Baron Liebig, adopting as the basis of his calculations an analysis of the Dorset Square sewage by Mr. Way, which showed nearly 18 grains of ammonia per gallon, estimated that (provided the quantity of phosphates which he considered requisite to render the whole of the ammonia available were employed with the sewage) the constituents in 1 ton of sewage of that composition would be worth about 4d. Now, according to our mode of estimate stated above, 18 grains of ammonia per gallon would indicate a value of 18 farthings, or 4½d., for the total constituents in 1 ton of the sewage. In January, 1865, Baron Liebig assumed the average sewage of the Metropolis to contain only 7·2 (instead of 18) grains of ammonia per gallon; and he estimated the value of the constituents in 1 ton of such sewage to be rather over 1¾d. Our estimate would also give rather over 7 farthings, or 1¾d. Lastly on this point, in 1857, Messrs. Hofmann and Witt concluded from their investigations that the average *dry weather* sewage of the Metropolis contained about 8·2 grains of ammonia per gallon; and calculating the value of the sewage according to the amount of ammonia, organic matter, phosphoric acid, and potassa, they estimated that of the total constituents in 1 ton of such sewage to be about 2·11d. It is clear that giving a value of ¼d. to the total constituents per ton of sewage, for each grain of ammonia per gallon, would yield almost identically the same result.

It is obvious, therefore, that in this part of the discussion we may, for all practical purposes, safely disregard everything but the amount of ammonia contained in the sewage, and that by so doing the consideration of the subject will be greatly simplified. It will be seen, too, that in adopting this course we do not in any way ignore, or undervalue, the importance of the associated constituents, but, on the contrary, accord to them the same value as Baron Liebig, Messrs. Hofmann and Witt, and others, have done by a much more elaborate process of calculation.

Numerous analyses have been made from time to time of samples of the Metropolitan and other sewage; and sometimes very important theoretical conclusions, and even propositions for the investment of enormous amounts of capital in utilization schemes, and anticipations of enormous profits from their adoption, have been based upon the results of a single analysis Such, however, is the variation in the dilution of the sewage of any one locality at different times, that it is quite impossible to draw any safe conclusions from the results of analysis without carefully taking into consideration the circumstances affecting the dilution at the time of sampling. This is strikingly illustrated by the results given in Table I., in which are recorded the grains of ammonia per gallon, as determined by various experimenters, in samples of the Metropolitan sewage, taken at different times and places, and also the estimated value of the total constituents in one ton of the sewage, reckoned according to the number of grains of ammonia per gallon as above referred to.

TABLE I.

Grains of Ammonia per gallon in different samples of Metropolitan Sewage, and estimated value of Constituents in one ton.

Authority.	Name of Sewer.	Time of Sampling.	Ammonia per Gallon.	Estimated Value per ton.
			Grains.	d.
Way	Barrett's Court	Day	41 ·28	10¼
	Dorset Square	Day	17 ·96	4½
Letheby	The Fleet	Noon	5 ·15	1¼
		Midnight	8 ·50	2
	London Bridge	Noon	6 ·69	1¾
		Midnight	8 ·10	2
	Dowgate Dock	Noon	10 ·03	2½
		Midnight	3 ·43	0¾
	Iron Gate	Noon	8 ·13	2
		Midnight	6 ·20	1½
	Paul's Wharf	Noon	12 ·01	3
		Midnight	3 ·13	0¾
	Whitefriar's Dock	Noon	5 ·35	1¼
		Midnight	3 ·41	0¾
	Custom House, West	Noon	6 ·25	1½
		Midnight	8 ·17	2
	Custom House, East	Noon	7 ·28	1¾
		Midnight	15 ·01	3¾
	Hambro' Wharf	Noon	7 ·69	2
		Midnight	5 ·69	1½
	Wool Quay	Noon	6 ·95	1¾
		Midnight	5 ·00	1¼
	Tower Dock	Noon	10 ·02	2½
		Midnight	7 ·15	1¾
	Mean		7 ·24	1¾
Hofmann & Witt	Savoy Street	24 hours	8 ·21	$2\frac{1}{10}$

The results given at the head of the table, on the authority of Mr. Way, are those of probably the first analyses made of the Metropolitan sewage, and it is only fair to say that at the time he published them, he expressly stated that although they showed that there was great manurial value in sewage, yet they could not be taken as in any way affording a measure of that value. It was, however, upon the analysis of the sample of the Dorset Square sewage, showing nearly 18 grains of ammonia per gallon, that Baron Liebig based his calculations as to the value of the Metropolitan sewage in 1863; and the advocates of particular sewage schemes, and even members of Parliamentary Committees, have sought to found much upon the results of those analyses.

From the varying circumstances under which the samples analysed by Dr. Letheby were taken, as indicated in the table, it is obvious that the results, though very valuable in that respect, must be considered rather as illustrations of the variation in composition of the Metropolitan sewage at different times and places, and as showing the danger of founding important practical conclusions upon the results of the analysis of an individual sample, than as affording direct evidence as to the average composition of the Metropolitan sewage.

The sample analysed by Messrs. Hofmann and Witt was a mixture of equal portions taken every hour during twenty-four hours of dry weather, and there is no doubt that that sample had better claims to be taken as representing the average dry weather sewage of the Metropolis than any other that had up to that time been collected and examined. It was upon the analysis of this sample that Messrs. Hofmann and Witt, calculating the value of the ammonia, organic matter, phosphoric acid, and potassa, which it contained, estimated that the constituents in one ton of such dry weather sewage would be worth rather over 2d., and, according to the information supplied to them for the purpose of their calculations, the quantity of sewage, exclusive of rainfall, would be about 158,000,000 tons per annum, or scarcely three-fifths as much as that assumed in the estimates of Baron Liebig and Mr. Thomas Ellis, as the total sewage, namely, 266,000,000 tons. Yet, Messrs. Hofmann and Witt's estimate of a little over 2d. for the value of the constituents in one ton of the normal dry weather sewage was taken by Mr. Ellis, in his application for the concession of the Metropolitan sewage, as applying to the whole amount of dilute sewage (inclusive of rainfall and subsoil water), which he estimated would be available for utilization (266,000,000 tons), and his calculations of profit to his Company and to the ratepayers were based upon this erroneous assumption.

To conclude in reference to the results recorded in Table I., attention may be called to the fact that the different samples show a variation of from about 3 to more than 41 grains of ammonia per gallon, representing approximately a difference of from about $\frac{3}{4}$d. to about $10\frac{1}{4}$d. for the estimated value of the total constituents in one ton of the sewage.

That the results of an analysis of a sample of sewage of any locality taken without careful reference to the circumstances of its dilution, are not only entirely inadequate as the basis of general conclusions, but may even be utterly misleading, is even more strikingly illustrated by the results next to be considered, which were obtained in the course of an investigation undertaken by the late Royal Sewage Commission.

Three members of the Commission, the late Mr. Henry Austin, C.E., Mr. Way, and one of the authors (J. B. Lawes) were appointed a sub-committee to undertake an investigation on the utilization of sewage. The agricultural experiments were conducted at Rugby, and their management, and the selection, collection, and preparation of samples for analysis, devolved upon the authors, the analyses being made in the laboratory of Mr. Way. The inquiry extended over a period of between three and four years, and involved the application of different quantities of sewage to meadow-grass and some other crops; the determination of the amounts of produce obtained; the feeding of fattening oxen and milking cows on the unsewaged and the sewaged grass; and the sampling, and more or less complete analysis, of the soil, of the sewage, of the drainage-water from the irrigated land, of the unsewaged and the sewaged grass, of the milk yielded by the cows fed upon it, &c., &c. It is proposed to embody in the sequel a brief abstract statement of some of the more important facts and conclusions brought out by the experimental inquiry above referred to, and the reader is referred for all fuller details to the Reports of the Commission.*

The mode of collecting samples of the Rugby sewage for analysis was, to take about a quart (from a gauge-tank holding between 3 and 4 tons, through which the sewage flowed before passing on to the land), at intervals of about two hours for several days together, well mix the quantity so accumulated, and take a sample of the mixture for analysis. 93 such mixed samples were collected and analysed, the period of collection extending over 31 months, from April, 1861, to October, 1863, inclusive. Table II. shows the highest, the lowest, and the average amounts of ammonia and total solid matter which the analyses of these numerous mixed samples indicated.

* Second and Third Reports of the Commission appointed to inquire into the best mode of Distributing the Sewage of Towns, and applying it to beneficial and profitable uses. 1862 and 1865.

Table II.

Showing the highest, lowest, and average amounts of Ammonia, and total Solid Matter, in mixed samples of Rugby Sewage at different times.

		Ammonia.		Total Solid Matter.	
		Grains per Gallon.	lbs. per 1000 Tons.	Grains per Gallon.	lbs. per 1000 Tons.
1861	Highest	15·64	500·5	216·5	6928
	Lowest	2·99	95·7	37·6	1203
	Mean of 24 analyses	6·39	204·5	75·1	2405
1861-2	Highest	11·38	364·2	129·3	4138
	Lowest	2·55	81·6	50·5	1616
	Mean of 34 analyses	5·95	190·4	80·3	2570
1862-3	Highest	12·81	409·9	269·9	8637
	Lowest	3·14	100·5	62·2	1989
	Mean of 35 analyses	7·08	226·5	103·2	3302

Thus, although each sample analysed was a mixture of samples taken over several days together, as above described, there was a variation among the 93 samples of from $2\frac{1}{2}$ to $15\frac{1}{2}$ grains of ammonia, and from $37\frac{1}{2}$ to 270 grains of total solid matter, per gallon; or, of from $81\frac{1}{2}$ to $500\frac{1}{2}$ lbs. of ammonia, and from 1203 to 8,637 lbs. of total solid matter, per 1,000 tons of sewage. Reckoned according to the number of grains of ammonia per gallon, the estimated value of the total constituents in 1 ton of sewage varied from about $\frac{5}{8}$d. to nearly 4d.

Notwithstanding the very great differences in the composition of the Rugby sewage at different times, much greater, indeed, than could have been expected, considering the circumstances of the sampling, it is still believed that the mean of so many determinations may be taken as indicating, at any rate approximately, the average composition of the Rugby sewage over the period to which they refer. The probability of this will be seen on a consideration of the average results for each of the three seasons, and for the total period of 31 months of collection, given in Table III.

TABLE III.

Mean Composition of Rugby Sewage, in 1861, 1862, *and* 1863.

Constituents		Means of: 24 Samples, April to Oct. 1861.	34 Samples, Nov. 1861 to Oct. 1862.	35 Samples, Nov. 1862 to Oct. 1863.	93 Samples, April 1861 to Oct. 1863.
		Grains per gallon.			
In suspension	Inorganic	14·36	20·86	34·45	24·30
	Organic..........	14·16	16·84	24·03	18·85
	Total	28·52	37·70	58·48	43·15
In solution	Inorganic	36·34	34·42	36·80	35·81
	Organic..........	10·28	8·20	7·92	8·63
	Total	46·62	42·62	44·72	44·44
	Total inorganic....	50·70	55·28	71·25	60·11
	Total organic	24·44	25·04	31·95	27·48
	Total solid matter..	75·14	80·32	103·20	87·59
Ammonia	In suspension	1·41	1·47	1·86	1·60
	In solution	4·98	4·48	5·22	4·89
	Total	6·39	5·95	7·08	6·49
		lbs. per 1000 tons.			
In suspension	Inorganic	460	668	1102	778
	Organic..........	453	539	769	603
	Total	913	1207	1871	1381
In solution	Inorganic	1163	1101	1178	1146
	Organic..........	329	262	253	276
	Total	1492	1363	1431	1422
	Total inorganic....	1623	1769	2280	1924
	Total organic	782	801	1022	879
	Total solid matter..	2405	2570	3302	2803
Ammonia	In suspension	45	47	60	51
	In solution	159	143	167	157
	Total	204	190	227	208

It is seen that the mean result of the analyses of 24 samples collected from April to October, inclusive, 1861, indicates 6·39 grains of ammonia per gallon; that of 34 samples collected from November 1861, to October 1862, inclusive, 5·95 grains, and that of 35 samples, collected from November 1862, to October 1863, inclusive, 7·08 grains. This difference in the average concentration of the sewage of the different seasons is perfectly consistent with the difference in the character of the seasons themselves. Thus, the season of 1861-2 was much the wettest, and its sewage was, accordingly, the most dilute; the season of 1862-3 was much the driest, indeed extremely dry, and its sewage was the strongest; and the season of 1861 being intermediate in this respect, its sewage was of intermediate strength.

Looking to the average result of the 93 analyses, it will be observed that the sewage contained about 87½ grains per gallon of total solid matter, of which about two-thirds was inorganic, and one-third organic. About half of the total solid matter was in suspension, and half in solution: of the half in suspension about four-sevenths was inorganic and three-sevenths organic, and of the half in solution, about four-fifths inorganic, and one-fifth organic. Lastly, of the nitrogen reckoned as ammonia, about one-fourth was in suspension, and three-fourths in solution.

The mean of the 93 analyses shows about 6½ grains of ammonia per gallon, indicating a value of about 1⅜d for the total constituents in 1 ton of the sewage. But taking into consideration the fact that the samples were not collected at exactly equal intervals throughout the total period, it is concluded that, by taking the mean result for each of the 31 months separately, and then the mean of the 31 means so obtained, the result will more nearly represent the real average composition of the sewage of the whole period, than will the direct mean of the 93 analyses; and the calculated average so obtained indicates about 7, instead of only 6½, grains of ammonia per gallon.

From all the information at command as to the population contributing to the sewers, the water-supply, the rainfall, and the drainage area, it was concluded that, taking the average of seasons, there are about 60 tons of sewage per head of the population of Rugby, per annum; but that, as the period of the experiments was drier than usual, the amount probably then reached to only about 55 or 56 tons.

Now, if we reckon 6½ grains of ammonia per gallon, and 60 tons of sewage per head per annum, it would result that 12½ lbs. of ammonia were contributed annually for each average individual of the mixed population, of both sexes and all ages; or, if we reckon 7 grains of ammonia per gallon, and 56 tons of sewage per head per annum, we equally arrive at the amount of 12½ lbs. of ammonia per head per annum; and from a careful consideration of the Rugby results, it was concluded, at the time the Report was issued, that this probably very nearly represented the actual truth.

Having, then, by means of the results of a great many analyses of sewage, and a consideration of the amount of sewage contributed by each average individual of the population, estimated that for each such average individual there would be about 12½ lbs. of ammonia contributed to the sewer-water, let us next see what

TABLE IV.

Amount of Nitrogen reckoned as Ammonia, and estimated value of total Constituents in Human Voidings, per head per annum.

	Ammonia.	Value of Total Constituents.
Adult Males; Hofmann and Witt.		
	lbs.	s. d.
Urine	15·8	10 0½
Fæces	2·3	1 8¾
Total	18·1	11 9¼
Adult Males; Thudichum.		
Urine	15·9	10 3½
Average, both sexes and all ages; Hofmann, Witt, and Thudichum.		
Urine	11·32	7 3
Fæces	1·64	1 2¾
Total	12·96	8 5¾
Average, both sexes and all ages; Lawes and Gilbert.		
According to Food	12·2	8 4
According to Voidings	12·6	
According to Voidings	12·7	
Mean	12·5	

result is arrived at by the other method of computation which has been referred to, namely, by the calculation of the amounts of fæces and urine, or of the various constituents of these, recorded as voided by persons of different sexes and ages. Table IV. very concisely summarises the information available on this subject, so far as it is necessary for our present purpose.

To check their estimates founded on the analysis of the 24-hours' mixed sample of the Savoy Street sewage, Messrs. Hofmann and Witt took the amount of urine estimated to be daily voided by an adult, and the amount of fæces recorded as voided on the average per head of the body-guard of the Grand Duke of Hesse Darmstadt (but allowing, as they said, a little more for "John Bull"), and applying the results of Berzelius' analysis of urine, and those of the analyses of Way, Liebig, and Wesarg, of fæces, they calculated the amount of ammonia, and other constituents, daily voided by such persons. According to their data, the amount of ammonia annually voided by an adult male was, in urine 15·8, in fæces 2·3, total 18·1 lbs.; and the estimated money value of the constituents was in urine 10s. 0½d., in fæces 1s. 8¾d., total 11s. 9½d. The result so obtained for adult males they take as applicable to each individual of a mixed population, of both sexes and all ages, assuming that other matters reaching the sewers would probably make up the difference. There can be little doubt that this was making far too liberal an allowance for other than human excretal matters contributing to the value of the sewage.

Some years later, in 1863, Dr. Thudichum, from much more comprehensive data, gave for the urine alone of an adult male 15·9 lbs. of ammonia, and 10s. 3½d. of value; amounts which, it will be seen, are almost identical with those of Messrs. Hofmann and Witt.

But Dr. Thudichum, instead of directly applying the results obtained for an adult male to each average individual of a mixed population, considered that two adult males would approximately represent 2·8 such average persons. Now, if we take the mean of the estimates of Messrs. Hofmann and Witt, and Dr. Thudichum, with regard to the urine, and those of Messrs. Hofmann and Witt with regard to the fæces, of an adult male, and reduce both in the proportion of from 2·8 to 2, according to Dr. Thudichum's basis of calculation, we shall, provided the estimates of these authorities be correct, arrive at amounts approximately applicable to an average individual of a mixed population of both sexes and all ages. By this process, as the Table shows, we have nearly 13 lbs. of ammonia, and nearly 8s. 6d. of value, to represent the mixed voidings of such an average individual.

In 1854, the authors, basing their estimates on very comprehensive data, relating both to the amounts of constituents consumed in the food, and voided in the urine and fæces, of persons of different ages and both sexes, concluded that probably about 10 lbs. of ammonia, and total constituents of the estimated manurial value of about 6s. 8d., were annually contributed to sewage per individual of a mixed town population. More recently, for the purposes of the Report of the Royal Sewage Commission, all the estimates relating to the constituents voided were carefully revised, bringing into the calculations such further information as was then at command;* and the results so obtained are recorded in the Table (IV).

The amount of nitrogen estimated to be annually consumed in the food of an average individual was deduced from the calculation of 86 dietaries, arranged in 15 classes, according to sex, age, activity of mode of life, and other circumstances, and corresponded to about 12·2 lbs. of ammonia; from which, of course, a deduction has to be made for the nitrogen retained in the body, and for loss in various ways. When the calculation was based upon determinations or computations of the amounts of nitrogen or ammonia-yielding matters voided by persons of different sexes and ages, the result arrived at was 12·6 lbs. of ammonia; and when upon the recorded amounts of fresh urine and fæces voided, and the average composition of these, the amount indicated was 12·7 lbs. of ammonia per head per annum. A careful consideration, however, of the circumstances of the majority of the cases contributing to the averages among those divisions of the population in relation to which the evidence is the most plentiful, and of the relative character of the results where it is the most deficient, led to the conclusion that the estimate of 12·6, or 12·7 lbs. for the amount

* For nearly the whole, if not the whole, of the data upon which the new estimates are based, *see* "On the Sewage of London," by J. B. Lawes, F.R.S., Journal of the Society of Arts, March 9, 1855; "The Composition of the Urine in Health and Disease," by E. A. Parkes, M.D., 1860; "On an Improved Mode of collecting Excrementitious Matter, with a view to its Application to the benefit of Agriculture, &c.," by J. L. W. Thudichum, M.D., F.C.S., Journal of the Society of Arts, May 15, 1863; and "On the Elimination of Urea and Urinary Water, in relation to the period of the Day, Season, Exertion, Food, &c., &c.," by Edward Smith, M.D., LL.B., F.R.S., Philosophical Transactions, vol. cli, p. 747.

of ammonia voided annually by an average individual of a mixed population, was in all probability too high.

Reviewing the whole of the evidence, both that relating to the composition and the amount of the Rugby sewage, and that relating to the amount of constituents voided by an average individual, it was concluded that the amount of ammonia annually contributed to the sewer-water by an average person of a mixed population was pretty certainly more than 10 lbs., as formerly assumed, but probably less than 12 lbs.; and, making allowance for the fractional part of the excretal matters of horses, cows, dogs, and other animals, of the refuse of slaughter-houses, of soot, and of other refuse matters that may reach the sewers, it was concluded that still not more than 12½ lbs. of ammonia would be contributed annually to the sewers from all sources, per head of mixed town population. This would indicate an estimated value of 8s. 4d. per annum for the total constituents in the sewage for each average individual.

It was admitted, however, to be a great desideratum, that when the Main Drainage of the Metropolis came to be completed, and the works to be in full operation, competent persons should be appointed to superintend the gauging, sampling, and analysis of the sewage, with a view to providing data which might serve to determine satisfactorily and conclusively the approximate amount, and average composition, of the Metropolitan sewage, as it will have to be dealt with in any plan of utilization, and also the relation of population to the composition of sewage generally.

Since the publication of the Report of the Commission, in March 1865, numerous gaugings and samplings of the sewage of the mid- and high-level sewers North of the Thames have been undertaken, and many samples have been analysed by Mr. Way. The results of this inquiry have not yet been published; but from information kindly communicated by Mr. Way, we are enabled to state their general bearing, so far, upon the point now under consideration.

From these new results it appears very probable that the amount of dry weather sewage averages only about two-thirds as much per head of the population as that generally supposed before, and assumed both in the inquiries of Messrs. Hofmann and Witt, and in the Report of the Sewage Commission; but the average amount of ammonia per gallon now found by Mr. Way in the dry weather sewage very nearly approaches that arrived at by Messrs. Hofmann and Witt. Both Mr. Way and Mr. Cresy frankly admit, however, in accordance with common experience the further a subject is investigated, that there are still many open questions, the settlement of which may materially affect the proper interpretation of the new gaugings.

Assuming them to indicate the result at present supposed, and above stated, it follows that the total amount of ammonia yielded by a given population will be only about two-thirds as much as that estimated by Messrs. Hofmann and Witt, on applying the results of their analysis to the higher estimated amount of the dry weather sewage. It further follows, from the same evidence, that the amount of ammonia annually contributed to the sewage, from all sources, per head of a mixed population, is more nearly 10 lbs., as formerly concluded by the authors, than 12½ lbs., as more recently estimated; and if this result should be confirmed, their former estimate of 6s. 8d. will more nearly represent the calculated annual value of the total constituents yielded per head of the population than the more recent one of 8s. 4d. It would then have to be concluded, as indeed is not improbably the case, that, in the calculations based on the mean composition and the estimated total amount of the Rugby sewage, the latter had been taken at too high a figure, too large a proportion of the rainfall having been assumed to reach the sewers; and that, in the estimates founded on the recorded amounts of constituents voided, the incompleteness of the records, as already pointed out, had, as was supposed, led to too high an estimate.

We have, then, from 10 to 12½ lbs. of ammonia, and an estimated value of from 6s. 8d. to 8s. 4d. for the total manurial constituents, contributed to sewage by each average individual of a mixed town population. Adopting these amounts, the questions arise—What will be the amount of ammonia, and what the estimated value of the constituents, in a given amount of sewage, at different dilutions? These points are illustrated in Table V.

TABLE V.

Ammonia, per gallon, and estimated value of total Constituents in one ton, of Sewage at different dilutions.

Dilutions supposed.		If 12½ lbs. Ammonia, per head per annum, from all sources.		If 10 lbs. Ammonia, per head per annum, from all sources.	
Per head per annum.	Per head per day.	Ammonia per gallon.	Estimated value per ton.	Ammonia per gallon.	Estimated value per ton.
Tons.	Gallons.	Grains.	Pence.	Grains.	Pence.
40	24½	9·77	2·44	7·81	2·00
50	30¾	7·81	1·95	6·25	1·60
60	36¾	6·51	1·67	5·21	1·33
70	43	5·58	1·43	4·46	1·14
80	49	4·88	1·25	3·91	1·00
90	55¼	4·34	1·11	3·47	0·89
100	61¼	3·91	1·00	3·13	0·80
200	122¾	1·95	0·50	1·56	0·40

According to the information supplied to Messrs. Hofmann and Witt, the dry weather sewage of the Metropolis amounted to between 36 and 37 gallons per head per day = about 60 tons per head per annum. Their analysis showed 8·2 grains of ammonia per gallon, equivalent to about 15¾ lbs. of ammonia per head per annum; and they reckoned the total constituents in 1 ton of such sewage to be worth 2·11d. But Table V shows that with a dilution of 60 tons, and with 12½ lbs. of ammonia per head per annum, there would be only 6·5 grains of ammonia per gallon, and total constituents in 1 ton of sewage worth only 1⅔d.; and that with only 10 lbs. of ammonia per head per annum, there would be only 5·2 grains per gallon, and constituents worth only 1⅓d. in 1 ton of the sewage.

If, however, we take the dry weather sewage as indicated by the recent gaugings as more nearly 24 gallons per head per day = a rate of 40 tons per head per annum, we have then, with 12½ lbs. of ammonia per head per annum, 9·77 grains per gallon, and 2·44d. worth of constituents per ton; or, taking 10 lbs. of ammonia per head per annum, we have 7·8 grains per gallon, and constituents in 1 ton of an estimated value of nearly 2d. Now, Mr. Way's conclusion is, that the mid- and high-level dry weather sewage North of the Thames averages scarcely, but nearly, 8 grains of ammonia per gallon, or almost exactly the amount last mentioned; and as Messrs. Hofmann and Witt's analysis shows 8·2 grains, it will be seen that both estimates, taken in connexion with the amended one as to the daily amount per head of the dry weather sewage, go to confirm the assumption that the amount of ammonia contributed to the sewage from all sources is much more nearly 10 than 12½ lbs. per head per annum.

Whatever may eventually prove to be the average dilution of the dry weather Metropolitan sewage, the actual amount of fluid varies immensely from time to time, according to rainfall and other circumstances. When it exceeds a certain amount, as in the case of continuous rains or storms, a portion will pass at once into the Thames; and according to Mr. Bazalgette's figures it appears that this will happen when the volume is such as, if continuous, would represent something over 200 tons of fluid per head per annum. But, so far as information at present at command enables us to judge, it is probable that the amount, inclusive of rainfall and subsoil water, that will be available for utilization, will be somewhere about 80, and will pretty certainly not exceed 100 tons per head per annum; that is, about twice, or not more than twice and a half, as much as the most recently estimated dry weather flow. Of course, to result in anything like such averages, the dilution would sometimes be at a rate very much greater than those amounts would indicate. But it may be observed, by way of illustration, that with 12½ lbs. of ammonia per head per annum, and an average of 80 tons of sewage, it would average less than 5 grains of ammonia per gallon, and only 1·25d. worth of constituents in 1 ton; or, reckoning an average dilution of 100 tons, it would average less than 4 grains of ammonia per gallon, and only 1d. of value of constituents in 1 ton. In like manner, reckoning only 10 lbs. of ammonia per head per annum, a dilution of 80 tons would show less than 4 grains, and of 100 tons little over 3 grains of ammonia per gallon, and an amount of constituents in 1 ton worth only 1d. and 0·8d. respectively.

In comparison with the figures just given, it may be stated that both Baron Liebig, and Mr. Thomas Ellis (one of the applicants for the concession of the Metropolitan sewage) assume its total amount at 266,000,000 tons per annum, which, with 3,000,000 population, represents nearly 90 tons per head per annum, and with this dilution the former estimates the sewage to contain an average of 7·2, and the latter 8·2 grains of ammonia per gallon; the latter, as already stated, applying the estimate of Messrs. Hofmann and Witt for the dry weather sewage to the total estimated amount of available sewage, inclusive of rainfall.

It is sufficiently obvious that, however variable, the dilution of the constituents in town sewage is at any rate very great, and that in any scheme for the utilization of sewage large quantities will have to be dealt with. It will be useful, therefore, by way of illustration, and as a means of conveying a more definite idea of the extent of this dilution, to show the relation of a given amount —say 1,000 tons—of sewage of certain assumed dilutions, both to population, and to some well-known portable manure, such as Peruvian guano. This is done in Table VI, which shows the amount of guano which would supply as much nitrogen reckoned as ammonia as 1,000 tons of sewage of different dilutions, also the number of tons of sewage which would be equal in this respect to 1 ton of guano, and both on the alternative assumptions of $12\frac{1}{2}$ lbs., and 10 lbs., of ammonia per head per annum. The assumed dilutions are 40, 50, and 60 tons per head per annum, which may be taken to cover the minimum and maximum estimated rates of flow for the dry weather sewage of the Metropolis; 80 and 100 tons, which may be taken to represent the range for the average total available sewage, inclusive of rainfall and subsoil water, and 200 tons, the probable frequent dilution in wet weather.

TABLE VI.

Relation of Sewage to Peruvian Guano in amount of Nitrogen reckoned as Ammonia.

If Sewage per head per annum.	Contributing 1,000 tons Sewage.	If $12\frac{1}{2}$ lbs. Ammonia, per head per annum, from all sources.		If 10 lbs. Ammonia, per head per annum, from all sources.	
		1,000 tons Sewage = Guano.	1 ton Guano = Sewage.	1,000 tons Sewage = Guano.	1 ton Guano = Sewage.
Tons.	Persons.	Cwts.	Tons.	Cwts.	Tons.
40	25	$16\frac{1}{3}$	1220	13	1525
50	20	13	1525	$10\frac{1}{2}$	1900
60	$16\frac{3}{4}$	11	1830	$8\frac{3}{4}$	2290
80	$12\frac{1}{2}$	$8\frac{1}{5}$	2440	$6\frac{1}{2}$	3050
100	10	$6\frac{1}{2}$	3050	$5\frac{1}{4}$	3810
200	5	$3\frac{1}{4}$	6100	$2\frac{2}{3}$	7620
1 Person = Guano.		$\frac{2}{3}$ cwt.		$\frac{1}{2}$ cwt.	

Thus, with 12½ lbs. of ammonia, and the minimum estimated dilution of the dry weather sewage at a rate of 40 tons per head per annum, 1,000 tons of such sewage would only contain nitrogen, reckoned as ammonia, equal to that in about 16⅓ cwts. of Peruvian guano, or to that in only 13 cwts. if the amount of ammonia per head per annum be reckoned at only 10 lbs. In other words, in the former case it would require 1,220, and in the latter 1,525, tons of sewage to supply the ammonia (or nitrogen reckoned as ammonia) of 1 ton of guano. In like manner, taking 80 tons of sewage per head per annum as a minimum estimate for the average sewage, inclusive of rainfall, with 12½ lbs. of ammonia per head per annum, 1,000 tons would represent the nitrogen of 8⅕ cwts., and with 10 lbs., 6½ cwts., of Peruvian guano; or reckoning 12½ lbs. of ammonia per head per annum, 1 ton of Peruvian guano would represent 2,440 tons, and reckoning 10 lbs., it would represent 3,050 tons.

The table also shows that reckoning 12½ lbs. of ammonia per head per annum, the sewage of an average individual would annually represent in nitrogen ⅔ cwt., or reckoning only 10 lbs. per head per annum only ½ cwt., Peruvian guano, per head per annum.

Crops to which Sewage is most applicable.

Hitherto, on grounds shown to be fully justified, we have, for simplicity of illustration, confined attention to the amount of nitrogen or ammonia in sewage, as the measure or indication of its composition, and of the theoretical manurial value of its total solid constituents. It is, however, obviously of interest to consider whether or not the mineral or incombustible constituents of sewage exist in it in sufficient proportion to the ammonia or nitrogen, for the requirements of the crops to be grown; and, as the phosphoric acid and potassa (the one or the other, or both, according to circumstances) are, perhaps, the mineral constituents most likely to be deficient relatively to the nitrogen, their proportion to the latter in sewage, and in various crops, may appropriately be referred to in illustration of the point. Table VII shows the proportion of phosphoric acid and potassa to 100 of nitrogen in sewage, according to the mean of ten analyses of the Rugby sewage, in which the phosphoric acid and the potassa as well as the ammonia were determined. It also shows what may be taken as approximately representing the average proportion of phosphoric acid and potassa to nitrogen in various crops.

TABLE VII.

Amount of Phosphoric Acid and Potassa to 100 *Nitrogen, in Sewage and in various crops.*

	Phosphoric Acid.			Potassa.		
Rugby Sewage	27			42		
	In Corn, Roots, &c.	In Straw, Leaves, &c.	In Total Produce.	In Corn, Roots, &c.	In Straw, Leaves, &c.	In Total Produce.
Meadow-Hay	..	..	27	..	..	100
Clover-Hay	..	..	23	..	..	52
Wheat	48	42	46	28	108	57
Barley	40	34	38	34	126	60
Oats	28	37	30	25	155	65
Beans	25	46	30	32	123	50
Mangolds	17	..	..	100	..	..
Swedes	27	16	21	82	44	63
Common Turnips ..	28	18	26	160	71	117
Potatoes	42	..	..	123	..	..

It is obvious that since the phosphoric acid of sewage, like the nitrogen, will be derived almost exclusively from excretal matters and food-refuse, its proportion to the nitrogen will, within comparatively narrow limits, be tolerably uniform; the amount of potassa, on the other hand, will vary very much according to locality, and be considerably greater where the streets or roads are constructed of potassic minerals than elsewhere.

The table shows that, according to the analyses referred to, the Rugby sewage contained 27 parts of phosphoric acid and 42 parts of potassa, for 100 of nitrogen. It also shows that, on the average, meadow hay contains almost exactly the same proportion of phosphoric acid to nitrogen as the sewage, but a much greater proportion of potassa than the latter.*

In the cereal grains the proportion of phosphoric acid to

* According to Baron Liebig's estimates, hay contains 51 parts of phosphoric acid to 100 of nitrogen; but having collated and averaged the results of numerous independent observers, we can see nothing to lead to the adoption of such a figure; whilst direct determinations in a number of samples of each, showed in the Rugby sewaged grass 25, and in the unsewaged 32 parts.

nitrogen is, on the other hand, higher than in the sewage; whilst in most of the other crops enumerated it is much about the same. Of potassa, the proportion is lower in the cereal grains (the only part of the crop which is, as a rule, sold off the land) than in the sewage, though in the other crops it is generally higher.

But there are various circumstances, the adequate discussion of which would occupy more space than it would be appropriate to devote to their consideration here, which render it quite inadmissible to draw direct practical conclusions as to the applicability of sewage to different crops from what may appear, at first sight, the obvious indications of the figures in the table. Nevertheless, a careful consideration of the subject leads to the conclusion that, if sewage alone were applied constantly to meadow land, potassa would be more likely to become deficient than phosphoric acid; but that, if it were applied to the ordinary crops of rotation, phosphoric acid would be more likely to become deficient than potassa. Still, granting it to be clearly shown that with this or that description of soil or management, town-sewage was, in proportion to its nitrogen, deficient in this or that constituent for the production of this or that crop, or crops generally, it would by no means follow that it was an inappropriate manure on that account; for, any defect in composition, whether in regard to phosphoric acid, potassa, or any other constituent, could be easily compensated from other sources.

Indeed, independently of what we know of the sources of the constituents of sewage, and can judge therefrom of their appropriateness as manure for different crops, there is nothing in the results of the analysis of the solid matter of sewage, from which we should be justified in concluding that it is not applicable as manure to crops generally. On the contrary, a dry and portable manure, having the composition of the solid matter of town-sewage, would undoubtedly be generally applicable both to corn and other rotation crops, and to grass; and its constituents could then fairly be valued by the same scale as other concentrated manures in the market.

But the great dilution of town sewage, its large daily supply at all seasons, and its greater amount in wet weather when the land can least bear, or least requires, more water, render it extremely inappropriate for application on a comprehensive scale to arable land, for the growth of corn and other ordinary rotation crops.

But, apart from these difficulties, if sewage can only be distributed in small quantities over large areas, at such a cost to the farmer as has yet been proposed, it is indeed vain to hope that any large proportion of the manurial constituents, derived from the consumption of human food in our towns, can be redistributed over the area from which they came; for such is the limit set by climate to the amount of manure and of water applicable for crops that have to ripen their seed, that, for corn more especially, only comparatively small quantities per acre could be employed, and hence, were sewage systematically applied for their growth, the area of utilization must necessarily be very large. On this point it may be stated that Mr. Rawlinson, one of the members of the Royal Sewage Commission, has given it as his opinion that it would cost more to distribute 500 tons of sewage per acre, by means of pipes, hydrants, and hose and jet, as would be requisite in the case of application to arable land and crops generally, than to apply 5,000 tons per acre by means of open runs, as in the case of its application to grass.

From these considerations it will be obvious, that that which may be called the theoretical value of sewage, reckoned according to the constituents it contains, is not necessarily its practical or available value when used in its highly diluted condition. It will be also obvious, that in that condition it is the most appropriate for grass, for which it can be employed at all seasons, and in comparatively large quantities on a limited area, and that it is the least appropriate for crops which have to ripen. The question arises—what is the practical or realizable value of the constituents of sewage when they are utilized in the condition of dilution in which they exist in that fluid? This point will be illustrated by reference, both to the results of direct experiments, and to the experience of practical men who have utilized sewage with a view to profit.

Results of direct Experiment on the Utilization of Sewage.

At Rugby two fields of meadow land were experimented upon; in each one plot was left without sewage, one received sewage at the rate of 3,000 tons, one at the rate of 6,000 tons, and one at the rate of 9,000 tons, per acre per annum. The experiments were so conducted through three consecutive seasons, and Table VIII summarizes the results obtained.

TABLE VIII.

Quantities of Sewage applied, and of Green Grass obtained, per acre per annum, in Experiments made at Rugby.

Seasons 1861, 1862, *and* 1863.

Seasons.	Plot 1. Unsewaged.				Plot 2. 3,000 Tons Sewage.				Plot 3. 6,000 Tons Sewage.				Plot 4. 9,000 Tons Sewage.			
	Grass obtained. Five-Acre Field.															
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1861	9	5	3	5	14	16	3	8	27	1	0	10	32	16	3	8
1862	8	3	1	10	27	18	0	18	34	10	0	19	32	9	2	22
1863	4	18	3	13	22	5	0	11	34	18	1	27	37	0	2	5
Average....	7	9	1	9	21	13	1	12	32	3	1	0	34	2	1	12
	Ten-Acre Field.															
1861	8	18	0	15	15	16	3	2	22	15	2	12	26	13	3	12
1862	16	10	0	25	27	11	0	20	32	2	1	14	31	12	1	20
1863	8	0	3	19	25	5	1	8	30	11	2	12	34	19	1	21
Average....	11	3	0	10	22	17	3	1	28	9	3	13	31	1	3	18
	Averages:—the three years and both Fields.															
1861, 2, and 3	9	6	0	24	22	5	2	7	30	6	2	6	32	12	0	15

The five-acre field was much flatter than the other; its soil and subsoil were much more porous; the mechanical and chemical examination of samples, taken to the depth of 9 inches, showed its soil to be much more stony, to retain much less water under equal external conditions, to contain much less organic matter, much less nitrogen, much less clay, and much more sand, than that of the ten-acre field. It was, in fact, considerably inferior in natural quality, and yielded, accordingly, considerably less produce without manure. Notwithstanding this, it will be seen that it gave upon the whole more total produce per acre under the influence of sewage than did the naturally better soil of the ten-acre field; and, it will be shown further on, that the sewage was in its case both more completely utilized and more completely purified.

It would be inappropriate to discuss in detail here the influence of season and other circumstances upon the produce of the different years or the respective plots. It will be sufficient to call attention to the general character of the results, and to the practical conclusions to which they seem to lead. By the application of sewage a supply of green food was obtained much earlier and much later in the season, and the total quantity per acre was increased several fold. There was, generally, though not invariably, the more produce the greater the amount of sewage applied, the exceptions being in the wet and cold season of 1862. In the other seasons, and in both fields, there was an increase of produce with each increase in the amount of sewage applied; and the largest amounts of produce obtained at all were, in both fields, in the third season of application, and on the plots which had received the largest amounts of sewage. Still, it is important to remark, that the amounts of increase of produce for a given amount of sewage applied were the less where the larger quantities were employed. Experience abundantly shows, indeed, that if the only object were to get the largest possible amounts of produce per acre, as much as 30,000, 40,000, or even 50,000 tons of sewage might frequently be applied per acre with advantage; but under such conditions the sewage would be very inadequately both utilized and purified, and a minimum amount of increase would be obtained for a given amount of sewage applied.

Looking, however, both to urban and to rural interests, and to purification as well as utilization, much more moderate applications than such as are required to yield the greatest amount of produce per acre, must be had recourse to. By way of practical suggestion on this point it may be stated that, on consideration of the circumstances under which the amounts of produce recorded in the Table were obtained, it is concluded that with an application of about 5,000 tons of average sewage per acre per annum, applied as it must be, pretty evenly throughout the year, there might be expected, taking the average of soils and seasons, an average of about 30 tons of grass. Assuming such a produce, and allowing £4 per acre for rent or natural yield, the grass would, if sold for 10s. per ton, give a gross return of 0·53d. per ton of sewage employed, if for 12s. 6d. per ton 0·7d., and if for 15s. per ton, 0·9d. From these amounts there would, of course, have to be deducted the cost of main distribution and application of the sewage, other expenses of the crop, and the farmer's profit, before anything was available as payment to the town for the manurial matters.

In comparison with the result here assumed it may be observed that in the neighbourhood of Croydon, where about 250 acres are laid down for sewage irrigation, and where there are probably more than 6,000 tons of sewage annually available for each acre, from 25 to 30 tons of meadow grass, selling for from £20 to £25, are obtained per acre per annum; and after deducting as before £4 for rent, the gross return per ton of sewage employed is from 0·6d. to 0·8d. With a somewhat similar application to Italian rye-grass, 30 to 35 tons, selling for from £25 to £30 are obtained, yielding, after deduction for rent or natural produce, from 0·8d. to 1d. per ton of sewage employed. It will be observed that in these cases the selling price of the grass is 16s. or 17s. per ton; but it is obvious that if sewage were extensively employed for the production of grass, its present price could not be maintained.

A marked effect of liberal sewage irrigation (indeed of active manures generally), on the mixed herbage of grass land, is greatly to develope the Graminaceous plants, nearly to exclude the Leguminous, and to reduce the prevalence of miscellaneous or weedy plants, but much to encourage individual species. Among the grasses, according to locality or other circumstances, the rough meadow grass (*Poa trivialis*), couch grass (*Triticum repens*), rough cock's foot (*Dactylis glomerata*), woolly soft grass (*Holcus lanatus*), and perennial rye-grass (*Lolium perenne*), have been observed to become very prominent; two or three only remaining in any considerable proportion after some years of liberal sewage application. But sewaged produce being generally cut or grazed comparatively young, the tendency which the great luxuriance of a few very free-growing grasses has to give a coarse and stemmy later growth is not an objection, as in the case of meadows left for hay.

The chemical examination of the grass grown at Rugby showed that, at the stage of growth at which it was cut, the sewaged grass contained a less proportion of dry or solid substance than the unsewaged; that the grass cut during the later portions of the season (both unsewaged and sewaged) contained less solid matter than that cut during the more genial periods of growth; that the proportion of nitrogenous substance (and also of impure fatty or waxy matter) was much greater in the solid matter of the sewaged than in that of the unsewaged grass; that the proportion of nitrogenous substance was also much higher in the and ether. It melts at 224·5° C. to a reddish-brown oil. A higher temperature it deflagrates, diffusing at the same time a aromatic odour. It is an almost perfectly indifferent substance. I could not even succeed in preparing a compound with dichloride of platinum; nitrate of silver, however, still gives, even in very dilute alcoholic solutions, a yellowish-green amorphous precipitate.

β-Diazo-amidonitrobenzol.—$\left\{\begin{array}{l} C_6H_3(NO_2)N_2 \\ C_6H_4(NO_2)(NH_2) \end{array}\right\}$

When β-nitraniline is submitted to the action of nitrous acid, almost exactly the same phenomena are observed as those which occur in the preparation of the preceding compound. The crystals which have been deposited, but which in this case exhibit a perfectly distinct form, are easily purified in the same manner.

The β-diazo-amidonitrobenzol differs only in a few points from the α compound. It is equally insoluble in water, and appears also to be as difficultly soluble in alcohol and ether. The two substances also seem to agree in their deportment with reagents, as far as could be decided by preliminary experiments. On the other hand, the melting point of β-diazo-amidonitrobenzol is 195·5° C., consequently 29° lower than that of α-diazo-amidonitrobenzol. The α compound crystallises as a rule in granular or moss-like shapes, whilst the β-diazo-amidonitrobenzol separates already during its preparation, in small though generally well-defined, ruby or reddish-yellow prisms, which by recrystallisation from alcohol or ether may be obtained of a considerable size.

Diazo-amidodibromobenzol.—$C_{12}H_7Br_4N_3 = \left\{\begin{array}{l} C_6H_2Br_2N_2 \\ C_6H_3Br_2(NH_2) \end{array}\right\}$

On passing a current of nitrous acid gas into a very dilute alcoholic solution of dibromaniline, the diazo-amidodibromobenzol is obtained as a bulky light-yellow precipitate. Repeated washing with alcohol renders it perfectly pure.

Diazo-amidodibromobenzol has a great tendency to crystallise in different forms. From alcohol and ether, in which it is very difficultly soluble, even at the boiling temperature, it crystallises in fine golden-yellow interlaced needles, which melt at 167·5° C., but deflagrate at a higher temperature. On allowing an alcoholic ation to evaporate spontaneously, yellowish-brown granules are frequently obtained which show a golden-yellow fracture and a radiating crystalline structure. On several occasions, and under conditions not accurately determined, α-diazo-amidodibromobenzol, prepared from not absolutely pure dibromaniline crystallised from ether in extraordinarily beautiful yellow or ruby well-defined prisms. As this form, differing in such a characteristic manner from the yellow needles, appertained to the dibromaniline obtained from dibromisatin, I should have been inclined, in spite of what I had previously stated in regard to dibromaniline, to seek the cause of this difference in the dibromaniline prepared by the different methods. I soon, however, convinced myself, that the beautiful red crystals are converted, on further re-crystallisation from ether, into the same golden-yellow hair-like needles.

Diazo-amidodichlorobenzol, $C_{12}H_7Cl_4N_3 = \left\{\begin{matrix} C_6H_2Cl_2N_2 \\ C_6H_3Cl_2(NH_2) \end{matrix}\right\}$,

is also prepared from dichloraniline and crystallises also in hair-like needles, which are, however, distinguished from the bromine compound by their light sulphur-yellow colour. It is insoluble in water, and very difficultly soluble in boiling alcohol and ether. It melts at 126·5° C.

In their deportment with reagents, diazo-amidodibromobenzol and diazo-amidodichlorobenzol exhibit the greatest analogy to the nitrogen-substituted aniline-derivatives already described, whilst under the same conditions they yield corresponding products of decomposition. They also form precipitates with nitrate of silver. Their basic character, however, has completely disappeared; they no longer give platinum-salts; in fact, they possess more the character of an acid than that of a base, as they dissolve with ease in alcoholic potash, forming a reddish-brown solution, from which the original substance is precipitated in a perfectly unaltered state on the addition of an acid. It is, however, not possible to prepare salts of a definite composition. Aqueous potash has no action upon these bodies.

From what has been stated it is obvious that the acidifying influence exerted by nitrogen, when taking the place of hydrogen in aniline, is repeated in an equal degree with the substitution-products of that body.

TABLE IX (*continued*).

	Plot 1. Unsewaged.	Plot 2. 3,000 Tons Sewage.	Plot 3. 6,000 Tons Sewage.	Plot 4. 9,000 Tons Sewage.
Increased produce of milk per 1,000 tons sewage applied (exclusive of oilcake,* if any) :—				
		Gallons.	Gallons.	Gallons.
1861—Grass (alone)...........		180	178	151
1862—Grass (with oilcake)		74	60	38
1863—{Grass (½ without, ½ with oilcake............}		154	132	101
Means..		136	123	97
Increased value of milk (at 8*d.* per gal.) per 1,000 tons sewage applied (exclusive of oilcake,* if any) :—				
		£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
1861—Grass (alone)...........		5 19 10	5 18 8	5 0 11
1862—Grass (with oilcake)		2 9 4	2 0 0	1 5 7
1863—{Grass (½ without, ½ with oilcake............}		5 2 7	4 8 1	3 7 7
Means..		4 10 7	4 2 3	3 4 8

It may be stated generally, that when the cows were fed on grass alone, as much as they chose to eat, a given weight of the animal was more productive, both of milk and increase, but especially of milk, on the unsewaged than on the sewaged grass. More milk was also produced from a given weight of the unsewaged grass, reckoned in the fresh or green state, than from an equal weight of the fresh sewaged grass. Of dry or solid substance, however, a given weight of that of the sewaged grass produced, on the average, more milk than an equal weight of that of the unsewaged.

The milk from the cows fed on the sewaged grass was, upon the

* The *value* of the milk, "exclusive of oilcake," is reckoned by deducting the cost of the cake consumed, less the estimated value of the manure it yields, from the gross value inclusive of oilcake; and the *amount* of milk, "exclusive of oilcake," by deducting from the gross amount of milk with oilcake at the rate of one gallon for every 8*d.* of deducted value. Such estimates are, however, obviously only approximations to the truth.

whole, slightly the less rich, containing generally somewhat less casein, butter, sugar, and total solid matter (though more mineral matter) than that from the unsewaged; but when oilcake was given with the grass, whether sewaged or unsewaged, the richness of the milk was notably increased.

The productive quality of the grass was very different in different seasons, and at different periods of the same season, being very inferior in the wet and cold season of 1862, and towards the close as compared with the earlier periods of the seasons.

Without commenting further on the difference of result obtained under different conditions of season, or under other varying circumstances, it will be sufficient briefly to call attention to the more general results which the records in the table bring prominently to view, and to the practical conclusion which, on a careful consideration of all the circumstances and details, may seem to be safely deducible from them.

It is seen that whether we reckon the total amount of food yielded per acre, or the amount, or the value, of the milk obtained from the consumption of the produce of each acre, there was a very great increase, varying from two to three-fold, according to season, by the use of sewage. The land upon which these experiments were made was good feeding pasture, of probably more than average quality, and the natural yield, without sewage, was, therefore, correspondingly high. Taking into consideration this fact, and other circumstances under which the results were obtained, it is concluded that, if not larger amounts of total produce per acre, at any rate larger amounts of increase for a given quantity of sewage may be expected when it is applied systematically over large tracts of land, with a view to the production of grass and milk.

It is estimated that with 5,000 tons of sewage per acre per annum, judiciously applied to Italian rye-grass or meadow-land properly laid down to receive it, an average *gross* produce of not less, and perhaps more, than 1,000 gallons of milk per acre per annum might be anticipated; and it may be observed that 1,000 gallons of milk at 8d. per gallon would represent a *gross* money return of £33 6s. 8d.

Putting the result in another way it may be stated that it required, according to circumstances, the consumption of between 5 and 6 tons of grass for the production of 1 ton of milk; and if we reckon 6 parts of grass for 1 of milk, and 30 tons of grass per acre, this would give a *gross* return in value of milk at 8d. per gallon of something over £37 per acre, or of about 25s. per ton, of grass consumed.

Still another illustration of the important bearing of the question of the utilization of the sewage of our town populations upon the re-production of food may be given. Supposing the whole of the sewage of a given population (which, however, would seldom be the case) were applied exclusively for the growth of grass for the production of milk, the result would be an increased yield of about 2½ pints of milk per week, or about ½ lb. per day, per head of such population. So far as the sewage were so applied, a portion of the milk produced would, of course, be represented, in consumption, by its equivalent in butter and cheese. A portion of the grass would, however, be used directly for the production of meat; and, in addition to the milk and meat produced by the consumption of the grass, a large amount of solid manure would be obtained, which would be applicable to arable land for the growth of corn and other rotation crops.

It would appear, then, that if town sewage were to a great extent utilized by the application of something like 5,000 tons per acre per annum to Italian rye-grass and meadow-land, a direct result would be a very greatly increased production of important articles of human food which are at present both scarce and dear. But the question remains—would the sewage, by such an application, be sufficiently purified to allow of the drainage from the irrigated land being turned into rivers which are to be used as a water-supply for other towns? Some light will be thrown on this subject by the results next to be considered.

In order to determine how far, in the experiments at Rugby, the sewage was deprived of its manurial or putrescible constituents in its passage over and through the land, samples of the drainage water were collected for analysis in each field, simultaneously with those of the sewage, commencing in May, 1862, and ending in October, 1863. In all 62 partial analyses of drainage-water, corresponding in detail with those of the sewage, were made. A few other analyses, in much more detail, were made of the sewage and drainage of the season of 1864. The results of the large number of partial analyses are summarized in Table X, which shows, in parallel columns, the average composition of corresponding samples of sewage and drainage.

TABLE X.

Mean Composition of the Rugby Sewage before application, and of the Drainage-water from the Irrigated Land, in the Seasons 1862 *and* 1863.

Grains per Gallon.

Constituents.		Five-Acre Field.		Ten-Acre Field.		The two Fields.	
		Sewage.	Drainage.	Sewage.	Drainage.	Sewage.	Drainage.
Season 1862; May—October, both inclusive.							
		11 Samples.	8 Samples.	11 Samples.	11 Samples.	22 Samples.	19 Samples.
In suspension	Inorganic	25·67	1·81	24·89	3·74	25·28	2·92
	Organic...	14·69	1·40	17·14	1·39	15·92	1·39
	Total...	40·36	3·21	42·03	5·13	41·20	4·31
In solution ...	Inorganic	34·49	34·50	32·38	37·10	33·44	36·01
	Organic...	7·83	7·18	7·60	7·83	7·71	7·56
	Total...	42·32	41 68	39·98	44·93	41·15	43·57
Total inorganic ...		60·16	36·31	57·27	40·84	58·72	38·93
Total organic......		22·52	8·58	24·74	9·22	23·63	8·95
Total solid matter...		82·68	44·89	82 01	50·06	82·35	47·88
Ammonia	In suspension	1·37	0·24	1·52	0·33	1·44	0·29
	In solution ...	4·13	0·80	4·26	1·85	4·20	1·41
	Total...	5·50	1·04	5·78	2·18	5·64	1·70
Season 1863; November, 1862—October, 1863, both inclusive.							
		23 Samples.	21 Samples.	22 Samples.	22 Samples.	45 Samples.	43 Samples.
In suspension	Inorganic	39·41	2·14	34·93	3·93	37·22	3·06
	Organic...	27·35	1·41	25·99	3·29	26·69	2·37
	Total...	66·76	3·55	60·92	7·22	63·91	5·43
In solution ...	Inorganic	39·57	38·55	38·77	41·35	39·18	39·98
	Organic...	8·35	7·46	8·30	7·98	8·32	7·73
	Total...	47·92	46·01	47·07	49·33	47·50	47·71
Total inorganic...		78·98	40·69	73·70	45·28	76·40	43·04
Total organic......		35·70	8·87	34·29	11·27	35·01	10·10
Total solid matter...		114·68	49·56	107·99	56·55	111·41	53·14
Ammonia	In suspension	2·08	0·15	1·98	0·31	2·03	0·23
	In solution ...	5·83	0·69	5·69	1·85	5·76	1·28
	Total ...	7·91	0·84	7·67	2·16	7·79	1·51

It is seen that of matter in suspension in the sewage, nearly the whole, both inorganic or organic, was retained by the soil; and probably a considerable part of the little which the drainage-water contained was derived from the soil itself.

Of matter in solution, on the other hand, a gallon of the drainage-water contained, on the average, much about the same amount, both inorganic and organic, as a gallon of the sewage; though, doubtless, a considerable portion of the soluble matters in the drainage had their immediate source in the soil—the sewage giving up valuable manurial matters to the soil, and the fluid in its turn taking up substances from it.

It is important to remark that the drainage from the more porous and less naturally fertile soil of the five-acre field (which, however, gave the largest amount of increase for a given amount of sewage), contained less of almost every constituent, or class of constituents, enumerated, than did that from the more argillaceous and more naturally fertile soil of the more steeply sloping ten-acre field. The result is particularly marked in the case of the ammonia. The fact here indicated is of considerable practical, as well as scientific, interest; and it is perfectly consistent with the results of common experience, which tend to show that a soil which may contain a comparatively small proportion of clay, but which is thoroughly porous, is, as a rule, much better adapted for sewage irrigation, both as regards the utilization and the purification of the sewage, than one which, though richer in clay and of higher natural quality, is but imperfectly permeable by the fluid.

The results given in Table XI show in more detail the changes in the composition of the fluid in its passage through the soil. They relate to samples of sewage and drainage taken in another field at Rugby, during very dry weather, in the summer of 1864. The plan of collection was, to take of sewage about a gallon, and of drainage about half a gallon, eight or ten times during the ten or twelve working hours of the day; at the end of the day, after well shaking, to take a gallon from each mixture; and to repeat this for six consecutive days, until six gallons of each were obtained, when, after well shaking, a two-gallon sample of each was bottled off for the purposes of analysis.

Table XI.

Detailed Composition of samples of the Rugby Sewage before application, and of the Drainage-water from the irrigated land, collected July, 1864.

	Constituents.	Grains per Gallon.			
		Collected July 6—11.		Collected July 13—18.	
		Sewage.	Drainage.	Sewage.	Drainage.
In suspension.	Inorganic matter :—				
	Oxide of iron and alumina......	4·57	..	6·30	..
	Lime........................	4·48	..	3·75	..
	Magnesia	0·65	..	0·25	..
	Carbonic acid	3·25	..	2·17	..
	Phosphoric acid	1·84	..	1·14	..
	Silica, sand, &c.	31·60	..	39·30	..
	Total	46 39	..	52·91	..
	Organic matter	40·40	..	32·40	..
	Total matter in suspension..	86·79	..	85·31	..
In solution.	Inorganic matter :—				
	Oxide of iron, &c.	Traces.	..	1·25	0·25
	Lime........................	8·45	10·25	8·23	10·08
	Magnesia	1·76	1·69	1 80	1·69
	Soda (1)	5 46	0 38	5·24	2·30
	Chloride of sodium (1).........	6·82	9·73	8·53	9·21
	Chloride of potassium (1)	6·08	1·50	6·17	2·34
	Sulphuric acid	4·39	6 55	4·01	6·75
	Phosphoric acid	1·28	0·44	1·66	0·32
	Carbonic acid	8 83	6·18	7·42	7·01
	Silica........................	1·80	0·80	1·00	0·80
	Total..................	44·87	37·52	45·31	40·75
	Organic matter	11·20	7·80	10·00	7·05
	Total matter in solution	56·07	45·32	55·31	47·80
	Total inorganic matter	91·26	37·52	98·22	40·75
	Total organic matter (2)........	51·60	7·80	42·40	7 05
	Total solid matter	142·86	45·32	140·62	47·80
(1) Containing	Potassa	3·84	0·94	3·90	1·48
	Soda	9 07	5·54	9·76	7·17
	Chlorine	7 03	6·61	8·10	6·70
(2) Containing	Ammonia — In suspension	2·92	..	2·42	..
	Ammonia — In solution	5·74	0·98	6·36	0·92
	Ammonia — Total..........	8·66	0·98	8·78	0·92
	Nitric acid in solution = Ammonia	....	(3) 1·33	..	(4) 1·41

(3) 4·227 Nitric acid = 1·096 Nitrogen = 1·331 Ammonia
(4) 4·483 " = 1·162 " = 1·411 "

The soil was light and gravelly, with a gravelly subsoil; but an examination of the figures in Table XI shows, that it had done the work of absorption, at any rate as well as, if not better than, on the average, did the soils in the other fields. It was intended to take samples for detailed analysis from this field under various conditions of the weather, but owing to the continuance of the drought, this could not be accomplished.

In judging of these results, as well as those already considered, it must, of course, be borne in mind that, excepting when the land is already saturated with water, a gallon of drainage will represent much more than a gallon of sewage; and that, hence, the amount of any constituent of the sewage found in a gallon of the drainage must have been derived from more than a gallon of the former. The non-retention of valuable manurial matters by the soil was, therefore, not so great as would at first sight appear on an inspection of the comparative composition of equal volumes of the sewage and of the drainage.

As in the larger number of cases, so in these, the quantity of matter in suspension in the drainage was very small, and being obviously in great part derived from the soil, it was not submitted to quantitative analysis. A considerable proportion of the phosphoric acid of the sewage was in suspension, but there was none of it in suspension in the drainage, the whole of the portion so existing in the sewage having been retained by the soil.

It is satisfactory to observe that among the inorganic constituents in solution in the sewage, by far the larger proportion of those which are, perhaps, the most likely to become relatively deficient, was retained by the soil. Thus, smaller proportions of both the potassa and the phosphoric acid of the sewage passed off in the drainage than of any other constituents. Soda was also retained by the soil to a considerable extent, magnesia in a less degree, and lime less still. Of lime, indeed, there was more in a gallon of drainage than in a gallon of sewage; of sulphuric acid also there was considerably more in the drainage than in an equal volume of the sewage. Lastly, of soluble silica a notable portion passed off in the drainage.

Of organic matter in solution a very considerable quantity was found in the drainage-water. The character of the soluble organic matter in the drainage is, however, very different from that in the sewage. It contains very much less ammonia, or ammonia-yielding matter; and, especially in periods of active vegetation, will, doubtless, frequently be derived from vegetable matter within the soil, rather than directly from the sewage.

A very important point to remark is, that, whilst the sewage scarcely contained an appreciable amount of nitric acid, the drainage contained more nitrogen in that form than as ammonia; the result being that the soil had retained a considerably less proportion of that important manurial constituent of the sewage than would have been supposed had only the more partial analyses been made.

The general result was, that, practically, the whole of the insoluble or suspended matter of the sewage was retained by the soil; and that, of the constituents of the sewage, whether in suspension or in solution, those which are of the most value, because the most liable to become relatively exhausted, were the most efficiently retained. Nevertheless, the drainage-water still retained so much of potassa, phosphoric acid, ammonia, and nitric acid, as clearly to show that the sewage had not been perfectly deprived of its valuable manurial matters, and also so much of total soluble matter, especially of soluble organic matter, as to show that it had not been by any means perfectly purified.

There is, indeed, a limit to the power which a soil possesses of removing substances from solution, or of preventing those already absorbed from being dissolved in water passing through it, the result being dependent on the physical and chemical characters of the soil itself, and on the amount and composition of the fluid passing through it. So far as the soluble organic matters of the drainage are derived from vegetable matter within the soil, it is a question whether there will not always be a considerable amount in that passing from land covered with luxuriant vegetation. So far, however, as the nitrogen of the drainage exists in the form of nitric acid, it is a pretty satisfactory indication that the organic matter has, to a great extent, already passed the stage of deleterious putrescence.

In the Rugby experiments the arrangements were not such as to allow of the water drained from one portion of the land being passed over another; but at Beddington, near Croydon, a great portion of the water does duty twice, and sometimes three times; and from results kindly communicated by Mr. Latham, the engineer to the Croydon Board of Health, and given in the following table, it would appear that there the water eventually passes from the land in a state of much greater purity than was the case in the Rugby experiments.

TABLE XII.

Partial Analyses of the Croydon Sewage before application, of the Drainage-water from the irrigated land, and of the River Wandle, above and below the Drainage Outfall from the irrigated land.

Constituents.	Croydon.		River Wandle.	
	Sewage.	Drainage.	Above Drainage Outfall.	Below Drainage Outfall.
	Grains per gallon.			
Inorganic matter	48·30	23·40	18·56	20·16
Organic matter	52·20	2·40	1·44	2·08
Total solid matter	100·50	25·80	20·00	22·24
Ammonia	6·70	0·21	0·18	0·18

The figures show much about the same amount of ammonia in the sewage of Croydon, as was found on the average in that of Rugby; but the amount in the Croydon drainage was extremely small. It is unfortunate that the quantity of nitric acid was not also determined; but we are informed that it undoubtedly exists in some amount in the drainage from the Beddington meadows. Still, although formerly the Croydon Board had to meet numerous law-suits on account of the pollution of the river by the sewage, the fluid is now so far purified before being discharged, that those having the right of fishing in the river have found it worth while to fix gratings to prevent the fish going up the main outfall from the sewage-irrigated land.

The results obtained in regard to this part of the subject—that of purification—however interesting and important, must still be looked upon as little more than initiative; but there can be no doubt that, when large quantities of sewage are applied to grass-land, the arrangements should be such as to allow of the drainage-water being collected and re-used in such a manner as to insure as far as possible both complete utilization and complete purification. It must be admitted, however, that further experience, and further investigation, are still wanting, to determine what amount of sewage, provided the drainage-water be properly re-distributed, can be safely applied to a given area, under different conditions of soil and subsoil, and under different conditions of season, so as to insure its sufficient purification.

Experience of Common Practice in the Utilization of Sewage.

Leaving the results of experimental inquiry, it will be well briefly to notice those of practical experience hitherto, in regard to the value and utilization of town sewage. The instance most frequently quoted is that of the neighbourhood of Edinburgh, relating to which some particulars are given in the following Table :—

TABLE XIII.

Relating to the Sewage-irrigated Meadows near Edinburgh.

Names of Meadows.	Imperial Acres under Irrigation.	Approximate Population contributing to each Acre.	Approximate Quantity of Sewage available for each Acre.
			Tons.
Lochend, Spring Gardens and Craigentinny	285	337	20,500
Roseburn and Western Dalry	80	112	17,000
Quarry Holes	8	562	65,000
Broughton Burn	6	1,666	102,000
The Grange	16½	302	97,000

These tabular statements are chiefly based upon direct information, obtained in part from Mr. McPherson, the Edinburgh City Surveyor, and in part from the occupiers or managers of the respective meadows. To prevent misunderstanding, however, it must be explained with regard to them, that, as water-closets are not universal, and as the sewage is frequently allowed to pass unused, the records of the amount of population contributing to, and of sewage available for, each acre, do not show the amounts actually utilized, but only approximately the total amounts available, whether used or wasted.

Sewage has been applied to some portions of the land in the neighbourhood of Edinburgh for about 200 years, to a considerable portion for more than 60, and to most of that now under irrigation for more than 30 years. In two instances arrangements have been made for raising the sewage, by pumping, an inconsiderable number of feet; but the cost has been found too great to allow of a sufficient quantity being applied per acre, and hence the application in this way has been much limited, if not on some portions of the land entirely abandoned. The application is confined to meadow land and Italian rye-grass, and the distribution is entirely by means of open runs. When Italian rye-grass is grown, the land is periodically broken up, and one or two other crops taken without sewage before laying down again to grass. The application to ordinary rotation crops on arable land forms no part of the system adopted.

There is no doubt that at Edinburgh larger amounts of sewage are applied per acre than anywhere else, and that it is under those conditions that there are there obtained larger amounts of produce per acre than anywhere else. Nor is there any doubt, on the other hand, that there is, at Edinburgh, not only very great waste of manurial constituents, but very imperfect purification of the sewage. Hence the experience there, however interesting and important in some points of view, cannot be taken as the foundation either of estimates of the value realizable in practice by the utilization of given amounts of sewage, or of the sewage of a given population, or of safe conclusions as to the amount of sewage that can advantageously be applied per acre when the drainage has to be passed into a river, which may have to serve as the water-supply of other towns, instead of, as at Edinburgh, having an immediate outfall into the sea.

It may be mentioned that generally four or five crops of grass are obtained per acre annually, amounting, according to circumstances, to 30, 40, 50, 60, and even more tons per Imperial acre, and selling for prices varying from £8 to over £40 per acre, but averaging perhaps about £25. These results are, indeed, sufficiently striking, and well merit careful inquiry and consideration; but, for the reasons above stated, the exact practice of Edinburgh is not applicable to towns generally, and is especially inapplicable to inland towns.

Table XIV summarizes the results of the experience of the most important instances of sewage utilization in other localities.

TABLE XIV.

Relating to Sewage-irrigation in various localities.

Towns.	Population contributing.	Acres.		Crops, &c.	Annual Payment to Towns.
		Original.	Reduced.		
Alnwick	6,500	270	0	Arable and grass; abandoned	Nothing
Carlisle	22,000	70	..	Meadow-grass; all grazed	?
Croydon	16,000	250	..	Meadow and rye-grass	£300
Malvern	4,000	50	..	Grass	Nothing
Rugby	6,700	{ 190 280	20 100	Meadow and rye-grass Meadow; chiefly grazed	} £50
Tavistock....	6,000	95	..	Grass	Nothing
Watford ...	4,000	210	{ 7 35	Rye-grass—Summer Meadow-grass—Winter	} £10
Worthing ..	7,000	42	..	Grass; not yet at work	Nothing

At Alnwick, the late Duke of Northumberland put down machinery and piping for the distribution of the sewage of the town over about 270 acres of mixed arable and grass land. After a very short time, the tenants, who had the free use of the sewage for the cost of its application, abandoned it altogether; and the Bailiff of the District, who reports the failure, expresses his opinion strongly against the general applicability of sewage to arable land.

At Carlisle, the sewage of only a portion of the town is utilized. It is deodorized by Mr. McDougall's disinfecting fluid, and raised by steam power some 10 or 12 feet into an open cut, from which it is diverted for application to the land by moveable iron troughs. It is estimated that from 8,000 to 9,000 tons of sewage are applied per acre per annum. It is understood that little or nothing is realised by the town; but that the tenant makes a considerable profit by sub-letting the sewage-irrigated land for grazing purposes.

In the neighbourhood of Croydon, as already referred to, the sewage of nearly 20,000 persons is applied to about 250 acres of meadow and Italian rye-grass. It is calculated that more than 6,000 tons of sewage are available for each acre. A considerable portion of the fluid is used two or three times over; and it finally passes from the land pretty satisfactorily purified. It is estimated that, after making deduction of £4 for rental, the *gross* return per ton of sewage applied is, at the present prices of the produce, with Italian rye-grass from ¾d. to 1d., and with meadow grass from ½d. to ¾d. The sewage is not applied in any systematic manner to other crops, but it has been tried on a small scale to root-crops. An enlargement of the area of irrigation is contemplated, which will, if carried out, somewhat reduce the amount of fluid and excretal matters available per acre below the quantities above stated.

About 12 years ago, arrangements were made for collecting the sewage of Rugby in a tank, from which it is pumped, by a 12-horse power engine, through iron pipes laid down for the distribution over about 470 acres of mixed arable and grass land. Up to last year 190 acres were held by Mr. James Archibald Campbell, but he has gradually limited the area of application, and during the last few years has abandoned the use of hose and jet, excepting occasionally on a small scale, and confined the application almost exclusively to from 12 to 20 acres of meadow and Italian rye-grass. The remainder of the land, amounting to about 280 acres, has passed through the hands of two tenants, both of whom are said to have sustained considerable loss. The last of the two had confined the application almost exclusively to about 100 acres of grass land, and applied the sewage almost entirely by open runs. The whole is now in the hands of the landlord, Mr. G. H. Walker, who, it is understood, is contemplating the abandonment of the use of steam power, pipes, and hose and jet, and the application to a limited area by means of gravitation.

The general result at Rugby is, then, that after about a dozen years of practical experience, with arrangements adapted for the application of small quantities of sewage per acre, to arable as well as to grass land, and to all crops, the area has been greatly limited, the use to any other crops than meadow and Italian rye-grass is quite exceptional, and the application by means of steam-power, pipes, and hose and jet, will probably soon be entirely abandoned. It may be added that, at the time of the experiments of the Commission, the sewage, which was considerably stronger than that of the Metropolis, cost the tenants only about ¾d. per ton at the hydrants in the fields; yet, rather than incur the loss of using it at that cost, both were glad to get rid of it to the Commission, at rates which, though three times as high during the six summer as during the six winter months, averaged the year round scarcely, but very nearly, 1d. per ton at the hydrants.

Some years ago, the Earl of Essex laid down pipes for the application of the sewage of Watford, by pumping and hose and jet, to about 210 acres of mixed arable and grass land. The results which his Lordship obtained on the application of only 134 tons of sewage per acre to wheat have frequently been held to be conclusive proof of its applicability in small quantities per acre over large areas, to arable land, and to all crops. But in the evidence given by his Lordship before the Sewage Committee of 1862, he stated, very emphatically, that his great error had been the piping of too much land; that he required 5,000 tons per acre for 10 acres of rye-grass; and that, applying the remainder to 35 acres of meadow, he had none to spare for wheat. In other words, although the abandonment of one acre of rye-grass would set free sewage enough for nearly 40 acres of wheat, if applied only at the rate which yielded the large gross return per ton of sewage so frequently quoted, yet his Lordship's practical experience had led him to prefer the application to the one acre of rye-grass rather than to the nearly 40 acres of wheat. Further, his Lordship gave it as his opinion that sewage would not be profitable to the farmer unless he could have it at from ½d. to ¾d. per ton.

Referring to the question of the application of sewage to corn crops, it may be stated that, in an experiment made by the Commission at Rugby, with oats, a very high gross money return per ton of sewage was also obtained. The experiment was made in the unusually productive season of 1863, and with sewage of about double the average strength of that of the Metropolis, applied during a period of very dry weather. The results were, therefore, quite exceptional, and cannot be taken as affording any indication of what might be expected from the application of small quantities of sewage to corn crops generally, on different soils, and on the average of seasons. There cannot, indeed, be a doubt, that to obtain a maximum gross value of produce from a given amount of sewage, it should be applied in small quantities per acre, and in dry weather. But sewage is produced in large daily amount at all seasons, and must be disposed of as soon as it is produced. It must, therefore, be applied in winter, when of comparatively little value, as well as in summer, when of more, and it would frequently be quite inapplicable to arable land. Moreover, to obtain an increased gross money return per ton of sewage by using it on a comprehensive scale for corn and other ordinary rotation crops, would involve the extra cost of main distribution over at least a ten-fold, if not frequently a twenty-fold area, and require the application to a great extent by the expensive means of pipes and hose and jet, instead of by the economical one of open runs.

At Malvern and Tavistock the application of sewage to grass land has now been carried on for some years, but at Worthing it has only very recently been commenced.

From this short review of the experience of practical men who have undertaken the utilization of sewage with a view to profit, it appears that, wherever arrangements have been made for the application of small quantities over large areas, to corn and other rotation crops on arable land, and by means of pipes and hose and jet, the undertaking has either been entirely abandoned, or the area greatly limited, and the application confined almost exclusively to meadow and Italian rye-grass. On the other hand, the undertakings which have been the most successful from the agricultural point of view are those in which the arrangements have been adapted for the almost exclusive application to grass, and the application to other crops is only exceptional.

The practical conclusions deducible from the whole inquiry may be briefly stated as follows :—

1. It is only by a liberal use of water that the refuse matters of large populations can be removed from their dwellings without nuisance and injury to health.

2. That the discharge of town sewage into rivers renders them unfit as a water supply to other towns, is destructive of their fish, causes deposits which injure their channels, gives rise to emanations which are injurious to health, is a great waste of manurial matter, and should not be permitted.

3. That the proper mode of both utilizing and purifying sewage is to apply it to land.

4. That, considering the great dilution of town sewage, its constant daily supply at all seasons, its greater amount in wet weather when the land can least bear, or least requires more water, and the cost of distribution, it is best fitted for application to grass, which alone can receive it the year round. It may, however, be occasionally applied with advantage to other crops within easy reach of the line or area laid down for the continuous application to grass.

5. That, having regard both to urban and rural interests, an application of about 5,000 tons of sewage per acre per annum, to meadow or Italian rye-grass, would probably, in the majority of cases, prove to be the most profitable mode of utilization, though the quantity would have to be reduced, provided experience showed that the water was not sufficiently purified; and it is pretty certain that the farmer would not pay $\frac{3}{4}$d., and it is even very doubtful whether he could afford to pay $\frac{1}{2}$d. per ton, the year round, for sewage of the average strength of that of the Metropolis (excluding storm-water) delivered on his land.

6. That the direct result of the general application of town sewage to grass land would be an enormous increase in the production of milk, butter, cheese, and meat; whilst, by the consumption of the grass, a large amount of solid manure, applicable to arable land and to crops generally, would be produced.

7. That the cost or profit to a town of arrangements for the removal and utilization of its sewage must vary very greatly, according to its position, and to the character and levels of the land to be irrigated. Where the sewage can be conveyed by gravitation, and a sufficient tract of suitable land is available, the town may realize a profit; but, under contrary conditions, it may have to submit to a pecuniary sacrifice to secure the necessary sanitary advantages.