SEWAGE DISPOSAL.

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FOR THE GUIDANCE OF SANITARY AUTHORITIES.

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PREFACE TO SECOND EDITION.

THE fact of this work having rapidly passed through its first edition indicates that there existed a want for a condensed description of the chief points which govern the question of sewage disposal, such as this book affords. Further data having been collected, I have incorporated it whilst revising the book for a second edition.

Much of the information has been obtained when advising sanitary authorities as to the best means of sewering their towns and of disposing of the sewage. In the course of the investigations that I have had to make into the several methods of dealing with town refuse, I have had opportunities of collecting data, the condensation of which into a compass convenient for reference, affords a ready means of obtaining guidance on points which are continually arising in sewerage practice.

Some of the contents of this book have appeared, in one form or another, in Papers which I have read before various Societies, or in Articles which I have contributed to the press.

The Official Bluebooks and other published information contain much valuable matter, but some of this has either become obsolete, or to enable it to be utilized it requires to be detached from that which is less useful, so far as relates to this subject.

There is now exhibited a better agreement than previously existed on the main points that have to be adhered to in dealing with sewage. The extravagant expectations, on the part of the advocates of precipitation processes, that fortunes were to be made out of sewage, if treated by a particular system, have died out, and the equally sanguine hopes of irrigationists, that the application of sewage to land would result in great pecuniary gain, have also been sobered by experience.

The recent data which I am able to give in this book as to the application of sewage to land will enable a safer opinion to be formed than heretofore as to the areas of land that should be employed for sewage disposal, by which probably less difficulty will be experienced by local authorities in being advised as to what land they require, and in obtaining it.

I have to acknowledge my indebtedness to many who have cordially co-operated with me in obtaining reliable data for this book. The assistance thus afforded me I have recognized where possible. The compilation of the Table in the Appendix would have been impossible had I not been aided by the Engineers, Town Clerks, and other officers of the several places referred to.

HENRY ROBINSON.

7, WESTMINSTER CHAMBERS, LONDON, S.W.,
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SEWAGE DISPOSAL.

CHAPTER I.

INTRODUCTION.

In this book the consideration of the disposal of sewage will be confined to that portion of the refuse of the community which is conveyed away by the water-carried system of drainage, and it will not include the methods known as the dry earth, pail, and other systems.

The disposal of sewage involves to so large an extent the health of the community that it deserves the most thoughtful consideration on the part both of individual householders and of town authorities. A better compliance with the well-recognized rules which govern the subject cannot be too strongly insisted on. A glance at the official tables of death-rate shows a serious proportion of deaths from preventable diseases produced by either defective house sanitation or town drainage. Besides the loss of population thus caused, an enormous number are annually enfeebled in mind and body by these diseases, and they become more or less a burthen to the community. It may be truly asserted that real economy is practised by a town which expends its funds liberally in the direction of sanitary improvements.

Although bad drainage and defective house sanitation may not be the only causes of the death-rates in large towns being higher than where the populations are less concentrated, nevertheless, they are important factors. The Registrar-General's returns show that a population of 12,892,982 persons living on 3,183,965 acres in the districts comprising the chief towns of England, gave an average death-rate for ten years of 24·4 per 1000, whilst a population of 9,819,284 persons living on 34,135,256 acres in districts comprising small towns and country parishes had an average death-rate for a similar period of only 19·4 per 1000.

It is essential that sewage should be promptly got rid of from the district producing it, and this can only be accomplished by taking care that the sewers are properly constructed both as to shape, capacity, and gradient. These desiderata are frequently not complied with in one or other respect, and, as a consequence, sewers are a source of danger to health, inasmuch as they retain, to a greater or lesser extent, the foul matters which they are intended to remove. The noxious gases liberated from decomposing sewage rise in the sewers and escape at every opening into the dwellings with disastrous effect to the health of the inmates. When proper ventilation is provided, the evil consequences may be diminished, as the dilution may lessen them.

Where the relative proportions of main and contributory sewers have not been properly studied, the velocity of flow is subject to unnecessary variation, and is reduced below that which would suffice to bear onward the solid matter, and thus deposits of putrescible substances are formed in the sewers which are dangerous to health.

A system of sewerage is frequently arranged on the erroneous assumption that the sewage will be delivered into it for transmission at a uniform rate during the twenty-four hours. Sometimes the sewers are too small to admit of their running only two-thirds full (as they should), and they have to run full even during ordinary rainfalls. It is found best in practice for sewers to be designed to be capable of delivering one-half the maximum flow in six hours.

The flow of sewage is at its maximum about midday, and at its minimum at midnight.

Most of the cases of flooding arise from the assumption that the rainfall will be distributed over a greater period than it is, so that when the calculated rainfall for twenty-four hours falls in three hours, the sewer is taxed far beyond its capacity, and serious mischief to property and danger to health accrue.

A remarkable instance of this came to our notice during an investigation in which we were engaged in 1878 with reference to the cause of an epidemic of diphtheria in London in the parishes of Hampstead and Marylebone. At one point of the sewerage system of those districts, and in the centre of the affected area, two sewers, about 6 feet in diameter each (draining a large area), were carried by a double junction into a sewer only 4 feet 10 inches in diameter, which latter sewer subsequently expanded to 7 feet in diameter. The effect of this contraction was to permanently interfere with the regular flow of the contributory sewers, and to create deposits of foul matter in them, causing a general pollution of the air in the district. During heavy rains the sewers became choked, and the neighbourhood was flooded (two floods having occurred in the year 1878).

These sewers were rectified by the Metropolitan Board of Works (who had jurisdiction over them), and when the works were being executed many months after the epidemic had subsided several cases of diphtheria again occurred in the immediate neighbourhood, confirming the opinion which we expressed at the time, that the polluted condition of the sewers in this district was a factor in regard to the epidemic.

Far too little attention is paid to absolutely trapping each dwelling from direct communication with the sewer into which it drains, and to thoroughly ventilating both the house-drains and the sewer. The most important points for practical guidance in reference to house sanitation are as follows:—

1. House-drains should be effectually trapped from the main sewer by means of a syphon.

2. House-drains should, where possible, be laid outside and not under a house; but where this is impossible great care should be taken that the pipes are sound, and well laid with perfectly air and water tight joints. No direct connection with a drain (that is without most careful trapping) should under any circumstances be made inside a house.

3. Sinks should discharge outside the house, on to the surface of a trapped gully on the ground-level having a grating communicating directly with the air.

4. Overflow and waste-pipes from cisterns, tanks, lavatories, baths, &c., should not be carried directly into a drain, soil pipe, or water-closet trap. They should deliver either into a sink cut off from the sewer, or on to the surface of a gully similar to the one already described. The cistern for water-closets should be distinct from that for supplying water for dietetic purposes.

5. Rain-water pipes, where in proximity to windows, should be cut off from direct communication with the drain.

6. Soil pipes should, where practicable, be carried outside houses, and should have no places in which foul matter can accumulate. They should be ventilated by being continued to a point above the roof, but away from windows.

7. The connection between the soil pipes and the drains should be by an oblique junction and curved pipe, to effect a prompt removal of the sewage from the vicinity of the house. An inlet for fresh air should be provided at the bottom of the soil pipe.

8. Water traps should not be solely relied upon as being sufficient without ventilation, as foul gases will pass through the water under sufficient pressure, or by condensation and transmission.

9. Every person intending to take a house should require a certificate as to the fulfilment of the above conditions, and should regard such a certificate as essential to his accepting a lease or agreement for a house, and as important as a certificate of its structural safety.

10. The connection between a house and the sewer should be inspected and certified by a competent person before the ground is closed, otherwise there is no protection against the serious evils consequent on either the ignorance or dishonesty of builders.

Parliament should enact that all houses let to the poorer classes should fulfil certain minimum requirements as to drainage, water supply, ventilation, and other essentials. If a certificate from the local sanitary authority was not forthcoming that these requirements had been complied with, the house should be deemed unfit for human habitation. It should be held as important for a house to be wholesome before it is let or sold as for food to be wholesome, and inasmuch as there exists statutory powers under which food that is unfit for consumption is condemned and destroyed, why should there not be similar legislation to meet the case of house property that is unfit for habitation?

In the United States recent legislation has made it a penal offence for bad plumbing to be done in a house. Considering the loss of health and life which results from the work of the plumber being executed negligently, some such legislation would be useful in this country.

CHAPTER II.

MEMORANDA ON SEWAGE.

A gallon weighs 10 lbs.

1 cubic foot weighs 62·4 lbs. and = 6¼ gallons.

1 cubic inch weighs ·036 lbs. and = ·16 cubic feet.

1 cwt. = 1·8 cubic feet = 11·2 gallons.

1 ton = 35·9 cubic feet = 224 gallons.

One inch in depth of sewage over an acre of land is equivalent to 101 tons (or 22,600 gallons).

The average weight of the solid and fluid excreta of a human being is 2½ lbs. per diem. The urine of 100,000 persons weighs 234,380 lbs., and the fæces of 100,000 persons weigh 15,620 lbs. The fæces or solid portion being to the fluid or urine as 1 to 16.

The average amount per head of the population is 39·1 oz. of moist material, containing 2·2 oz. of solid matter, of which about 291 grains are insoluble in water.

Dr. Letheby ascertained that a gallon of midday London sewage contained 94 grains of solid matter per gallon, 55·7 of which were in solution and 38·2 in suspension. The organic matter was 31·2 grains per gallon, of which 15·1 were dissolved and 16·1 suspended.

Professor Way found, as the result of ninety-eight analyses of Rugby sewage, that a gallon of sewage contained 92·5 grains of solid matter, 29 of which were organic and 63·5 mineral. The nitrogen in the complete analyses amounted to 6·18 grains per gallon, the phosphoric acid to 1·68 grains per gallon, and the potash to 2·81.

Dr. Letheby considered that 1000 persons of a town population contributed 3750 gallons of sewage a day, containing about 167 lbs. of organic matter, 33·3 lbs. of nitrogen, 9·4 lbs. of phosphoric acid, and 6·9 lbs. potash.

A gallon of sewage yields as the mean of analyses by Letheby, Hoffman, Witt, Way, and Voelcker :—

Organic matter	27·72	grains.
Nitrogen	6·21	„
Phosphoric acid	1·57	„
Potash	2·03	„

Dr. Hoffman and Mr. Witt, in 1857, took hourly samples of London sewage from the Savoy Street sewer (which was chosen as giving a fair specimen of London sewage), and mixed these samples to produce an average. This yielded 30·7 grains of organic matter per gallon, 6·76 grains of nitrogen, 1·85 of phosphoric acid, and 1·03 of potash.

Professor Williamson, in September 1877, analysed the metropolitan sewage, at the northern outfall into the River Thames, with the following result, according to a Report by Captain Calver, F.R.S., on the Discharge of Metropolitan Sewage into the River Thames :—

CONTENTS IN GRAINS PER GALLON.

	One Hour before Low Water.	Two Hours after High Water.
Suspended Matter—		
Organic matter	37·24	104·97
Sand	44·10	23·52
Iron	4·90	1·96
Alumina	4·90	8·40
Carbonate of lime	12·07	11·20
Oxygen and iron combined with other matters undetermined	4·80	1·45
Total suspended solids	108·01	151·50

CONTENTS IN GRAINS PER GALLON—*continued.*

	One Hour before Low Water.	Two Hours after High Water.
Dissolved Matter— Total	81·00	103·60
Containing common salt	43·92	51·88
Ammonia in one gallon of sewage containing suspended and dissolved matters—		
Free	4·13	4·09
Albuminoid	2·46	4·55
Total	6·59	8·64

The following are other official analyses of *London Sewage*:—

	Solids suspended in Grains per Gallon.
Letheby.—Average at all hours from ten large city sewers	38·15
Hoffman and Witt.—Average from March to June 1857	42·23
Rivers Pollution Commissioners.—Average from February to June 1869	43·75

Mr. Keates analysed the raw sewage discharged into the Thames at the Southern Metropolitan Outfall, at Crossness, during August, September, October, and November, 1872, and the mean of twelve analyses is as follows:—

IN GRAINS PER GALLON.

Total Solids in Solution.	Mineral Matters.	Organic Matter.	Organic Nitrogen as Ammonia.	Ammonia.	Total Nitrogen as Ammonia.
72	61·3	10·7	·265	1·615	1·947

The average amount of solid matter per gallon of sewage may be taken at 90 grains, of which 28 grains are organic and 62 grains inorganic.

Other analyses of sewage are given in the Tables in the Appendix.

Sewage varies in quality, and the ammonia contained in it ranges from 2½ grains per gallon to upwards of 15 grains per gallon. The chemist's theoretical value is one farthing per ton for each grain of ammonia in one gallon.

An average individual of a town population yields annually 12·6 lbs. of ammonia.

Dr. Letheby considered the constituents of urine when dried to be worth 18*l.* 14*s.* 1*d.* a ton, and of fresh fæces when dried 5*l.* 17*s.* 7*d.* a ton, and the dry matter of both solid and liquid excreta of a mixed population 14*l.* 16*s.* 4*d.* per ton.

A sample of Thames mud (550 cubic centimetres) taken from a mud bank on the north side of Lambeth Bridge, July 10, 1876, was examined by Professor Wanklyn, and consisted of—

Water	69 parts.
Solids, dry	31 ,,
	100

For agricultural purposes, 10 tons of average water-closet sewage may be taken to be equal to 12 tons of sewage from a non-water-closeted town.

To convert parts per 100,000 into grains per gallon, multiply by 7, and remove the decimal point one place to the left.

FLOW IN SEWERS.

x = area of sewer ÷ the wetted perimeter in feet.
f = fall in feet per mile.
V = velocity in feet per minute.
A = area in square feet.
C = cubic feet delivered per minute.

$$V = 55\sqrt{x \times 2f}$$
$$C = V \times A$$

Mr. Hawkesley's formula for calculating the flow through pipes and sewers is as follows:—

$$V = \cdot 77 \sqrt{\frac{H D}{L + 2\frac{1}{4} D}}.$$

Where

V = velocity in yards per second;
H = head in inches;
D = diameter in inches;
L = length of pipe in yards.

Sewage when fresh causes no nuisance, but after about twenty-four hours, according to the weather, decomposition sets in and it becomes putrefactive, producing deleterious gases. If sewage is dealt with either on land or by chemicals before putrefaction sets in, it is deprived of its capacity for mischief or power to create a nuisance, as it is defecated and rendered inodorous as soon as it leaves the sewers.

CHAPTER III.

SEPARATE SYSTEM OF SEWERAGE.

Where the sewage of a town or district cannot be got rid of without its having to be purified on land or by chemicals, it is desirable where possible to exclude from the sewers such part of the rainfall as is free from serious pollution; and this should be conveyed away by natural drains or watercourses. A heavy rainfall cleanses the surfaces of roads, yards, gutters, courts, &c., and the first flow of storm water may be very highly charged with pollution. This, of course, would be greatly reduced by a good system of scavenging, such as should exist in large towns.

Notwithstanding the most complete system of scavenging and cleansing, the filth removed from gutters and bye-streets by rain is very great. Analyses of the water flowing in the London gutters after a heavy rain succeeding a dry period, have proved it to be as foul as ordinary sewage as regards the amount of putrescible organic matter it contained.

Where provision can be made for disposing of the surface water, the expense and difficulties attending a system of sewerage are greatly reduced. The sewers can be arranged to carry a volume which is, comparatively speaking, uniform; consisting as it would of the fluid refuse from the houses, without the addition of any but a small proportion of the rainfall. In flushing the sewers from which the rainfall is so largely excluded, the flushing chambers might receive the first rush of storm water, carrying with it the foul surface washings.

By bringing the volume of sewage to a more uniform flow, the arrangements for purifying it can be more easily carried out, whether by land filtration or by chemical treatment in tanks.

A second sewer is sometimes employed to carry off the rainfall independently of the refuse. Where there are two sewers, special care has to be taken to prevent confusion arising between them, as workmen in connecting a house-drain with the sewerage system might resort to whichever sewer might happen to be the nearest. The second or clean sewer might advantageously be employed to lower the level of the subsoil water. Experience has proved the advantage to health that results from the subsoil being drained to a sufficient depth to preserve in a dry state the basements and surroundings of houses.

CHAPTER IV.

RIVERS POLLUTION.

THE streams and rivers of Great Britain are likely to remain polluted unless the efforts of the legislature to effect their purification are better enforced, or unless the Acts of Parliament bearing on the subject are so amended as to be made capable of being carried into effect by the sanitary authorities upon whom is imposed the duty of administering them.

The great fault in sanitary legislation is that it is either permissive in its character instead of compulsory, or where it is compulsory it is, through inherent defects, unable to be enforced.

The Public Health Act of 1875 states that nothing in the Act shall authorize any local authority to make or use any sewer, drain, or outfall for the purpose of conveying sewage or filthy water into any natural stream or watercourse, or into any canal, pond, or lake until such sewage or filthy water is free from all excrementitious or other foul or noxious matter such as would affect or deteriorate the purity and quality of the water in them.

The Rivers Pollution Prevention Act of 1876, which came into operation in August 1877, prohibits the passage of sewage into streams, and enacts that it shall be an offence to continue the pollution. It states that, "in determining whether or not such an offence has been committed, it should be noted that a marked distinction is drawn between the cases in which the sewage is conveyed into the stream along channels, the construction of which had not been commenced at the time of the passing of the Act, and those in which it is so conveyed along channels then already existing or in process of construction. In the former case, it will be an offence against the Act for any sanitary authority to cause or permit the discharge into any stream of any solid or liquid sewage matter. In the latter an offence will not be deemed to have been committed if it can be shown to the satisfaction of the court having cognizance of the case that the *best practical and available means* are used to render the sewage harmless." The words in italics, in the absence of any authoritative guidance, involve difficulties which have caused the Act to be practically inoperative.

It is desirable to have a reasonable definition of what will be considered admissible under the varying circumstances of towns, so as to enable the Act to be administered without the friction which is experienced. To arrive at an authoritative definition requires an intelligent grasp of the whole subject, and as it would be difficult to frame clauses in an Act which would be operative under all conditions, considerable latitude ought to be given to meet the circumstances that arise in practice.

There is no necessity to insist on the high standard of purity for the effluent water proceeding from either irrigation or precipitation such as was fixed on by the Rivers Pollution Commissioners. This was, so far as regards sewage pollution, that the fluid should not contain more than 0·3 parts by weight of organic nitrogen in solution in 100,000 parts by weight. It would be unnecessary to obtain as high a degree of purity in an effluent discharging into rivers such as the Clyde, the Thames below London Bridge, the Irwell at Manchester, as into a small trout stream. The degree of purity required should depend entirely upon the circumstances of each case.

Whilst referring to the Rivers Pollution Prevention Act, attention may be called to the exemption which was made in it with regard to the metropolitan sewage and the River Thames.

The Metropolitan Board of Works was created in 1855 for the purpose of sewering London and of purifying the Thames. This duty was imposed on the Board at its formation, and it has fulfilled it to the extent of executing an admirable system of sewerage, with outfalls into the Thames at Barking and Crossness. These are supposed to remove the sewage to where it no longer pollutes the river or the metropolis, but it is generally considered that a large portion of the sewage oscillates to and fro, and so returns to pollute the river within the metropolitan area, and that the Board of Works has only partially accomplished the task for which it was specially created. In Clause III. of the Metropolis Local Management Act Amendment of 1858, it expressly states that the power conferred by the original Act of 1855 shall "extend to be applicable as well to works for *deodorizing* sewage." This clearly indicates that at that time it was contemplated to apply some treatment to the sewage at the outfall, before its discharge into the river.

The Conservators of the River Thames are supposed to have statutory powers to prevent the Metropolitan Board from causing or continuing this pollution, but the powers of the Conservators as regards pollution appear from their Act of 1867 to be confined to the preservation of the purity of the river to the western boundary of the metropolis, so that it may be necessary to establish the fact of the sewage passing from the outfalls westward before steps can be taken to diminish the evil.

The Conservators took action with respect to the outfalls under the 20th and 21st sections of the Thames Conservancy Act of 1870, on the ground that they have injuriously affected the navigable channel by the formation of mud banks. These sections of the Act provide that any banks or other obstruction to navigation which resulted from the discharge of London sewage into the river must be rectified at the expense of the Metropolitan Board. This part of the case has been dealt with by arbitration, and the award of the umpire (made in the form of a report to the Board of Trade) has been adverse to the Conservators.

The sanitary aspect of the question however was not gone into, the inquiry being limited to what may be termed the commercial part of the subject, which has reference to ascertaining whether the Board of Works or the Conservators are to bear the cost of dredging certain mud banks. The result of this arbitration must not be considered to have decided the sanitary part of the case. It would have been more satisfactory had the consideration of the matter as it bears on the public health been regarded as of equal importance to the consideration of an interference with the river bed.

To enable the sewage that is now discharged into the Thames at Crossness and Barking to be diverted and utilized on land, an expense would have to be incurred in the acquisition of the enormous acreage required, as well as in pumping the sewage to a sufficient height to control this area. Crops produced on metropolitan sewage farms cannot cover the cost of the additional pumping to command them. The sanitary requirements of the case may probably be fulfilled by applying inexpensive chemicals to act as deodorants and precipitants, whilst avoiding an unnecessarily high standard of purity.

Abundant information is now available to enable a town to adopt a system which is the best suited to its requirements, and of avoiding the unnecessary expense which many towns have incurred by adopting an unsuitable method of sewage disposal. It can be no longer alleged that there exist reasons why any town, however situated, should continue to cause river pollution.

CHAPTER V.

FILTRATION.

In many places efforts have been made to remove the impurities from crude sewage by artificial filters, or strainers, formed of various materials, such as straw, burnt clay, charcoal, coke, ashes, sand, gravel, broken stone, &c.

The glutinous character of sludge invariably clogs the filtering material, which then ceases to be operative, and a nuisance is created by the accumulation and decomposition of the foul matter on the filter. The difficulty in disposing of the offensive solids thus collected, together with the cost of constantly cleansing and renewing the filtering material, has led to this system being regarded as impracticable except on a comparatively small scale and under favourable circumstances.

Some interesting experiments were made by Mr. George Higgin (recorded in the 'Proceedings of the Institution of Civil Engineers,' vol. lvii.), for the purpose of removing the suspended matter from the water of the River Plate, and these apply to a certain extent to the filtration of sewage water. He described the water in its best condition as dirty-looking and yellowish. Left in a stoppered bottle for months together in perfect repose, it never became clear, always remaining yellowish and opalescent. The matter in suspension appeared to be finely comminuted clay, almost in a colloid or gluey form, and incapable of mechanical precipitation in any reasonable time. Only by the addition of alum, or one of the persalts of iron, did it seem possible to effect a precipitation of it. The finest filter paper, even in double or triple folds, was powerless to separate the impurity. The result of many experiments led to his arranging a filter which appeared to act efficiently. It consisted in placing finely pulverized cinders between a layer of coarse sand at the top and fine gravel at the bottom, each layer being a foot thick; and even this could have been reduced. The efficiency of the filter appeared to be entirely governed by the interposition of the layer of cinders, the absence of even the fine dust in the cinders diminishing the effect of the filter. To obtain a perfectly brilliant water it was necessary to pound the cinders very fine, and not to separate the dust. From these observations it appeared that an efficient filter could be made in the following manner:—

1st layer. 6 inches of fine sand at top.

2nd layer. 6 inches of finely pounded cinders, including the dust.

3rd layer. 6 inches of fine sand.

4th layer. 2 inches of coarse sand.

5th layer. 6 inches of fine clear gravel at bottom.

The speed of an efficient filter should not much exceed 675 gallons per square yard per day, the proper head to obtain which discharge would be from 4 inches to 6 inches.

These observations have reference to the filtration of foul water, not to sewage.

In constructing filters for waterworks one square yard of filter of the following construction is usually allowed for each 700 gallons a day:—

1st layer. 2 feet 6 inches of fine sand at top.

2nd layer. 6 inches of coarse sand.

3rd layer. 6 inches of shells.

4th layer. 2 feet 6 inches of gravel at bottom.

Dr. Frankland made some experiments as to the filtration of London sewage through 15 feet of sand and chalk, and he found that a very satisfactory purification was effected when the sewage treated amounted to 5·6 gallons per cubic yard in twenty-four hours, the purifying action being one of oxidation, the organic matter being converted chiefly into carbonic acid, water, and nitric acid.

CHAPTER VI.

IRRIGATION.

The progress that has been made in the study of agricultural chemistry of late years has helped to solve many of the problems involved in the application of sewage to land. The published data, which have reference to the properties of the various soils to decompose sewage (at the same time effecting its purification) and to utilize the ammonia and other fertilizing ingredients for the nourishment of plants, are of especial interest.

Dr. Voelcker, Dr. Frankland, Professor Way, and other eminent chemists, have done good service in this direction, and their investigations on the subject of the combinations and changes which occur by the application of artificial manures to different soils, and of sewage to land, deserve the most careful study by those who have to advise in regard to sewage disposal.

The following practical conclusions of Dr. Voelcker respecting the absorption of various soils by ammonia (the most valuable fertilizing constituent of sewage) and its salts may be advantageously quoted from the 'Journal of the Royal Agricultural Society,' No. XXVIII., p. 544:—

"1. All soils experimented upon had the power of absorbing ammonia from its solution in water.

"2. Ammonia is never completely removed from its solution, however weak it may be. On passing a solution of ammonia, whether weak or strong, through any kind of soil, a certain quantity of ammonia invariably passes through. No soil has the power of fixing completely the ammonia with which it is brought into contact.

"3. The absolute quantity of ammonia which is absorbed by a soil is larger when a stronger solution of ammonia is passed through it; but relatively weaker solutions are more thoroughly exhausted than stronger ones.

"4. A soil which has absorbed as much ammonia as it will from a weak solution, takes up a fresh quantity of ammonia when it is brought into contact with a stronger solution.

"5. In passing solutions of salts of ammonia through soils the ammonia alone is absorbed, and the acids pass through generally in combination with lime, or when lime is deficient in the soil, in combination with magnesia or other mineral bases.

"6. Soils absorb more ammonia from stronger than from weaker solutions of sulphate of ammonia, as of other ammonia-salts.

"7. In no instance is the ammonia absorbed by soils from solutions of free ammonia, or from salts of ammonia, so completely or permanently fixed as to prevent water from washing out appreciable quantities of ammonia.

"8. The proportion of ammonia which is removed in the several washings is small in proportion to that retained by the soil.

"9. The power of soils to absorb ammonia from solutions of free or combined ammonia is thus greater than the power of water to re-dissolve it."

Thoroughly drained land has the property of converting the nitrogenous organic matters in sewage into nitrates. These, however, are not stored up in the soil for utilization when required; but such as are not quickly absorbed by vegetation pass through the ground beyond the reach of the plant roots. In other words, the fertility of land is not increased by applying larger volumes of sewage than the growing crops on it can assimilate. This has been shown in the case of the well-known Craigentinny sewaged meadows near Edinburgh, which were (and remain) composed of poor, sandy land. Analyses of the soil, after many years of continuous irrigation with large volumes of sewage, prove that it now contains only about 1½ per cent. of organic matter, and this is due solely to root fibres. These meadows, therefore, instead of having become converted into rich agricultural land, still remain as they originally were, composed of about 98 per cent. of pure silica.

A report by Mr. McKie, the City Surveyor of Carlisle, describes some interesting experiments of Dr. Hatfield Walker, the City Analyst of that town, on six samples of earth, three being taken from land which had been for years under sewage irrigation, and three from land which had not been irrigated.

The soil was at the surface of a rich alluvial character, from 6 inches to 2 feet in depth, weighing, *in situ*, 68 lbs. per cubic foot. This rested on a bed of sandy, alluvial soil, from 3 feet 6 inches to 10 feet in depth, a cubic foot of which, *in situ*, weighed 80 lbs.; and contained 34½ per cent. of pure sand. The samples experimented upon were taken from one foot to three feet from the surface. The following were the results:—

Irrigated Soil.	Per cent.
Organic matter, humus, &c.	3·4
Ammonia	·016
Organic nitrogen	·006
Nitrates and nitrites ..	trace
Phosphates	·016
Chlorides	none

Non-irrigated Soil.	Per cent.
Organic matter, humus, &c.	3·1
Ammonia	·013
Organic nitrogen	·005
Nitrates and nitrites ..	trace
Phosphates	·015
Chlorides	none

These observations show that there is, practically, no difference between the composition of the irrigated and non-irrigated soils, the former being very slightly richer in the more insoluble substances contained in sewage; but the characteristic ingredients of sewage, namely, chlorides and nitrates, are conspicuously absent. It is therefore clear that the nitrogenous matters are either absorbed by vegetation or pass through the soil.

The practical conclusion to be drawn from these and similar experiments is, that however well land may act as a purifier of sewage for sanitary purposes, it can only be relied on to utilize the manurial constituents of the sewage according to the requirements of the crops for the time being assimilating them, and that any excess of the supply of manure over the demand by the crops is not stored up for subsequent use, but is wasted, and passes off in the subsoil drainage either partially or wholly purified, according to the nature of the land, and of its preparation to filter and oxidize the sewage passed through it. Land is not made more fertile by filtering the sewage of a thousand people through an acre, than it is if the sewage of a hundred only is applied.

The varying nature of the results derived from irrigation is evidenced by the fact that in one case Dr. Frankland found nearly 70 per cent. of the nitrogen originally in the sewage escaping in the effluent water from the Lodge Farm, Barking, when the sewage was not being properly applied to the land. On the other hand, Colonel Hope states that on his farm at Romford, during a whole year only 10·69 per cent. escaped in the effluent, as the most careful supervision was exercised.

Further experiments made at Carlisle by Dr. Walker and Mr. McKie in 1880 and 1881 are of great interest and value in enabling practical conclusions to be deduced as to the proportions of land to population. The experiments were made on soil (known locally as Willow Holm) which consisted of 3 feet of loamy earth overlying sandy soil. The observations were made on the soil without the aid of vegetation.

It should be stated that the sewage of Carlisle is weak, being only one-third of the average strength of the analyses which are given at page 71, taking the albuminoid ammonia as the basis.

A box contained a column of topsoil 3 feet high by 6 inches square, equivalent to ¾ cubic foot, representing the soil from the surface to the depth of 3 feet. Great care was taken to have the soil of the same density as when *in situ.* This was done by taking the weight of a cubic foot of the soil *in situ,* putting ¾ of this weight into the box, and shaking it down to the 3-foot mark.

Experiment 1.

The experiments commenced on the 16th July, 1880. Two ounces of sewage were applied night and morning. This was equal to 4 ounces daily, or 8712 gallons per acre drained 6 feet deep, or nearly 1 gallon per cubic yard. Two ounces of water were also applied, which was equal to 35 inches rainfall per annum.

ANALYSIS OF THE SEWAGE BEFORE FILTRATION.

Free ammonia..	25· milligrammes *	per litre.†
Albuminoid ammonia	7	„	„

ANALYSES OF EFFLUENTS.

1880.	Free Ammonia.	Albuminoid Ammonia.
Sept. 10.	·46 milligrammes per litre	·38 milligrammes per litre.
Nov. 1.	·48 „ „	·38 „ „
Dec. 10.	·44 „ „	·40 „ „
1881.		
Jan. 5.	·52 „ „	·40 „ „

1881, January 31st.—Commenced to apply 8 ounces (or twice the previous amount) daily, equal to 17,424 gallons per acre 6 feet deep, or 2 gallons per cubic yard; the 2 ounces of water being applied as before.

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* A milligramme = ·015 grains. † A litre = ·22 gallons.

ANALYSES OF EFFLUENTS.

	Free Ammonia.	Albuminoid Ammonia.
March 4.	·38 milligrammes per litre	·80 milligrammes per litre.
July 12.	·35 milligrammes per litre	·75 milligrammes per litre.
Aug. 18.	·20 „ „	·58 „ „

Experiment 2.

A second box was set up similar to the first in every respect. In this case, however, the sewage was applied twice weekly, instead of twice daily. The experiment commenced on the 22nd of May, 1881, and represented the application of 17,424 gallons 6 feet deep (or 2 gallons per cubic yard), together with 35 inches rainfall. The soil was saturated with water before putting in the sewage.

ANALYSES OF EFFLUENTS.

1881.	Free Ammonia.	Albuminoid Ammonia.
June 1.	1·68 milligrammes per litre	·64 milligrammes per litre.
„ 13.	3·80 „ „	·60 „ „
July 12.	·70 „ „	·35 „ „
Aug. 8.	·30 „ „	·30 „ „

Experiment 3.

A box exactly similar to the two previous ones was filled with bottom soil taken from 3 feet to 6 feet below surface. The experiments commenced on the 16th July, 1880. Two ounces of sewage were applied night and morning together with 2 ounces of water.

ANALYSES OF EFFLUENTS.

1880.		
Aug. 26.	·48 milligrammes per litre	·28 milligrammes per litre.
Sept. 9.	·40 „ „	·24 „ „
Oct. 29.	·42 „ „	·28 „ „
Nov. 16.	·38 „ „	·26 „ „

Feb. 21st, 1881.—The quantity was increased to 17,424 gallons per acre drained 6 feet deep, together with 35 inches rainfall per annum.

ANALYSES OF EFFLUENTS.

1881.	Free Ammonia.	Albuminoid Ammonia.
June 4.	2·90 milligrammes per litre	1·00 milligrammes per litre.
„ 13.	2·00 „ „	1·8 „ „
July 12.	·75 „ „	1·9 „ „
Aug. 8.	7·0 „ „	2·6 „ „
„ 30.	11·0 „ „	3·2 „ „

Experiment 4.

A square foot of the soil was dug out, and put into the box, care being taken as before that each foot in depth occupied a foot of the box, thus when the box was filled the soil was exactly in the same "compactness" as when *in situ.*

The experiment commenced on the 23rd April, 1881, by applying 71·08 oz. twice daily, equal to 4 gallons per cubic yard, or nearly 40,000 gallons per acre.

During the first fortnight it percolated within one hour with the following effluent:—

ANALYSES OF EFFLUENTS.

	Free Ammonia.	Albuminoid Ammonia.
May 23.	1·12 milligrammes per litre	·40 milligrammes per litre.

On June 4th it percolated in 4⅓ hours.

On June 9th it percolated in 6 hours.

On June 13th it did not pass through in 12 hours.

An equivalent quantity was then applied twice a week with the following results:—

ANALYSES OF EFFLUENTS.

	Free Ammonia.	Albuminoid Ammonia.
June 13.	·86 milligrammes per litre	·36 milligrammes per litre.
„ 23.	1·50 „ „	1·25 „ „
July 1.	(percolating in 5½ hours).	
„ 3.	3·80 milligrammes per litre	1·30 milligrammes per litre.
Aug. 4.	9·00 „ „	3·70 „ „
„ 12.	(after a week's stoppage an equivalent quantity was passed).	
„ 13.	8·40 milligrammes per litre	1·60 milligrammes per litre.

The more important conclusions to be learnt from the foregoing experiments are:—

1st. A confirmation of the well-known fact, that it is necessary to give the soil sufficient time to become thoroughly aerated (the soil operated on required at least one week's rest). If the sewage be applied too often not only does the nitrification often completely stop, but the soil entirely ceases to allow percolation and becomes clogged.

2nd. The results of No. 2 experiment show the advantage of the intervals of rest, the analyses improving as the soil gets established.

3rd. Provided that sufficient time be allowed between the application of the sewage (four to eight days), and that the quantity of sewage be not in excess of the power of the soil to deal with, it does not appear that the soil loses its power (even unaided by vegetation), and does not tend to become saturated.

4th. The amount of sewage that this soil dealt with would appear to be about 3 gallons per cubic yard, or 30,000 gallons per acre. As, however, the effluents are not so pure as is usually desired, and as the sewage is very weak (having only one-third of the albuminoid ammonia contained in the sewage of the towns referred to in the analyses at page 71), it would be safe to regard this soil as being capable of purifying only 2 gallons of average sewage per cubic yard, or 20,000 gallons per acre.

5th. The most striking fact that these experiments exhibit is that the top 3 feet of loamy soil has a much better purifying effect than the bottom or sandy soil.

From the Table in the Appendix it will be seen that the average of nineteen towns gives 195 acres to a million gallons of sewage, or 5128 gallons per acre. It follows therefore from the foregoing conclusion 4 that the soil experimented upon at Carlisle was capable of purifying about four times the average given in the Table where (in the majority of instances) ordinary irrigation was in operation. As the Table shows that the sewage of 137 people to the acre was the average result in these cases, it further follows that with soil similar to that at Carlisle the sewage of from 500 to 600 people could be purified per acre, were the land prepared and drained as described.

Dr. Frankland many years ago made experiments on the filtering power of certain earths, which led to the assumption that the sewage of 3300 people could be purified on an acre of land. These anticipations have not been realized in practice, but the experiments of Dr. Frankland have been useful in indicating the points which have to be kept in view to obtain efficient filtration. He showed the necessity for the filtering area being allowed from six to twelve hours' rest between each application of the sewage, for aeration, and that this alternation will not suffice if the effluent water does not flow freely off from the bottom of the filter. When this takes place, atmospheric air follows the last part of each dose of sewage as it sinks through the filtering material, and so oxidizes the organic matter retained in its pores. The difference that has been found between theoretical and practical results has been attributed to the fact that those who made deductions from Dr. Frankland's experiments made no allowance for the soil being of a less density than in its natural state. His experiments led him to the opinion that one cubic yard of sand or of Hambrook soil could purify continuously 4·4 gallons of London sewage per twenty-four hours, whilst one cubic yard of Beddington soil could cleanse 7·6 gallons, and one cubic yard of Dursley soil could cleanse 9·9 gallons, or nearly 100,000 gallons per day per acre, provided the land were drained 6 feet deep.

The application of sewage to land in the maximum volumes has sometimes been termed "intermittent filtration," and this has generally been considered as involving a sacrifice of agricultural results. This view, however, is disclaimed by Mr. Bailey Denton in a recent pamphlet, in which he defines intermittent filtration as "the concentration of sewage *at regulated intervals* on as few acres of land as will absorb and cleanse it without preventing the production of vegetation." He expresses the opinion that the sewage of 1000 persons can be applied to an acre of such soils as are most suitably constituted, and of 250 persons to those soils which are least suitably constituted. Intermittent filtration need no longer be regarded as a system.

The information that is now available should be the means of preventing in future those prolonged conflicts which occur when land is required by a local authority for sewage disposal. There can be no longer any justification for experts advancing the widely dissimilar views that have been met with as to the areas of land that should be acquired, or the conditions which should obtain in reference to irrigation. Most towns should be able to effect the purification of their sewage on land, and if a large area cannot be obtained for broad irrigation, a skilful manipulation of a much smaller area will enable a large volume of sewage to be purified on it.

Loamy, porous soil is the best for sewage irrigation from a sanitary point of view. Where the land is of a stiff, clayey nature, it requires to be broken up and deep drained. In laying the drains, special care is necessary to ensure their protection from the direct passage of the sewage and surface water into them through cracks and open spaces. These are so difficult to prevent, that clay soil is a very undesirable one to employ. There are several instances where great expense has been incurred in the attempt to convert clay land into a farm suitable for sewage purification. Such land should be regarded as unsuitable for the purpose.

Sewage farming has too frequently been regarded only from its agricultural point of view, whereas it must be treated as a combination of both sanitary and agricultural interests. These two, however, can only be successfully combined where a sufficient area of land is acquired to enable the crops cultivated on it to receive the sewage only when it can be utilized. When this cannot be accomplished, the agricultural part of the matter must be disregarded, and the filtration and purification of the sewage as a sanitary necessity only kept in view. The attempt to combine the two under these circumstances involves a sacrifice of the sanitary requirements.

The reason why sewage farming has been so unduly pressed and advocated is, that in the early days of sewage utilization (before it had been subjected to any accurate scientific scrutiny), those who directed public opinion on the question came to the conclusion that the full chemical value of sewage could be realized by its application to land.

With reference to the sanitary aspect of sewage farming, it has been asserted by some that the health of those living in the immediate neighbourhood is injuriously affected, and it has been stated with equal positiveness that this is an entire fallacy. There are times when the sewage carriers will have films of sewage over their surfaces, which thus evolve gases or germs capable of polluting the air.

The fear of sewage farming being badly conducted is so great that the opponents of irrigation schemes have no difficulty in creating a prejudice when they are near dwellings.

Sewage farming has in many cases cost far more than is necessary, owing to the works for distributing the sewage over the land having been constructed of a needlessly expensive character. Simple and inexpensive arrangements will suffice, and economy in this respect cannot be too strongly insisted on.

If the main channels or carriers are constructed substantially in concrete, the tributary ones can be made by hand or by the plough. Main carriers should have a fall of about 1 in 400, and the distributing carriers should have a fall of about 1 in 300.

Before applying sewage to land, the solid portions should be removed by subsidence in catchment tanks, which ought to be open, and be placed remote from dwellings. They require frequent cleansing, the solids being removed or dug into the earth, otherwise a serious nuisance will be occasioned.

Italian rye-grass is one of the best crops for sewage, as its capacity for absorption is enormous, and it occupies the soil so as to choke down weeds, which are a source of trouble and expense on sewaged land. The cultivation of a particular crop must, however, be adopted with reference to the local markets, so as to prevent the loss of the produce. Many excellent and valuable crops are wasted owing to the consumption in the district being less than the supply.

In the Local Government Board Bluebook, p. xxxiii, it is stated that "no growing crop, save natural grass, should be sewaged during the depth of winter, and for potatoes, turnips, most vegetables, and certainly for all pulse and cereals, the land ought rather to be enriched by frequent irrigation in the preceding season, than treated with sewage when these crops are growing, except in times of great drought, and even then care is requisite."

Osiers are very useful plants to absorb the organic impurities in sewage. The American water-weed, anacharis, is a very gross feeder, and will assimilate enormous quantities of organic impurity. A small area planted with a little of this weed will soon become an excellent purifier of sewage.

There are other plants which are capable of absorbing organic impurities, such as duckweed, sedges, common reed, flowering rush, white and yellow lilies, frogbit, water ranunculus, liverwort, and watercress.

The fertilizing value of sewage, on which so many erroneous expectations have been based, has been proved to be seriously reduced to the sewage farmer by the fact that for sanitary purposes sewage must be disposed of day by day throughout the entire year, and that the volume to be disposed of is generally greatest when it is absolutely useless to the land.

It is desirable to apply sewage to green crops, or root crops proper, and to avoid plants which must flower or fructify before being gathered.

In nineteen towns referred to in the Table in the Appendix the average amount of land employed is an acre to 137 people and the average flow per head of population per diem is 38 gallons of sewage.

The difficulties attending the employment of too small an area of land for sewage purification purposes are experienced by a great number of towns where sewage farms have been established, and where the efforts of the sanitary authorities to acquire further land are met either by exorbitant claims or determined opposition on the part of the owners of it.

A very interesting paper, by Dr. Allen Sturge, was read before the Institution of Surveyors in 1879 on the sewage of Paris. It appears that about 70 per cent. of all the houses in Paris are provided with large cesspools, and even where this system is not adopted, the solid excrement is not allowed to enter the sewers. It follows therefore that the refuse conveyed by the sewers of Paris is wanting in the organic constituents which govern the arrangements in regard to its purification.

The composition of the sewage of Paris was given by Mr. Target, in a paper which was read at the Institution of Civil Engineers, as being 8700 grains of organic matter and 18,920 grains of inorganic matter per cubic yard. The mean of analyses of sewage by Letheby, Hoffman, Witt, Way, and Voelcker, as given on page 7, yielded 27·72 grains of organic matter per gallon, which is equivalent to 4667 grains per cubic yard. The mean of analyses of London sewage (where the houses are all connected) was determined by Hoffman and Witt as yielding 30·7 grains of organic matter per gallon, which is equivalent to 5168 grains per cubic yard. It is clear that the above analyses of Paris sewage, must refer to exceptional samples.

Several analyses of sewage from the Collecteur d'Asnières gave, according to Mr. Target, the following as the composition of one cubic yard:—

	lbs.
Organic matter, including ·07 lb. of nitrogen	1·24
Mineral or inorganic matter, including ·03 lb. of phosphoric acid	2·70
	3·94

This is equivalent to 56·5 grains per gallon of organic matter and 123 grains per gallon of inorganic matter.

The water-carried sewage of Paris, to the extent of 10,000,000 gallons a day (the whole sewage of Paris amounting to 60,000,000 gallons a day), is pumped on to 914 acres of land at Gennevilliers. This land is of a character exceedingly suitable for the filtration of sewage, inasmuch as it consists of 4 to 5 inches of vegetable soil with about 10 feet of mixed sand and gravel subsoil. The foregoing figures show that the proportion of land to sewage is 91 acres per million gallons, whereas it is shown in the Table in the Appendix, that nineteen towns in England give an average of 195 acres per million gallons of sewage.

These towns, however, have to deal with sewage proper, containing all the organic impurities which are really the measure of the purifying work the land has to accomplish, so that the data in regard to the disposal of the sewage of Paris must not be relied on as directly applicable to towns in this country.

However satisfactory the agricultural results may be of disposing of this portion of the sewage of Paris, objections have been apparently experienced to the Gennevilliers sewage farm. Dr. Sturge says in his paper, "Great complaints have been made at Gennevilliers by those who are opposed to the irrigation scheme, that the health of the inhabitants is not so good as before its introduction, in consequence of a rise in the level of the subterranean water, which now invades the cellars of their houses." M. Lefèvre, President of the Société des Géomètres of France, who has had to make valuation surveys of this district for the Civil Courts of Paris, says, "Gennevilliers is a large agricultural village, and at one time had fine prospects of extension. The value of building land had increased to a very large degree, but as soon as the neighbourhood between Gennevilliers and Asnières was seen to be invaded by the muddy and infected waters of Paris this land lost a great part of its value. The soil, however, has acquired a high degree of fertility." And again, "My personal opinion is, that the dispersion of the sewage outside the great town must be considered as a public misfortune for the localities infected by it."

The agricultural value of the land, however, has risen since the cultivators of it have had the means of irrigating it. Land of the 3rd class, which before irrigation sold for about 40*l.* per acre, sold for 90*l.* per acre after irrigation, first class land selling for 77*l.* per acre before irrigation. It is estimated that the advance in value of the land averages not less than 3*l.* to 3*l.* 10*s.* per acre per annum.

Whatever agricultural advantages may accrue from utilizing sewage on land, the situation of the land requires careful consideration, as it must not be too near to habitations, otherwise the advantages are outweighed by the disadvantages.

If the neighbourhood of large towns in this country resembled that of Paris less difficulty would be experienced in the utilization of the sewage on land. The great subdivision of property at Gennevilliers, together with the sandy, hungry nature of the soil, creates a demand for liquid manure such as is rarely found in England. The small holders of land near Paris utilize the sewage on 700 acres out of the 914 under irrigation for "culture maréchaire," or market gardening.

Owing to the prejudice on the part of the cultivators against employing the sewage of Paris, it has been necessary to allow them to have the sewage for nothing, and the town has been glad to dispose of it thus.

The agricultural results accruing from the application of the sewage water of Paris to this kind of soil is exhibited in a Report issued by the Société des Agricultures de France, in 1876, as follows:—

On Irrigated Lands, per Acre.	On Lands not Irrigated, per Acre.
Wheat, from 30 to 55 bushels .. .. } Rye (green), from 122 to 210 cwt. .. }	From 38½ to 65 cwt.
Grass lands—	
Green Lucerne, from 492 to 923 cwt. .. } Rye grass, 1023 cwt. .. .. }	From 84 to 131 cwt.
Mangold wurzel, 892 cwt.	369 cwt.
Potatoes, from 687 to 797 bushels	453 bushels.

A further Report, issued by a Commission which was appointed in 1877, gave the following results :—

Cabbages	28	tons per acre.
Carrots	20	,, ,,
Beetroot	48	,, ,,
Beans	6	,, ,,

The quality of these products, however, has been to some extent questioned, as the potatoes were found at times to be watery and poor in quality.

CHAPTER VII.

CHEMICAL TREATMENT.

Chemical treatment (or precipitation) of sewage, if efficiently conducted, enables the solid and part of the dissolved impurities in sewage to be removed, and an effluent water produced which could be passed into large rivers or where the highest degree of purity is not required. The remainder of the impurities which chemical treatment cannot remove, may be abstracted by passing the effluent from the precipitating tanks through a small area of land serving as a filter.

The purification of sewage by chemicals has been the subject of misapprehension, owing to the extravagant advantages which have been claimed for the system by its advocates. By a skilful combination of the best chemical systems with filtration of the effluent through land, many towns which are unable to get land, can deal with their sewage at a moderate cost, and can produce an effluent water quite capable of complying with a high standard of purity.

At Bradford, where the lime process is admirably worked, the effluent contains 4 parts per million of albuminoid ammonia, at Birmingham 6·6 parts per million of albuminoid ammonia, and at Burnley 3 parts per million; in all three lime is used. The two latter cases are shown in the Table in the Appendix. At Aylesbury, the effluent from the native guano process (which is based on sulphate of alumina as a precipitant) contained the smaller proportions of 1·57 and 2·60 on two occasions, and the effluent from the third settling tank is shown by the Table in the Appendix to give as low as 0·7 of albuminoid ammonia per million parts, the crude sewage from which this good result was obtained containing 6·60 of albuminoid ammonia per million.

Most of the published information about precipitation has been written from one stand-point, to advocate some special system, rather than to afford data to enable a comparison to be made between systems.

The data as regards precipitation which are given in the Local Government Board Bluebook of 1876, might advantageously be studied in conjunction with those recently obtained for the Department by Dr. Angus Smith.

In order to enable reliable deductions to be made regarding the cost and efficiency of precipitating systems, it is necessary that certain main principles should be laid down at the outset to serve as a basis on which comparisons can be founded. For instance, the quality of sewage and the number of the population connected with the sewers, as well as the flow per head, should be kept in view. The cost of the chemicals should be considered, both with reference to the quality of sewage operated upon, and also with reference to the standard of purity of the effluent produced. The bulk and value of the resultant sludge also must not be overlooked.

In making analyses of effluent waters from precipitation processes, a note should be made as to the qualities of the sewage from which they are derived. For instance, the time of day at which the sample examined is taken should be recorded, the amount of dilution of the sewage by subsoil water noted, the presence or absence of manufacturing refuse, and the extent to which water-closets are employed should be observed, all these being factors. All practical purposes will be served if what are termed sanitary analyses only are made. These show the amounts of chlorine and of free and albuminoid ammonia, the latter being a sufficient guide as to the sanitary condition of the water.

The amount of chlorine contained in an effluent water may be generally taken as a guide to the strength of the sewage operated upon.

The varying methods adopted by chemists of describing analyses is very inconvenient, and it is desirable for them to adopt a uniform system by which analyses can be compared with each other. In many analyses it is necessary to convert parts per 100,000 into grains per gallon, which is done by multiplying by seven and removing the decimal point one figure to the left.

Dr. Voelcker, F.R.S., in the 'Journal of the Royal Agricultural Society of England,' No. XXVIII., states, "What is to be done with the sewage in localities where clay soils abound or the land is so situated as to render irrigation impracticable? In such a case the best plan would appear to be to purify raw sewage by means of chemical precipitating agents sufficiently to admit of the clarified and partially purified effluent being poured into a watercourse without creating a nuisance. Numerous experiments with all kinds of precipitating agents, and the experience of others on a large scale, have led me to the conclusion that by far the most efficacious and on the whole the most economical precipitating agent is crude sulphate of alumina, assisted by the addition of just enough lime to render the effluent slightly alkaline, and to effect the complete precipitation of the alumina from the crude sulphate."

During the last year or two considerable advances have been made in increasing the efficiency and simplifying the working of chemical treatment of sewage, and these results have done much to remove the previous difficulties which attended precipitation.

Sulphate of alumina, sulphate of iron, and perchloride of iron have long been known as disinfectants and purifiers of sewage. The disinfecting properties of a salt of iron were brought prominently forward in 1859 in Dr. Frankland's Report to the Metropolitan Board of Works in reference to the various schemes then under consideration for deodorizing the sewage at the outfalls. He stated that after examining all the processes only one appeared to satisfy the necessary conditions, and that system was "Dale's Muriate of Iron," which was essentially a concentrated solution of perchloride of iron. Dr. Frankland compared the action of lime and chloride of lime and perchloride of iron, and showed that, both for immediate action and permanency of effect, the iron exhibited markedly superior results. He ascertained by experiments in a tank holding 7500 gallons, that this quantity was immediately deodorized by either of the following agents:—

	Proportion.	Cost per 1,000,000 Gallons.
		£ s. d.
Perchloride of iron	⅛ gallon	1 13 3
Chloride of lime	3 lbs.	2 2 10½
Lime	1 bushel	3 6 6

Careful trials were made as to the permanency of the effect, and with this result, that whereas the sewage to which lime alone was added soon became offensive, that to which the iron had been applied remained free from smell even after the lapse of nine days.

Mr. Dover in 1851, Mr. Herepath in 1853, and Professor Way more recently, have employed salts of iron to purify sewage.

Dr. William Wallace, of Glasgow, has given great attention to the comparative merits of lime and sulphate of alumina. The following is the opinion he has formed, as stated in a valuable paper read by him on the "Chemistry of Sewage Precipitation." He considers that although alumina produces a somewhat more satisfactory effluent, the increased cost of it is not a sufficient compensation. He states, "If, however, a very cheap variety of sulphate of alumina with some sulphate of iron can be obtained, or if the liquor obtained by lixiviating calcined alum shale is available, if in fact the cost of alumina or a mixture of alumina and oxide of iron could be approximated to that of lime, I would have no hesitation in recommending its use in preference to lime."

In all these combinations the practical objects to be accomplished should be: 1. To obtain with cheap chemicals a fairly good effluent, relying on filtration through a small area of land to complete the work of purification; 2. To effect this with the production of the minimum amount of sludge.

Some of the sulphates of alumina of commerce, containing about 14 per cent. of alumina, can be used without involving patent rights. The efficiency of the sulphate of alumina is increased when it contains a salt of iron.

The proportions in which the sulphates of alumina, salts of iron, or other chemicals should be employed, cannot be safely or readily stated, inasmuch as they vary with the circumstances of each case.

Those towns which are situated near the coal-fields can utilize the shale derived from the coal workings, and by applying acid to it, a cheap sulphate of alumina can be made.

A combination of chemicals has been tried at Taunton with apparently satisfactory results. The mixture for the treatment of 500,000 gallons of sewage a day is as follows:—

10 cwt. of lime, costing 5*s.*
1¼ cwt. of coarse mineral salt brought from Droitwich, costing 1*s.* 1½*d.*
3 quarts of carbolic acid, costing 9*d.*

This makes a total daily cost of 6*s.* 10½*d.* for treating 500,000 gallons, or 13*s.* 9*d.* per million.

The results derived from the application of chemicals to sewage, depend a great deal on the construction of the tanks in which precipitation takes place. Where they are shallow and the velocity of the sewage through them is great, the suspended particles, although heavier than the fluid in which they float, are unable to sink by gravitation, but remain suspended long enough to be carried through the tanks by eddies and upward currents. Many precipitation works now in operation have this defect.

An error that is frequently fallen into, is that of applying the cost of treatment of small volumes of sewage to large ones. Dr. Frankland and Dr. Hoffman, in their Report to the Metropolitan Board of Works on the deodorization of the sewage of London by chemicals, state: "We beg to express our opinion, based upon the experience acquired during this investigation, that the disinfection of vast volumes of sewage can be more easily accomplished than is generally believed, and than we ourselves anticipated at the commencement of our inquiry."

CHAPTER VIII.

LIME PROCESS.

Lime being a cheaper precipitant than sulphate of alumina and other chemicals, it may seem that its use necessarily produces economic results. This is, however, not always the case, as any saving in the purchase of the cheaper precipitant may be more than counterbalanced in dealing with the large volume of sludge which it produces, and which is composed principally of carbonate of lime and non-nitrogenous organic matter.

An objection to the use of lime arises where the effluent passes into a river containing fish, as free lime is most injurious to fish. Where it is used under these circumstances great care must be taken that free lime does not escape.

The effect of the addition of lime to sewage was carefully observed many years ago by the leading chemists, and it was found by Dr. Letheby that the dissolved impurities were reduced from 70 to 67 grains per gallon, and the suspended matter from 19 to 1·7. Further experiments on London sewage showed that with 12 grains of lime per gallon, and with an average of many samples of sewage containing 15·0 grains per gallon of dissolved organic impurity, 4·20 only were removed, and of 94·0 grains per gallon of suspended and dissolved organic and mineral impurities 54 grains only were removed.

Dr. Frankland investigated the effects of treating the sewage of Leicester with lime, and gives the following as the results:—

ANALYSES EXPRESSED IN PARTS PER 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total combined Nitrogen.	Suspended Matter.		
Leicester sewage	107·3	2·017	·809	2·083	2·524	10·50	11·62	22·12
Leicester sewage after treatment with lime ..	85·9	1·514	·452	2·552	2·553	12·10	4·70	16·80

The analyses in Dr. Angus Smith's Report relating to Birmingham give the following results expressed in parts per 100,000:—

Description.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Crude sewage	2·70	1·05	24·16
Effluent from settling tanks ..	3·22	0·66	15·78
Effluent after irrigation	1·275	0·21	11·46

Dr. Letheby, in a Report to the Referees appointed by the Metropolitan Board of Works, gave the following practical directions to be observed where the lime process is employed:—

1. The lime should be used in a perfectly caustic state, and in the proportion of not less than 12 grains per gallon of sewage.

2. It should be well slaked with water and got into a finely divided or creamy state.

3. It should be thoroughly mixed with the sewage, and well agitated before it is set aside to deposit.

4. The precipitate should be allowed to settle with the liquid quiet for at least one hour.

5. The deposit should be consolidated and deprived of its water as speedily as possible.

In practice it is found that to enable perfect rest to be given to the combined precipitants and sewage, very large tank accommodation is involved, and to obtain a clear effluent the process has to be worked on the intermittent, and not the continuous system. In hot weather the lime process has to be used still more carefully, as putrefaction sets in rapidly, and makes both the effluent water and the sludge become offensive.

Lime of a particular quality is desirable, as will be seen by reference to the analyses on page 47.

Lime Process—Bradford.

This place may be taken as a good example of the lime process now in operation, and data respecting it are derived from Mr. Alsing, the Manager.

The population is about 173,000, covering an area of 7221 acres, giving a density of population of 24 to an acre. The number of water-closets is about 2000, and of dry closets 3000. The flow of sewage is 8 to 8½ million gallons per day, or nearly 50 gallons per head. The sewage is of a manufacturing character, containing much dye refuse.

The Corporation having been compelled by injunction in 1868 to cease polluting the Bradford Beck, works were erected by them at a cost of about 60,000*l.* to enable a company to filter the sewage through peat charcoal. This was a commercial failure, and the Corporation adopted precipitation by lime. The works were accordingly altered to suit at a further cost of 3600*l.*, part of the original expenditure being thrown away. It should be recorded that the 60,000*l.* referred to includes the outfall sewers from the town to the works, and the diversion of and covering over the Bradford Beck. The cost of the precipitation works alone may be taken at about 40,000*l.*

Before the application of lime to the sewage, the solids are strained away from the sewage, yielding about 300 tons a year in a dry state, which are sold for garden manure at 2*s.* 6*d.* a load. After the removal of the solids, the sewage is passed through four culverts (to diminish its velocity), and it is then delivered into the precipitating tanks. There are 34 tanks, each 23 feet by 28 feet, having an average depth of 5 feet, the capacity of each being 18,000 gallons.

The combined sewage and lime are allowed to remain at rest from half an hour to forty minutes. The supernatant water from the tanks passes through a series of 34 filter tanks, 12 feet by 23 feet, filled with 2 feet of coke. The sludge runs from the precipitating tanks by its own gravity into a sludge collector, from which it is pumped into open-air drying beds specially constructed for that purpose. From these it is removed in a portable condition, and is utilized by the farmers of the neighbourhood. The cost of the removal of the sludge is defrayed by people who have contracted to take all that is produced.

The following was the actual cost for the year 1876, according to the abstract of the Corporation accounts for that year:—

	£	*s.*	*d.*
Salaries and wages	2636	17	4
Rates and taxes	35	0	2
Materials, &c.	1448	8	11
Repairs	203	9	0
Miscellaneous	479	8	2
Total	£4803	3	7

In the year 1877 further improvements were made by concentrating the machinery, &c., so that the item for salaries and wages became reduced in the year 1878 to 1998*l.* The average cost of dealing with sewage and sludge since then has been 4000*l.* per annum.

Allowing 5 per cent. interest on 40,000*l.* as representing the capital expended on the precipitating works and appliances, an addition of 2000*l.* would have to be made to the above sum of 4000*l.* to arrive at the total cost to the Corporation for the clarification of the sewage of Bradford. This would be 6000*l.* a year as the cost, or rather more than 8*d.* per head per annum of the population.

About 8 tons of lime are used per diem, or 1 ton per 1,000,000 gallons. The lime requires to be thoroughly disintegrated and reduced to an almost impalpable powder, in order to ensure its being completely dissolved and mixed with the sewage, otherwise the quantity of lime that would be used to produce the same result would be much greater.

Numerous experiments have proved that in order to obtain satisfactory results the best lime only must be employed. Analyses of suitable and unsuitable qualities of lime have been made by Dr. Wallace, of Glasgow, and are as follows:—

ANALYSES OF THE INGLETON LIME USED AT THE BRADFORD CORPORATION SEWAGE WORKS, AND OF TWO OTHER DESCRIPTIONS FOUND TO BE UNSUITABLE:—

	Ingleton.	Shipley.	Knottingly.
Lime	94·78	65·94	60·76
Magnesia	·36	·99	·90
Oxide of iron	·14	·28	·70
Phosphoric acid	trace	·48	·06
Sulphuric acid	trace	3·46	1·63
Carbonic acid	3·05	6·40	17·54
Alumina	·75	3·75	1·75
Silica	·95	7·50	8·75
Water	..	10·36	7·63
	100·03	99·16	99·72

NOTE.—The Shipley and Knottingly lime had been kept for some time, and had absorbed some carbonic acid and water.

The following analyses relating to Bradford, are given in the Report by Dr. Wm. Wallace, of Glasgow, on the methods of disposing of sewage, which was prepared for the authorities of that town:—

ANALYSIS OF A SAMPLE OF SEWAGE TAKEN AT A TIME OF DAY WHEN IT WAS FOULEST.

	Grains per Gallon.
Ammonia, free or saline	9·3
(Equivalent to 133 parts per million.)	
Ammonia albuminoid	1·4
(Equivalent to 20 parts per million.)	

ANALYSES OF EFFLUENTS.

	Grains per Gallon.
Ammonia, free or saline	·56
(Equivalent to 8·00 per million.)	
Ammonia, equal to nitrogen, combined in other forms..	·28
(Equivalent to 4 parts per million.)	

Lime Process—Hillé.

A modification of the lime process is that known as Hillé's, in which lime is the chief precipitant, the patent consisting in the addition of magnesium chloride and tar.

It has been employed at several places, and Tottenham (where it is now in operation) is claimed as a good example of its working as exhibiting its economy.

Tottenham has a population of 46,000, and is well water-closeted. The daily flow of sewage (which is chiefly domestic) is between 1½ and 2 million gallons.

The sewage works were erected about twenty-three years ago, at a cost of some 11,000*l.*, for treating sewage with lime alone. The effluent water is not filtered, but flows direct from the precipitating tanks into the River Lea. The sludge is run off into shallow stanks.

The cost of chemicals for the year from 17th of February, 1876, to 17th of February, 1877, was stated in a paper read before the Society of Arts Conference, 1879, to be as follows:—

	£	s.
For 353 cubic yards of lime at 13s. 6d. per cubic yard	238	5
For about 1000 gallons of tar	25	0
For chemical salts	208	0
	471	5
To this must be added the royalty charged for using the patent	100	0
	£571	5

The Sanitary Authority of this district have expressed their satisfaction with the system. Inasmuch, however, as the effluent does not appear to be equal to that from other systems (as shown by the following analyses), it would not be safe to apply the figures which obtain at this place to other towns where the standard is higher.

ANALYSES OF EFFLUENTS FROM TANKS AT TOTTENHAM AS DISCHARGED INTO RIVER LEA.

Date.	Grains per Gallon.	Parts per Million.	
	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
September 3, 1877	..	36·4	2·40
November 7, 1878	4·5	40·0	3·50

Lime Process—Scott.

General Scott, F.R.S., has patented a method of dealing with the sewage sludge derived from the lime process by burning it into cement.

The Corporation of Burnley, in Lancashire, have adopted this system. The population of Burnley is now about 55,000. The number of water-closets is 900. The daily flow of sewage now varies from 1,500,000 gallons in dry weather to 2,000,000 gallons in ordinary wet weather, and it is of a domestic character. An annual subsidy is paid by the Corporation of 6*d.* per head, or not less than 1050*l.*, to Scott's Sewage Company, which undertakes for a term of 12 years to produce the best effluent which can be obtained from the lime process, and to deal with the sludge by the patented cement process. The cost of the precipitation works was 12,000*l.* The total cost to the town of clarifying the sewage and disposing of the sludge, would therefore appear to be about 7·2*d.* per head of the population.

From an interesting Report prepared for the Corporation by Mr. William Bryan, C.E., the following particulars are gathered. The sewage, on reaching the works, is passed through two small tanks (catchpits), where the grosser matters, such as pebbles, sand, &c., sink to the bottom. These tanks are cleaned out alternately about once a week. The sewage is then strained through iron gratings, with bars about ¾ inch apart, which arrest the rags, shavings, cotton-waste, and other articles likely to choke the pumps. The amount of matter thus intercepted is, however, small; not exceeding 1 cwt. per diem. The necessary quantity of milk of lime, proportioned to the strength of the sewage, is then added, and the limed sewage, which becomes thoroughly precipitated, is passed into one of two series of tanks, where the precipitate is deposited in the form of sludge. Each series of tanks is divided into three compartments, the two first being each 50 feet by 40 feet, and the third or final compartment 100 feet by 40 feet. The bulk of the sludge is deposited in the two first tanks, and the third, through which it passes more slowly, arrests only the very light suspended matters. The effluent then flows into the river.

The sewage takes about four hours to pass through the tanks. When a sufficient quantity of sludge has been collected, it is pumped from the tanks into filtering beds, where, after eight or nine days, it parts with the greater part of the moisture, and contains on an average only 65 per cent. of water. The sludge should then be sampled to test the amount of lime it contains, and if necessary a further small quantity is added to bring up the amount to that required for a good cement. This addition is, however, rarely needed, as practice soon enables those in charge to proportion the lime with sufficient nicety in the precipitation of the sewage.

The sludge is dried, and finally burnt in kilns (of which there are three, costing about 120*l.* each) similar to those used for burning Portland cement. The resulting clinker is ground up, and produces what is described as an excellent hydraulic cement, having a composition similar to that of Portland cement.

The cost of drying is 7*s.* per ton. The coke for burning in kilns is 1*s.* 4*d.* per ton. Labour, grinding, and bagging, 15*s.* per ton.

The tensile strength after 14 days is stated to be 400 to 500 lbs. per 1½ inch square, and after two months to become 800 to 900 lbs. The manufacture of Portland cement from sewage requires greater care than when the ordinary raw materials, such as chalk and clay, are employed. Although fluctuations in the flow of the sewage may occasionally render it necessary to add an additional quantity of lime to the precipitated sludge, yet it is stated that at Burnley no such addition has been made to it for some time past, and the demand for the cement produced is greater than the works can supply.

The present total expenditure per week for labour and materials in purifying the sewage of Burnley and converting the resultant sludge into cement, is stated to be 25*l.*, and the total cement produced averages 13¼ tons a week, which sells for 36*s.* per ton.

The Official Report lately issued, gives the following analyses relating to Burnley, expressed in parts per 100,000:—

Description.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Crude sewage	1·45	1·20	5·12
Effluent from sewage works	1·33	0·305	5·06

CHAPTER IX.

COVENTRY PROCESS.

The population of Coventry is 45,000, having 6000 water-closets, and a daily flow of manufacturing sewage, with much dye, of about 2¼ million gallons.

The system employed is precipitation, supplemented by irrigation, with the effluent water on nine acres of land, drained to an average depth of 4 feet. There are four precipitating tanks, each capable of holding 225,000 gallons.

About 5 cwt. of solids, garbage, &c., are extracted daily from the sewage before it passes into the tanks, and are utilized as a manure.

The first chemical process which was used at this place was Dr. Anderson's. It consisted in employing a crude sulphate of alumina, made from sulphuric acid and clay, with milk of lime. This was soon abandoned, and coal shale was substituted for clay to produce the crude sulphate, and was in use until 1878, when a protosulphate of iron was added to a crude sulphate of alumina, procured from alum works. Enough milk of lime is added to make the liquid faintly alkaline.

The Town Council of Coventry lease their sewage works to the Rivers Purification Association, for an annual subsidy of 2200*l.*, and this company undertakes to carry on all the operations.

The Report of Dr. Angus Smith to the Local Government Board of October 1879 contains the following analyses relating to Coventry, expressed in parts per 100,000 :—

Description.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Crude sewage	2·58	1·700	6·85
Effluent from settling tanks (filtered)	2·40	0·245	6·30
Effluent after irrigation (drain out of order)	2·12	0·205	5·73
Effluent after irrigation	0·52	0·061	4·99

Effluents from the filter beds, analysed by Professor Wanklyn in 1876 and 1878, gave the following:—

Date.	Chlorine in Grains per Gallon.	Parts per Million.	
		Free Ammonia.	Albuminoid Ammonia.
1876	4·0	13·30	1·35
1878	4·2	18·00	1·00

The deposited material amounts to about 25 tons per diem, containing 90 per cent. of moisture. This is equivalent to 9000 tons per annum.

If reduced to a portable form, containing 50 per cent. of moisture, the weight would be reduced to about 1800 tons per annum, in which state it is capable of utilization on land. Satisfactory trials have been made with a filter press of Johnson and Co., to reduce the volume of sludge by pressing.

An analysis of the Coventry sludge was made by Dr. Voelcker, F.R.S., for the Local Government Board, and is given in the Bluebook. The theoretical value, with 47·36 per cent. of moisture, is stated to be 16*s.* 9½*d.* a ton in comparison with Peruvian guano, and 5*s.* 6*d.* to 8*s.* 4*d.* a ton is stated to be the market value in comparison with farmyard manure. Dr. Wallace, of Glasgow, has assigned a value of 27*s*. a ton to this air-dried sludge, with 10 per cent. of moisture.

The Corporation have expressed their satisfaction with the system.

CHAPTER X.

THE A B C (OR NATIVE GUANO) PROCESS.

THE precipitants employed are alum, blood, clay, and charcoal.

This process is in operation at Aylesbury, a town of 8000 inhabitants. A subsidy of 300*l.* a year is paid to the Company. The ordinary flow is about 300,000 gallons a day of domestic sewage, which is increased in wet weather.

The following are the ingredients employed:—

	Parts by Weight.
A. Crude alum cake, containing 47 per cent. of sulphate of alumina	2
B. Blood..	$\frac{1}{24}$
C. Clay containing 35 per cent. of moisture	4
Charcoal, containing 40 per cent of moisture ..	3

The crude alum cake containing 47 per cent. of sulphate of alumina, costs at the works 3*l.* 4*s.* 10*d.* per ton (14*s.* 10*d.* per ton being for carriage).

The blood costs 1*s.* per week, and is obtained from local slaughter-houses. It is mixed while fresh with dried clay, dug from a field in the immediate vicinity of the works for about 2*s.* per ton.

The carbon or charcoal is a waste product from prussiate of potash manufactories at Manchester, and is obtained for 2*s.* per ton there; but its carriage to Aylesbury raises its cost to 16*s.* 10*d.* per ton.

The blood, clay, and charcoal, after being ground together in a pug mill, with sufficient water to enable them to flow, form the first ingredients, which are mixed with the sewage. The alum is next added in a dissolved state.

The sewage thus treated flows along a salmon ladder mixer into brick tanks (of which there are three), 50 feet long, 30 feet wide, 7 feet 3 inches deep at the inlet end, and 5 feet 3 inches at the other. There is a lip 2 feet below the coping, so that the average depth of each tank is 4 feet 3 inches, containing 40,000 gallons. These tanks are worked, as a rule, in pairs, the effluent from one passing to a second for further precipitation before it is discharged into the River Thame, at that point a small stream a few feet in width. The effluent water is clear and practically inodorous. Four samples of effluent taken at the dates stated gave the following analyses:—

Samples.	Parts per Million.	
	Free Ammonia.	Albuminoid Ammonia.
Effluent water after passing through one tank, 2.30 P.M., 2nd October, 1877 ..	45·4	1·50
Ditto, ditto, after passing through two tanks, ditto	37·2	0·90
Effluent water after passing through one tank, 4 P.M., 5th October, 1877	80·0	2·60
Ditto, ditto, after passing through two tanks, ditto	45·6	2·10

In Dr. Angus Smith's Official Report, the following analyses are given, expressed in parts per 100,000:—

Description.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Crude sewage	4·00	0·66	7·97
Effluent from 3rd settling tank ..	1·02	0·07	5·44

The degree of purity of the effluent will be observed to depend on the number of tanks it flows through.

ANALYSES OF EFFLUENTS BY PROFESSOR WANKLYN.

Date of Collection of the Sample.	Grains per Gallon.		Parts per Million.	
	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
4th October, 1880 ..	43·	6·1	22·00	0·76
5th "	41·	3·5	12·10	0·60
6th "	43·	2·7	5·30	0·36
7th "	34·	2·7	4·30	0·32
8th "	34·	2·5	4·10	0·20
9th "	54·	3·5	5·00	0·40

Any one of these effluents may be (according to Prof. Wanklyn), with safety, discharged into a river.

The sludge is partially dried by filter presses, and further by artificial heat or exposure to the air, when it is ground into a powder containing 14 per cent. of moisture, and bagged for sale.

The quantity of sludge obtained in twenty-four hours at these works, when dried, produces 480 tons of native guano per annum, containing 14 per cent. of moisture, or rather over 1¼ ton a day.

The daily quantity of ingredients in use for treating the sewage is as follows:—

	tons.	cwt.	qrs.	lbs.
Alum	0	7	0	0
Blood..	0	0	0	14
Clay	0	14	0	0
Charcoal	0	10	2	0
	1	11	2	14

The weekly cost of treating the sewage at Aylesbury is:—

	Per Week.
Chemicals, 10 tons 5 cwt., costing	£10 16 3
Coal, engines, 7 ton 10 cwt., at 14*s*.	5 5 0
Wages, enginemen	2 19 6
Wages, A B C men	2 16 0
Cleaning tanks	0 3 7
Oil, tallow, and petty expenses	1 10 0
	£23 10 4

Or 2*l*. 7*s*. per ton of native guano.

In addition to this, the cost of drying, grinding, bagging, &c., is about 15*s*. per ton, so that the total cost of a ton of finished native guano is as follows:—

	Per Ton.
Chemicals, labour, &c.	£2 7 0
Drying, grinding, and bagging	0 15 0
Total cost per ton	£3 2 0

It must be borne in mind that these figures would require modification were the clay not obtained at the point where it is required, as at Aylesbury. If the clay had to be carted from a distance, the extra cost would have to be added, and this might be considerable.

The following is Professor Wanklyn's analysis of a sample of A B C Aylesbury manure, taken fresh from the filter press (and five days from tanks):—

Water	59·05
Organic matter	12·23
Ash	28·72
	100·00

0·07 per cent. free ammonia.
0·02 per cent. albuminoid ammonia.

Dr. Wallace, of Glasgow, calculates the value at 33*s.* per ton containing 12·60 per cent. of moisture.

It will be seen that a very large proportion of this sludge or manure consists of the ingredients added to the sewage. The cost of these ingredients will vary with the situation of the town, so that the foregoing figures of cost might vary greatly in different towns.

The addition of clay and charcoal no doubt exercises the influence claimed for them, namely, that the charcoal aids the deodorizing properties of the sulphate of alumina, whilst the clay, in a state of fine subdivision, offers a large surface for the absorption of impurities which are carried down with the precipitate. The addition of the clay increases the bulk of the precipitate, and when the value of the resultant product realizes the value claimed for it, the cost of obtaining the clay and of manipulating the bulky product would be justified. If, however, the value required to be realized to cover the cost of the process be not obtained, there are no sufficient reasons for incurring the expense of these ingredients, because a good effluent can be obtained by sulphate of alumina and lime alone at much less cost.

The value claimed for the sludge dried to 14 per cent. of moisture is 3*l.* 10*s.* per ton, and it has been shown from the figures that it costs 3*l.* 2*s.* to produce a ton. No opinion can be expressed as to the commercial results in consequence of chemists not recognizing that the sludge is worth the price claimed for it. An opinion, however, can be expressed as to the sanitary result of the process at Aylesbury, and it is that an excellent effluent is produced from chemicals alone, unaided by land, and without nuisance. It should also be stated that the Sanitary Authority are satisfied with the system.

CHAPTER XI.

SEWAGE SLUDGE.

The sludge from raw sewage deposited in catchment tanks, such as are often adopted in either irrigation works, or before discharging the sewage at the outfall into the sea or otherwise, contains an amount of organic matter which is valuable for utilization as a manure on land. The composition of such deposit varies with the nature of the sewage. That from a well water-closeted town is richer than that from a manufacturing town where the refuse is not chiefly human excreta. Dr. Frankland, at the Society of Arts in November 1879, stated that experiments with the sewage of London had led him to the conclusion that after the separation of the detritus the maximum percentage of organic matter was 63, whilst the minimum was 21, the average being 39½, and he considers that it would not be safe to calculate on more than 33 per cent. of organic matter in the dried sludge, which would much reduce the value of the manure, for the value of a manure diminished in an accelerated rate as its strength was reduced.

The sludge produced from the precipitation of sewage by chemicals will be more or less valuable according to the chemicals employed. If lime is the only precipitant, the resultant sludge is larger in volume and less in value than is the case where sulphate of alumina or other chemical is used which clarifies the sewage with but a trifling addition of solid material to that derived from the sewage.

There are four methods now practically in use for dealing with sludge. (1) Reducing it by exposure or by presses to a semi-dried condition containing about 50 per cent. of moisture. (2) Drying it to powder by artificial heat to about 15 per cent. of moisture. (3) Fortifying it with materials of a highly fertilizing value. (4) Burning it by Scott's process into a cement.

The liquid sludge can be reduced to the consistency of stiff clay (containing about 50 per cent. of moisture) by exposure to the air in thin layers on land drained to receive it. Another method is to employ filter presses to reduce the sludge to 50 per cent. of moisture, and the drying can be carried still further if it is left exposed to the air under sheds.

Sewage sludge containing 50 per cent. of moisture is stiff enough to be readily handled, carted, and distributed on land. After it is brought to this state, it is capable of being stored in a comparatively small space without nuisance, and ready for application to land at the proper season.

The fortification of sludge by the addition of a more valuable material enhances its fertilizing properties, and should ensure its acceptance by agriculturists.

A plan on this basis has been adopted by Col. Jones, V.C., at Wrexham, by which a manure is produced from the solids removed from sewage in catchment tanks. The sludge is first dried to about 20 per cent. of moisture, and it is then fortified as follows:—

12 parts dried sewage sludge.
7 parts fine raw bone meal.
1 part sulphate of ammonia.

This it is stated shows on analysis 4 per cent. of ammonia and 20 per cent. of bone phosphate, and it is sold for 6*l.* 10*s.* per ton, which is said to give a fair profit.

Various chemical values have been assigned to sludge manures according to the methods employed in their production. The Native Guano Company claim a value of 3*l.* 10*s.* per ton for their manure when dried to 14 per cent. of moisture, but this is not recognized by chemists. The safest view to take is that a sludge produced from the lime process is of little agricultural value, but a sludge from a sulphate of alumina or other process, which contains the least bulk with the maximum of the manurial ingredients of sewage, is worth carting to a distance like farmyard manure.

The Table on page 65 is given in Dr. Wallace's Report on Glasgow Sewage in November 1879, and shows very clearly the relative composition of sewage sludge produced by the various precipitating processes. It also confirms the truth of what has been already stated as to the advantage of employing sulphate of alumina as one of the chemicals, inasmuch as the amount of phosphoric acid contained in sludge from systems where this is employed is fully twice as much as it is in sludge produced from the lime process.

It may be recorded that Dr. Voelcker found from a number of experiments which he had made that sewage sludge after it had been thoroughly drained for 48 hours contained over 80 per cent. of water; after three or four days it contained 75¾ per cent.; after five days 72 per cent.; and after eight days of rest lost little more.

In estimating the bulk of sewage sludge (and the same applies to mud of any kind), errors are frequently made in calculating the volume and weight of it with the various proportions of moisture.

The bulk of sewage sludge when removed from precipitating tanks and after the supernatant water has been drawn off, may be taken to consist approximately of 90 parts water and 10 parts solids. As the sludge becomes dried, its weight diminishes in a ratio which is frequently misunderstood, and which it may be useful to define by the following rule:—

Let

X = weight of sludge to be ascertained.
S = weight of solids in the sludge (which is constant).
P = percentage of moisture in the sludge.

Then

$$X = \frac{S \times 100}{100 - P}.$$

For instance, to ascertain what weight 25 tons of sludge containing 90 per cent. of moisture would be reduced to when it is dried to 15 per cent. of moisture.

Twenty-five tons of sludge with 90 per cent. moisture contain 2·5 tons of solids (which is constant), therefore, applying the formula:—

$$X = \frac{2 \cdot 5 \times 100}{100 - 15} = 2 \cdot 94 \text{ tons.}$$

The following Table shows the diminishing weights of 100 tons of sludge with proportions of moisture varying from 90 to 15 per cent:—

		Tons.		Per cent.
100 tons with 90 per cent. of moisture.. ..	=	50	with	80
" "	=	33·3	"	70
" "	=	25	"	60
" "	=	20	"	50
" "	=	16·6	"	40
" "	=	14·3	"	30
" "	=	12·5	"	20
" "	=	11·76	"	15

ANALYSES OF SEWAGE SLUDGE (AIR-DRIED).

Name of Town.	Aylesbury.	Birmingham.		Bolton.	Bradford.		Coventry.		Leeds.		Leicester.	Windsor.
Process of Precipitation.	A B C.	Lime. 1	2	Lime and Charcoal.	Lime.		Sulphate of Alumina.		Modified. A B C.	Hanson's Process.	Lime.	Hillé's Process.
Date.	1879	1879.	1879.	1879.	1876.	1879.	1877.	1879.	1876.	1876.	1879.	1877.
Water	12·60	12·70	13·16	14·34	8·90	6·92	14·04	10·04	9·56	16·40	11·93	11·76
Organic matter, carbon, &c.	35·60	19·19	20·04	26·18	33·75	34·53	20·58	23·09	20·82	27·92	22·18	12·06
Phosphoric acid	2·11	·40	·72	·62	·80	·73	1·56	2·07	·64	·75	1·21	·87
Sulphuric acid	2·70	1·45	·35	·61	·64	1·74	1·32	·56	2·15	1·02	·51	·49
Carbonic acid	..	7·62	8·53	8·30	10·53	13·77	6·64	5·71	8·42	13·11	15·25	22·71
Lime	2·18	11·19	12·74	14·50	16·90	20·27	9·16	6·65	9·68	17·51	20·16	31·09
Magnesia	·18	·90	1·37	1·06	1·66	5·07	·86	·61	5·64	7·67	1·48	1·58
Oxide of iron	6·20	2·70	3·20	1·98	2·11	2·01	4·14	2·66	4·61	2·32	2·66	1·68
Alumina	6·75	2·68	2·58	2·97	3·49	3·89	4·13	5·80	7·04	6·30	1·63	2·31
Sand, &c.	33·50	41·13	37·93	29·50	21·80	10·23	37·83	42·00	31·60	7·36	22·30	14·16
	101·22	99·96	100·62	100·06	100·58	99·16	100·26	99·19	100·16	100·36	99·31	98·71
Phosphate of lime	4·61	·87	1·57	1·35	1·74	1·59	3·40	4·52	1·39	1·64	2·64	1·90
Nitrogen	1·60	·52	·49	·61	·62	·66	·92	1·27	·66	·70	1·08	·52
Equal to ammonia ..	1·94	·63	·60	·74	·76	·80	1·11	1·55	·80	·84	1·31	·63
	s.	s. d.	s. d.	s. d.	s. d.	s. d.	s.	s. d.	s. d.	s. d.	s. d.	s. d.
Calculated value per ton	33	10 9	11 5	13 4	15 1	15 4	20	27 2	14 2	17 2	21 7	11 5

CHAPTER XII.

DISCHARGE OF SEWAGE INTO THE SEA.

A very general impression prevails that if a town is situated close to the sea it is necessarily in a more advantageous position than inland towns respecting the disposal of sewage, as it has only to avail itself of its proximity to the sea to discharge into it. That this is not a safe assumption the experience of many watering-places proves, and it is therefore desirable to offer a caution to those who are contemplating adopting a similar course.

In the Local Government Board Bluebook of 1876, one of the conclusions arrived at is as follows:—"That towns situate on the sea-coast or on tidal estuaries may be allowed to turn sewage into the sea or estuary below the line of low water, provided no nuisance is caused; and that such mode of getting rid of sewage may be allowed and justified on the score of economy." Also there follows the qualifying expression, "provided no nuisance is caused." It would have been better to have further indicated the conditions which require to be complied with to prevent a nuisance, as it will be found that in a great number, if not the majority, of cases the conditions do not exist. It might have been stated that to avoid a nuisance the sewage must be discharged into the sea at a point not only below low water, but where there is a well-ascertained current which would carry it permanently seaward. A point of discharge complying with these conditions cannot always be found to exist close to the town, or requires to be ascertained by careful tidal and other observations. At the outfall there should be a continuous movement seaward during the twenty-four hours, instead of an oscillating action to and fro, resulting in a return of the sewage and its deposition along the shore, not only at the outfall and in its immediate neighbourhood, but also at distant places to which the tide carries.

The foreshore of many watering-places is being polluted in this way, and in time it will prejudicially affect them, as the knowledge that the foreshore is polluted becomes generally known. The expenditure necessary to ensure an efficient system of sewage disposal, although it may appear heavy at first, is in the end the truest economy.

The difficulties attending the discharge of sewage into the sea would be diminished were it not that it has a higher temperature and a lower specific gravity than sea or river water, which causes it to rise to the surface. If it is not carried seaward quickly, part of the suspended solid impurities are deposited on the coast wherever there is still water and no tidal current, whilst the rest of the suspended together with the dissolved impurities float on the surface and are carried backwards and forwards by every tide, decomposing and liberating offensive gases.

This action was pointed out by Professor Stanley Jevons, in a letter to the 'Times' of December 2nd, 1878, with reference to the formation of sewage mud banks in the Thames, by the discharge of sewage at the outfalls of Crossness and Barking. He pointed out that matters which would remain suspended for many days in fresh water would be readily precipitated in a few hours when the water is saline, and states that "much of the sewage matter, indeed, would if left to itself float in the water, but in the presence of saline matter, which kills the pedetic or oscillating motion of suspended particles, cohesive attraction comes into play. The minute particles of suspended clay will then adhere to the organic sewage particles and carry them to the bottom of the river, where they will form foul pestiferous banks of ooze.

In the same way unhealthy results are produced at seaside watering-places, where the sewage is poured into the sea in front of the town. Unless there be strong tidal currents the foul particles are not carried away, but are precipitated and mingled with the sand and mud of the beach.

In the 'Proceedings of the Boston Society of Natural History' for February 1874, Dr. Hunt states, "I have called attention to the fact that the clay resulting from the decay of rocks remains for many days suspended in pure water, though not in waters even slightly saline, and is therefore readily precipitated in a few hours, when the turbid fresh waters mingle with those of the sea, thus forming fine argillaceous sediments. The geological significance of this fact was, it is believed, first pointed out in 1861, by Mr. Sidell, in Humphrey's and Abbot's 'Report on the Physics and Hydraulics of the Mississippi River' (Appendix A., p. xi.), where he applied it to explain the accumulations of mud at this river's mouth."

Sea-water delays the oxidation of organic matters, so that the foul constituents of sewage, which in river water would be liberated and got rid of in a short time, are preserved in sea-water, which causes them to accumulate and form dangerous deposits ready for the quickening action of the summer sun, when gases injurious to health are evolved.

The objectionable nature of deposits from sewage is evidenced by the observations made by the late Dr. Letheby on the mud banks that are forming in the River Thames. He describes them as being "composed of black and fœtid mud in a state of active putrefactive decomposition, and when examined under the microscope they were found to consist of broken-up sewage matters, the remains of animalcules, the disintegrated tissue of vegetables, and swarms of diatomaceous remains;" and he stated "that the mud and the suspended matters of the river contained from 6·3 to 18·9 per cent. of the solid constituents of sewage. To prevent the possibility of doubt, the connection between the deposits in the river and the sewage discharge from the outfalls has been clearly traced by analyses, and the chemical correspondence between the two unmistakably established."

The same opinion is held by Dr. Frankland and Dr. Tidy as to the similarity in chemical composition between the mud banks in the Thames and the sewage at the outfalls.

In some cases, by means of long outfall sewers, the sewage is carried away from the place producing it to the sea, but they are frequently simply transferring the refuse to others, a set of the tide carrying it so as to cause mischief and nuisance elsewhere.

These outfall sewers require careful ventilation, as the sewer gases are otherwise liable to be forced back into the town drains at high tides, or after storms, and thus into the houses, even if the house drains are trapped from the main sewer, either by pressure, or by absorption and transmission, through the water forming the seal of the traps.

CHAPTER XIII.

COMPARISON BETWEEN IRRIGATION, CHEMICAL TREATMENT, AND THE PRINCIPAL CHEMICAL SYSTEMS.

THE Report, made in October 1879, by Dr. Angus Smith to the Local Government Board, furnishes some interesting comparisons between the results obtained by passing sewage through land at Aldershot during both wet and dry weather, and those obtained by chemical treatment *per se*, and also when supplemented by filtration through a small area of land. It may be observed that the results at Aldershot are probably the best that could be obtained on land, as at that place the quality of the land is especially adapted to filtration, inasmuch as it is very porous.

It would have been desirable to have recorded the effect of chemical treatment under circumstances as similar to each other as were possible. For instance, if observations had been made on samples of effluent taken from a single tank to show the effect of the treatment during a similar period of time. The sample taken at Aylesbury after the sewage has passed through three tanks is compared with those taken at Coventry after the effluent has been filtered through land, the conditions being clearly dissimilar.

Whilst indicating in what respect these observations are defective, with the view of their being remedied in any future ones, they may be regarded as affording useful data at a time when further observations were much needed. It is obvious that a series of experiments of this nature cannot be undertaken except at the public expense, and those who are interested in the sewage question will appreciate the value of these official experiments.

The results of these experiments are given in the following

Tables, which record the analyses of samples of effluent water taken from the sewage farm at Aldershot during dry and wet weather, from Aylesbury (where the A B C Company's process is in use), from Coventry, and also from Birmingham and Burnley (where the lime process is employed).

In order to make these Tables better capable of being understood it is desirable to refer, in the first place, to the quality of the sewage of the various towns referred to. Table No. 1, therefore, is compiled to give this information.

TABLE No. 1.—SHOWING COMPOSITION OF THE CRUDE SEWAGE IN PARTS PER 100,000.

Town.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Aldershot (dry weather)	12·00	5·25	12·08
„ (wet weather)	3·66	1·750	4·38
Aylesbury	4·00	0·66	7·97
Birmingham	2·70	1·05	24·16
Burnley	1·45	1·20	5·12
Coventry	2·58	1·70	6·85

The presence of free ammonia is of no disadvantage on sanitary grounds, although it is useful as a manure when absorbed by the soil. The next Table shows the amount of free ammonia abstracted.

TABLE No. 2.—FREE AMMONIA.

Town.	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot (*b*)..	11·775	97·96	0·245	2·04
Coventry..	2·06	79·8	0·520	20·2
Aldershot (*a*)..	2·913	80·10	0·747	19·9
Aylesbury	2·980	74·5	1·020	25·5
Birmingham (*a*)	1·425	52·9	1·275	47·1
Burnley	0·120	8·3	1·330	91·7
Birmingham (*b*)	added 0·520	added 18·8	3·220	118·8

NOTE.—Aldershot (*a*) specimen collected in wet weather; (*b*) in dry weather; Birmingham (*a*) after lime precipitation and irrigation; (*b*) after lime alone.

The next Table gives the amount of albuminoid ammonia abstracted, which is a measure of the sanitary results obtained.

TABLE No. 3.—ALBUMINOID AMMONIA.

Town.	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot (*b*)	5·195	98·95	0·055	1·05
Coventry	1·639	96·40	0·061	3·60
Aylesbury	0·59	89·40	0·070	10·60
Aldershot (*a*)	1·543	88·2	0·207	11·8
Birmingham (*a*)	0·840	80·0	0·210	20·0
Burnley	0·895	74·6	0·305	25·4
Birmingham (*b*)	0·390	37·1	0·660	62·0

The next Table shows the amount of residual ammonia abstracted, which is also a factor in regard to the sanitary results effected.

TABLE No. 4.—RESIDUAL AMMONIA.

Town.	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot (*b*)	11·36	100·0	0·00	0·00
Coventry	5·081	99·8	0·009	0·2
Aylesbury	4·269	88·0	0·581	12·0
Aldershot (*a*)	3·177	83·0	0·636	17·0
Birmingham (*a*)	3·351	61·4	2·109	38·6
Burnley	1·200	29·65	2·503	70·35
Birmingham (*b*)	1·530	28·0	3·930	72·0

The next Tables give the total organic ammonia and the total ammonia.

TABLE No. 5.—TOTAL ORGANIC AMMONIA (i. e. Albuminoid and Residual).

Town.	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot (*b*)	16·555	99·65	0·055	0·35
Coventry	6·720	98·97	0·070	1·03
Aylesbury	4·859	88·20	0·651	11·80
Aldershot (*a*)	4·720	84·84	0·843	15·16
Birmingham (*a*)	4·191	64·40	2·319	35·60
Burnley	2·095	42·73	2·808	57·27
Birmingham (*b*)	1·920	29·60	4·590	70·40

TABLE No. 6.—TOTAL AMMONIA.

Town.	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot (*b*)	28·31	98·9	0·300	1·1
Coventry	8·78	93·6	0·590	6·4
Aldershot (*a*)	7·633	82·7	1·590	17·3
Aylesbury	7·839	82·4	1·671	17·6
Birmingham (*a*)	5·616	60·9	3·594	39·1
Burnley	2·215	34·9	4·138	65·1
Birmingham (*b*)	1·400	15·2	7·810	84·8

The amount of oxidation effected on the organic matter is evidenced by the following Table :—

TABLE No. 7.—NITRIC ACID.

Town.	Sewage.	Effluent.
Aldershot (*b*)	..	9·23
Aylesbury	None	3·19
Aldershot (*a*)	Traces	2·79
Birmingham (*b*)	None	2·13
Coventry	"	1·22
Burnley	..	1·20
Birmingham (*a*)	None	1·19

The tendency of the effluents to putrefy is shown by the following Table, in which it will be seen that the lime effluents changed most:—

TABLE No. 8.

Town.	Date.	Free Ammonia.	Albuminoid Ammonia.
Burnley, collected 16th June, 1879	June 20, 1879	1·33	0·305
	July 17, ,,	1·92	0·23
	,, 28, ,,	1·92	0·30
	Sept. 4, ,,	2·15	0·13
Birmingham, collected 23rd June, 1879	June 25, ,,	3·222	0·662
	July 17, ,,	4·20	0·336
	,, 18, ,,	4·15	0·336
	,, 28, ,,	3·90	0·324
Aldershot (wet) .. .. Effluent C.	July 7, ,,	0·44	0·144
	,, 28, ,,	0·364	0·130
	Sept. 4, ,,	0·140	0·092
Aldershot (dry)	Sept. 16, ,,	0·245	0·055
	Oct. 11, ,,	0·240	0·058
Aylesbury, collected 2nd July, 1879	July 23, ,,	0·96	0·067
	,, 26, ,,	1·00	0·06
	,, 29, ,,	0·96	0·06
	Sept. 4, ,,	0·045	0·035

The ammonia in the Birmingham effluent rose in twenty-three days from 3·222 to 4·2, then began to fall; Burnley in twenty-seven days from 1·33 to 1·92; Aylesbury did not change in a week; Aldershot (dry) may be said not to have changed in twenty-five days.

APPENDIX.

Analyses of Specimens of Waters from Sewerage Works, made by Dr. Angus Smith, expressed in Parts per 100,000.

Samples from Burnley, collected 16th June, 1879.

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness. Before Boiling.	Hardness. After Boiling.
Stream above sewage works	0·476	0·025	0·024	0·075	0·124	0·50	3·26	1·28	17·0	3·0	20·0	7·50	10·81	7·78
Ditto below ditto	0·987	0·236	0·070	0·219	0·525	0·56	4·12	1·90	18·5	6·5	25·0	9·00	12·64	8·22
Crude sewage	20·33	1·45	1·20	3·703	6·353	..	6·35	5·12	49·0	148·0	197·0	13·00	..	..
Effluent from sewage works	3·737	1·33	0·305	2·503	4·138	1·20	7·38	5·06	40·0	14·0	54·0	13·00	20·92	17·16

SAMPLES from BIRMINGHAM, collected 23rd June, 1879.

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity.	Hardness. Before Boiling.	Hardness. After Boiling.
Crude sewage	20·44	2·70	1·05	5·46	9·21	None	25·23	24·16	102·0	75·0	177·0	13·83	45·0	44·0
Effluent from settling tanks	4·09	3·22	0·66	3·93	7·81	2·13	22·65	15·78	74·0	26·5	100·5	11·32	39·0	38·4
Effluent after irrigation ..	2·303	1·275	0·21	2·109	3·594	1·19	18·19	11·46	88·5	24·0	112·5	37·77	66·8	29·22

SAMPLES from COVENTRY, collected 24th June, 1879.

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity.	Hardness. Before Boiling.	Hardness. After Boiling.
Crude sewage	11·33	2·58	1·700	5·09	9·370	None	11·33	6·85	59·0	31·0	90·0	25·35	32·80	9·85
Effluent from settling tanks (filtered)	1·418	2·40	0·245	0·511	3·156	None	7·21	6·30	55·0	16·0	71·0	22·34	37·15	15·62
Effluent after irrigation (drain out of order) ..	0·587	2·12	0·205	0·895	3·220	1·22	13·21	5·73	58·0	19·0	77·0	12·62	35·45	17·65

SAMPLES from COVENTRY, collected 10th July, 1879.

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness. Before Boiling.	Hardness. After Boiling.
Effluent after irrigation ..	0·618	0·52	0·061	0·009	0·590	1·62	13·39	4·99	58·5	12·0	70·5	21·0	40·70	19·72

SAMPLES from ALDERSHOT, collected 1st July, 1879 (wet weather.)

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness. Before Boiling.	Hardness. After Boiling.
Crude sewage	16·90	3·660	1·750	3·813	9·223	Traces	2·04	4·38	41·0	32·0	73·0	9·40	6·71	3·38
Effluent "A" from sewage farm	..	0·920	0·276	0·803	1·999	2·69	5·14	4·54	24·0	16·0	28·0	2·50	6·57	6·29
Effluent "B" from sewage farm	2·282	0·880	0·200	0·788	1·868	1·59	1·89	3·14	15·0	11·0	26·0	1·90	5·00	4·57
Effluent "C" from sewage farm	2·240	0·440	0·144	6·318	0·902	4·08	2·40	3·20	20·0	14·5	34·5	0·70	7·86	6·86

SAMPLES from ALDERSHOT, collected 13th September, 1879 (dry weather).

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness. Before Boiling.	Hardness. After Boiling.
River Blackwater ..	0·536	0·0108	0·03	0·0542	0·095	1·56	2·40	2·46	32·50	6·00	38·50	20·40	28·55	10·88
Crude sewage (camps)	43·76	12·00	5·25	11·36	28·61	..	4·29	12·08	48·0	93·0	141·0	16·40	11·70	4·43
Effluent from sewage farm	0·970	0·245	0·055	..	0·268	9·23	4·84	15·53	24·5	16·5	41·0	Neutral.	12·28	12·00

SAMPLES from AYLESBURY, collected 2nd July, 1879.

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness. Before Boiling.	Hardness. After Boiling.
Crude sewage	6·76	4·00	0·66	4·85	9·510	None	14·42	7·97	76·0	29·0	105·0	35·50	48·6	20·0
Effluent from 3rd settling tank ..	0·633	1·02	0·07	0·581	1·671	3·19	30·21	5·44	76·0	13·5	89·5	11·20	66·40	37·1

TABLE.

Name of Town.	Population.	Daily flow of Sewage in gallons.	Annual rateable Value.	Area of Land irrigated in Acres.	Number of Inhabitants to each acre irrigated.
			£		
Abingdon	5,662	150,000	16,361	30	189
Banbury	12,127	400,000	49,526	138	87
Bedford	19,552	900,000	74,500	139	140
Blackburn ..	104,012	2,800,000	307,410	500	208
Cheltenham ..	43,972	1,250,000	264,809	{131, 330}	95
Crewe	24,371	900,000	69,978	257	95
Croydon	78,000	3,000,000	430,000	525	149
Doncaster	23,098	700,000	96,316	262	88
Kendal	13,697	1,800,000	49,563	16	856
Leamington ..	26,000	800,000	123,274	469	55
Merthyr Tydvil	48,500	1,200,000	135,000	{380, 20}	121
Northampton ..	51,847	1,000,000	149,625	327	158
Norwich	88,000	6,000,000	260,000	500	176
Rugby	10,000	400,000	35,629	78	128
Tunbridge Wells	24,309	650,000	177,212	285	85
West Derby ..	26,000	780,000	188,456	207	125
Wigan	48,196	2,000,000	139,000	273	176
Wolverhampton	70,000	2,500,000	216,081	330	212
Wrexham	10,978	300,000	42,000	84	131

From the above the following averages are deduced:—

137 people to each acre irrigated.
195 acres to each million gallons of sewage (or 5128 gallons per acre).
38 gallons of sewage per head of population per day.

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