VAN NOSTRAND'S SCIENCE SERIES.

No. 60

THE TREATMENT OF SEWAGE.

BY

Dr. C. MEYMOTT TIDY.

Abridged from the "Journal of the Society of Arts."

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TREATMENT OF SEWAGE.

Liquid Excreta.

Every adult male person voids on an average 60 ozs. (= three pints) of urine daily. The 60 ozs. contains an average of 2.53 ozs. of dry solid matter, consisting of—

Urea	512.4	grains.
Extractives (pigment, mucus, uric acid)	169.5	"
Salts (chiefly chlorides of sodium and potassium)	425.0	"
	1106.9	"
	=2.53 ozs.	

The urine, therefore, of a population of 10,000 adults may be taken as 600,000 fluid ozs., or 3,750 gallons per day.

Urine rapidly decomposes, the urea becoming the volatile body carbonate of ammonia, and the urine thereby losing a valuable manurial constituent. After a time, but at a later stage, certain foul smelling gaseous products of decomposition are evolved. To collect and preserve urine, therefore, presents practical difficulties. The ammonia from stale urine was formerly distilled and converted into a sulphate, at Courbeville, near Paris.

Solid Excreta.

Every adult male person voids about 1,750 grains (or 4 ozs.) of fæces daily, of which 75 per cent. is moisture. The dry fæcal matter passed daily is therefore about 1 oz. per adult head of the population. Of this *dry* fæcal matter, about 88 per cent. is organic matter (of which 6 parts are nitrogen) and 12 per cent. inorganic, of which 4 parts are phosphoric acid. Of this dry fæcal matter 11 per cent. is soluble in water.

Taking a population of 10,000 adults, it follows that the moist fæcal matter passed daily is equal to 2,500 lbs. (= 1 ton, 2 cwt., 8 lbs.) or 1.116 ton, whilst the dry fæcal matter is equal to 625 lbs. (5 cwt., 2 qrs., 9 lbs.).

The facts, therefore, respecting the excreta of a population of 10,000 adults may be thus tabulated :

TABLE I.—FÆCAL MATTER PASSED PER 10,000 OF ADULT POPULATION PER DIEM.

	Pounds.
Moist fæcal matter excreted............	2,500
Dry " " " (calculating 75 per cent. as moisture).............	625
Soluble in water=68.55 lbs...... / Insoluble in water=556.45 lbs....	= 625

TABLE II.—URINE AND FÆCES PASSED PER DAY BY 10,000 ADULTS.

	Total solids.	Water.	Solids dry.	Solids soluble.	Solids insoluble.
	Moist lbs.	Gallons.	lbs.	lbs.	lbs.
Fæces	2500	187.5	625.0	68.55	556.45
Urine.	—	3750.0	1581.21	1581.21	—
		3937.5	2206.21	1649.76	556.45

The following table has been adapted from Letheby. The quantities given are somewhat below the normal. The facts

Constituents.	Weight in ounces avoirdupois of chief constituents of urine and fæces passed by children and adults in 24 hours.					Weight in lbs. of urine and fæces contributed by a mixed population of 10,000 persons (1,644 boys, 3,020 men, 1,662 girls, 3,674 women) in 24 hours.				
	Males.		Females.		Average at all ages.	Males.		Females.		Total at all ages.
	Boys.	Men.	Girls	Wom.		Boys.	Men.	Girls.	Wom.	
URINE.	oz.	oz.	oz.	oz.	oz.	lbs.	lbs.	lbs.	lbs.	lbs.
Fresh urine..................	19.875	48.490	16.881	42.157	31.851	2073.2	9152.5	1753.6	9680.3	22659.6
Dry constituents................	0.969	2.197	0.750	1.588	1.376	99.6	414.7	77.9	364.6	956.8
(a.) *Organic matter*.............	0.677	1.720	0.574	1.216	1.072	69.5	324.6	59.6	279.2	732.9
Containing nitrogen.........	0.166	0.481	0.161	0.326	0.284	17.1	90.8	16.7	74.9	199.5
(b.) *Mineral matter*.............	0.292	0.477	0.176	0.372	0.332	30.0	90.0	18.3	85.3	223.9
Containing phosphoric acid.	0.035	0.069	0.024	0.049	0.044	3.6	13.0	2.5	10.6	29.7
" potash..........	0.040	0.078	0.027	0.055	0.050	4.1	14.7	.8	12.7	34.3
FÆCES.										
Fresh fæces....................	3.421	5.240	1.061	1.414	2.784	351.5	989.9	110.2	324.7	1775.5
Dry constituents	0.879	1.112	0.282	0.376	0.662	90.3	209.9	29.3	86.3	415.8
(a.) *Organic matter*.............	0.762	0.939	0.244	0.325	0.567	78.3	177.2	25.3	74.6	355.4
Containing nitrogen.........	0.049	0.062	0.016	0.022	0.037	5.0	11.7	1.6	5.0	23.2
(b.) *Mineral matter*.............	0.117	0.173	0.038	0.051	0.095	12.0	32.6	3.9	11.7	60.2
Containing phosphoric acid.	0.039	0.062	0.013	0.018	0.033	4.0	11.7	1.3	4.1	21.1
" potash..........	0.014	0.023	0.004	0.006	0.012	1.4	4.3	0.4	1.4	7.5

were collected from a number of sources, the ratio of children to adults being that adopted by Röderer and Eichhorn.

My own experiments would lead me to give one pint as an average quantity of urine passed by children daily up to the age of ten years, the quantity gradually increasing up to three pints in the adult. The solid constituents of the urine which, at the age of ten, are on an average 0.8 oz. daily, increase, according to my observation, up to 2.5 ozs. in the adult. The quantity passed by girls and women is rather less than that passed by boys and men.

The fæces passed by girls and women are considerably less than that passed by boys and men. The calculations in the table state the amount as less than one-third. My own observations, however, scarcely support these numbers. It would, I think, be more accurate to regard the fæcal matters passed by female children and adults as about one-half that passed by male children and adults.

Value of Night Soil (Human Excreta).

Urine, in its natural condition, has a theoretical value of between 15s. and 16s. per ton. The dry solid matters of the urine have a theoretical value of about £18 16s. per ton.

The quantity of ammonia per year voided by the average individual in the urine has been stated as from 10 lbs. to 11.32 lbs., having a value on the lower quantity of 6s. 8d., and on the higher of 7s. 3d.

Fæcal matter, in its moist and natural condition, has a theoretical value of £1 7s. 6d. per ton. The dry solid matters of fæces have a theoretical value of £5 17s. 7d. per ton.

The quantity of ammonia voided per year in the fæces, by an average individual, is estimated at 1.64 lbs., having a value of about 1s. 3d.

The estimates given above are based on the agricultural values of the nitrogen calculated as ammonia, together with the phosphoric acid and potassium salts, these being materials of sparing occurrence in land, but entering largely into the composition of every variety of agricultural produce. Lime, magnesia, and iron, equally essential to plant development, occur largely in most soils. The details are stated in the second table.

Respecting the value of the nitrogen, however, of sewage, Voelcker regards it as at least of 10 per cent. less value than the nitrogen of ammoniacal salts ready formed.

Authorities differ between 6s. 6d. and £1 in estimating the annual value of the excreta of one adult. Thudichum gives it at £1; Hofmann and Witt at 11s. 9¼d.; Voelcker at 9s.; Lawes and Way at 8s. 5¾d.; Anderson, of Glasgow, at 8s.

In the table we have estimated the mixed excreta of the population as worth 15s. 8d. per ton in their natural condition, and the solid matter of such mixed excreta as worth £14 16s. 4d. per ton.

In this table, moreover, no corrections are made in stating the value of the solid constituents, either for the loss of ammonia that would occur during evapora-

COMPOSITION AND ESTIMATED VALUE OF THE SOLIDS OF URINE AND FÆCES, AND OF THE MIXED EXCRETA OF A POPULATION.

Constituents per ton.	Ammonia (= 7d. per lb.)	Phosphoric acid.		Potash* (= 3d. per lb.)	Estimated value per ton.		
		Soluble (= 4d. per lb.)	Insoluble* (= 2d. per lb)				
A. Natural State.	lbs.	lbs.	lbs.	lbs.	£	s.	d.
a. Urine	23.94	2.94	—	3.39	0	15	10
b. Fæces	35.45	—	26.62	9.46	1	7	6
c. Mixed excreta of population	23.13	2.70	1.93	3.83	0	15	8
B. Solid Matters of.							
a. Urine	567.14	69.53	—	80.32	18	14	1
b. Fæces	151.77	—	113.67	40.40	5	17	7
c. Mixed excreta of population	441.31	48.47	34.43	68.21	14	16	4
d. Sewage of mixed population	172.10	22.89	10.19	48.20	6	3	2
Rotten farm-yard dung	16.0	3.92	5.77	10.00	0	14	1
Fresh farm-yard dung	15.0	3.0	3.92	12.50	0	13	6
Peruvian guano	381.8	67.0	201.00	13.50	14	1	4
1,000 tons of average London sewage.	219.37	27.61	24.20	50.65	0	0	$1\frac{3}{4}$

* 2d. per lb. would perhaps be nearly the value of potash, and 1d. the value of phosphate of lime.

tion, or for the soluble phosphoric acid of the fresh excreta becoming insoluble by its combination with lime, after drying. No doubt the loss from these causes is considerable, and tend to show that, when used as a manurial agent, sewage should be applied to the land in its fresh state.

These estimations of value are theoretical only. Cesspool matter in Paris fetches from 1 franc to 1 franc 25 cents per cube meter (about 1 ton), whilst in Holland and Belgium the average is one shilling per head per annum for the excreta. It would scarcely be an exaggeration to place the real value of the excreta at about one-sixth their calculated value.

Certain comparisons, in respect of fertilizing power (and, therefore, of agricultural value), are worth noting:

1 lb. of human excrement=13 lbs. horse dung.

1 lb. of human excrement
=6 lbs. of cow dung (Macaire and Marcet).

Excreta of one adult (solid and liquid)
=Droppings from one sheep (Mechi).

Yearly excreta (solid and liquid) of one adult
=75 lbs. of Peruvian guano (Voelcker). (This will yield 3.2 bushels of grain.)

Yearly excreta (solid and liquid) of one adult
=Yield of sufficient nitrogen (16.41 lbs.) to furnish the nitrogen of 800 lbs. of wheat, rye, or oats; or 900 lbs. of barley, value £5. (Boussingault.)

Middens.

Sewage absorbents.—The cesspool and the midden were the first attempts at collecting excreta, not so much, however, for the purpose of profit as with the idea of preventing nuisance. The cesspool had many and great disadvantages, not the least of which were the noxious inhalations evolved, the necessity for occasional emptying, and the pollution of the drinking water of the wells in the neighborhood. The ash pit midden had, and has, its advantages and its difficulties. Of the difficulties, the education of the people to use them properly was chief, a difficulty, however, that applies almost as much to water closets as to middens. A second difficulty in the use of the middens consisted in securing proper scavengering arrangements by the local authority, a difficulty, it may be again noted, not one iota less great in securing the efficient treatment of sewage. Provided the midden be regularly attended to and properly constructed, *e. g.*, erected away from the house—the pit small—roofed in so as effectually to stop out rain or other water—floored with sloping flags to render the removal of the contents easy—impervious to surface water and not drained, dryness of contents being effected by the use of ashes well distributed over the soil—there are more objectional ways of dealing with refuse than by the midden system. Under conditions of individual and general supervision, the compost, if sufficiently often removed, need not be a nuisance. But if the midden be neglected by the public authority and by the householder, no doubt it may become a prolific source of disease, as Manchester and Liverpool can testify.

The advantages of the pail system are not to be overlooked. Thus the pails are always placed outside the house; whilst a certain regular process of inspection is rendered necessary, ensuring the detection of a nuisance before it becomes a source of danger. In time of epidemics, again, disinfectants may be extensively used in the pails as they are being distributed.

Another great advantage of the midden system is to be found in the diversion of excremental matters from rivers and watercourses. Much sewage at Manchester is thus kept out of the River Medlock. Strange to say, however, the Rivers Pollution Commissioners (Dr. Frankland) state that the sewage from water closet towns is no worse than that from midden towns. The following is an abstract of the results recorded by Dr. Frankland:

AVERAGE RESULTS.

	Matters in Solution.		
	Total Solids.	Chlo-rine.	Total Nit-rogen.
Midden town sewage (37 samples from 15 towns)	57.68	8.08	4.52

	Matters in Suspension.	
	Total.	Organic.
Midden town sewage (37 samples from 15 towns)	27.38	14.91

	Matters in Solution.		
	Total Solids.	Chlo-rine.	Total Nit-rogen.
Water closet town sewage (50 samples from 17 towns).......	50.54	7.46	5.41

	Matters in Suspension.	
	Total.	Organic.
Water closet town sewage (50 samples from 17 towns.......	31.29	14.36

On this, one question suggests itself—how is it that the suspended matter in the sewage of midden towns is almost identical with that from water closet towns, seeing that Dr. Frankland states that an average of 25,561 tons of solid matter per annum is annually kept out of the sewers at the several midden towns mentioned.

The pail system may consist either in the use of a little disinfectant or of some absorbent material.

Adopting Mr. Gilbert R. Redgrave's classification of the pan, pail and midden systems of disposing of sewage, we shall discuss the subject under the following three heads:—I. Pails without absorbents. II. Pails with absorbents. III. Pails used for the joint collection of ashes and excreta.

I. Pails Without Absorbents.

Of these the Rochdale system may be regarded as principal. In support of the non-use of any absorbent, it is urged that to keep out "the profligate associate" is a main object; concentration, not increase of bulk, being the point to be aimed at. The execreta and dry house refuse should be collected at intervals in separate tubs of special construction, the excreta tub being fitted with an air-tight lid, so that transport may be effected without causing a nuisance. The cost per pail per annum is about 5s. 8d. The ashes are carefully screened and sorted.

From the experience of many towns (Rochdale, Salford, etc.) it would appear that two men and one horse (say at a working cost of £3 per week) can remove 600 tubs or pails per week. each pail containing an average of 84 lbs. of excremental matter. This equals 22½ tons per week at a working cost of 2s. 9d. per ton. At Rochdale 10,112 pails were in use in 1882, the weight of excreta collected being 8,518 tons and of refuse ashes 18,396 tons, from 15,289 houses and 237 mills and workshops, with an estimated population of 65,500. In 1881, 552 tons of manure was manufactured. It is calculated that each tub is used by 9.2 persons living in 2.2 houses, the yield being 2.07 cwts. of excreta per head per annum. At Halifax it was calculated that each tub is used by 10.9 persons living in 2.6 houses, the yield being 3.26 cwt. of excreta per head per annum. At Birmingham the returns give from 9.6 to 11.5 lbs. per week per head.

II. Pails With Absorbents.

In many places the use of boxes, pails, or tubs, charged with various absorbent materials (ashes, etc.) has been adopted. Numerous substances have been suggested as absorbents. Of these Liebig recommended coarsely powdered bog turf, and Stanford charred seaweed Stanford claims that seaweed is three times, weight for weight, as effective as dry earth (1 cwt. being sufficient for one month for a closet daily used by six persons). He claims, moreover, that it is easily reburnt, and that the ammonia and fixed salts have been recovered, the charcoal remains as effective as before. Various forms of refuse too have been suggested as absorbents, of which may be noted, refuse wool or shoddy, dry horse dung, spent dye stuffs, etc. At certain towns spent dye wood (such as fustic), in the manner suggested by Goux, viz., ramming into a tub by a central core, so as to give a uniform lining to the tub, has been employed. Thus splashing is prevented. This method necessitates the frequent removal of the excreta (otherwise the absorbent lining would break down and a semi-liquid mass result), and it is also necessary that the receptacle should be tightly secured before removal, to prevent escape of offensive effluvia during transit.

III. Pails Used for the Joint Collection of Ashes and Excreta.

Of this method the system adopted at Nottingham is a case in point. Here the tub takes the place of the midden pit. It is to be noted that the ashes are of less quantity in summer time, when the chance of nuisance is greatest.

With respect to the mechanical appliances suggested for sifting the ashes, so as to apply only the smaller breeze to the excreta, practice proves them somewhat unsuccessful.

The compost is removed every two or three months and conveyed to the manure wharf, where it is emptied into barges and sold at a price that covers two-thirds of the cost of scavenging.

At Birmingham, where galvanized pails are used to the extent of some 40,000 (representing a population of 250,000), the contents are collected weekly. These are emplied into a vat at the place of deposit, and some sulphuric acid added to fix the ammonia. The contents are passed into a drying machine, consisting of a steam jacketed cylinder within which are revolving arms, the necessary heat being obtained by burning the cylinders and garbage collected in the town. The clinkers are utilized for various purposes.

The process adopted at Manchester, devised by Mr. Leigh and carried out by Mr. Whiley, was described in detail by Mr. Alliott, of Nottingham, at the Society of Arts Conference, 1877. The objects are (1) the disinfection of the pail contents by the use of charcoal, produced by charring street sweepings; and (2) the reduction in bulk of the matters so collected. For the purpose of reducing bulk the liquid in the pails is drained off, and concentrated by a low heat to the consistency of treacle (about one-tenth the original bulk.)

I do not propose discussing the pneumatic system of collecting excreta. In certain places on the Continent (Paris, Milan, &c.), the sewage is collected in water-tight cesspools. These are emptied by atmospheric pressure, the contents being forced into movable exhausted iron tanks, through flexible tubes lowered into the cesspool for the purpose. By this means the escape of noxious effluvia is supposed to be prevented.

The cost of removing the excreta at Paris is about £5 per house per annum. The material is converted at Villette into *poudrette*, great nuisance resulting. The arrangements of Liernur (which have been adopted in Amsterdam, and to a certain extent in Prague), are, in many respects, similar. Liernur suggests cesspool tanks being placed in the middle of a street, each tank communicating with from fifteen to twenty houses.

The systems of Berlier, partly in use in Paris since 1881, and of Shone, a method of pumping sewage by small pneumatic pumping engines, the power being generated at a central station, need only be mentioned.

As general rules we consider :

1. That the removal of the pails should be under the control of the local authority.

2. That on an average they should be renewed once a week, a clean, well-washed pail being substituted for the full one.

3. That air-tight covers should be fitted to the pails before removal, and that they should be conveyed in air-tight vans to the depot.

The utilization of the excreta collected in pails is a matter of great difficulty. At best a low class of manure results, unless some form of concentration be adopted.

Voelcker states that having examined every form of night-soil manure, he never found one having a theoretical value greater than £1 per ton, unless the manure had been specially fortified with guano, or superphosphate, or sulphate of ammonia, etc. The better varieties he valued at from 15s. to 17s. 6d. per ton, whilst those less carefully prepared were not worth more than from 7s. 6d. to 12s. 6d.

The Earth Closet.

The disinfecting power of earth has been known from remote antiquity. In China, the formation of a manure by mixing earth with the excreta is of ancient date.

In this country Rosser in 1837 proposed the admixture of urine and fæcal matter with earth, lime, etc. The suggestion took no practical shape until 1858, when the Rev. Henry Moule, the vicar of Fordington, investigated the disinfecting and deodorizing power of earth on privy soil. As the result he invented his earth closet. At his own vicarage, where the cesspool proved to be dangerously near the well, he abolished the cesspool, and placed buckets beneath the pans. Their contents were, in the first instance, mixed with dry sifted earth, earth afterwards being placed in the bucket itself, and the compost left to consolidate in a shed. After five or six weeks he found that the material had entirely lost its offensive odor, and was sufficiently dry to be used again. Thus eventually he not only disinfected his sewage, but produced a manure containing one-third its weight of dry excrement. The next point was the mere mechanical construction of a closet, worked by a handle, with contrivances to secure the application of a proper proportion of dry earth. The earth may, however, be thrown into the closet in one application daily, a method adopted in the latrines at Lancaster, which are under the control of the local authority.

As regards the earth best adapted for the purpose, a well-dried clayey earth, that is, a heavy soil loaded with clay, holds the first place; peaty earth comes next, although for efficiency a long way behind a clayey earth. The peaty earth used at the Wimbledon Camp in 1867 was not satisfactory, as it produced a wet and sour compost. Sand and clay are found to have very little deodorizing power, and are therefore ill suited for the earth closet. The clay soil must be well dried artificially (for in a damp condition its absorbent power is inferior), and after drying, powdered and sifted.

About 4½ lbs. of dry earth per head per day (*i.e.*, 1½ lbs. for each visit, three visits being allowed for each person) is required to obtain a consolidated and unoffensive compost. This quantity was ultimately used at the Dorset County Jail, the 3 lbs. per head of earth, used in the first instance, being found insufficient. A village of 1,000 persons would need, therefore, about 2 tons of dry earth per day. The dry earth system was used at the Dorset County School, at the villages of Halton and Aston Clinton near Windover, in Lancaster, and at the Wimbledon Camp. In this latter case Dr. Buchanan closely investigated the working of the process.

After the removal of the earth it may be dried and returned to the closet until its manurial value justifies its sale.

As regards composition and value of the product, much will depend on the demand, and on the method adopted in working (*i.e.*, how many times the material had been used). At Lancaster the compost fetched 7s. 6d. to 10s. per cubic yard. At Dorset County Jail it reached £1 per ton, and at the Dorset County School £2 to £3 per ton. Perhaps 10s. per head of the population annually might be taken as an approximate value.

The dry earth system has certain definite advantages over the water closet. The first cost is less. It reduces the quantity of water required by each household. The closet is less liable to go wrong, to suffer injury from frost, or to be damaged by improper substances being thrown into it. No doubt an intelligent person can manage it, but if it be used in villages it should be managed by the local authority, easy access to the closets by the scavengers being in such case indispensable. Of course a dry earth system does not supersede the necessity for some independent means of removing slops, rain, and subsoil water.

A still further advantage claimed for the earth closet is the manurial value of the compost, and the ease with which it may be stored until required.

No doubt the earth closet has its objections. Of these a certain filthiness (real or imaginary), and the difficulties of supplying the necessary quantity of dry earth and of removing the compost, are those chiefly urged. No doubt the collection of material that may be more or less foul as the closet has or has not been attended to by the scavengers, and the after distribution of the compost, compare, at first thought, unfavorably with the cleanliness of water, and the ease with which it serves to convey the filth from the closet to the field. But this assumes (1st) no misadventure of the water-carried sewage between closet and field; (2d) a farm and a crop ready at all times and seasons—wet or dry, summer or winter—to receive and to appropriate it; and (3d) no escape of noxious effluvia and miasms, no spread of disease, and no pollution of water courses. How far such assumptions are realized, I shall consider presently.

Earth closets have been largely used, and their use is rapidly extending, in India, where the drying of the earth is a comparatively easy process. The authorities in India, in 1867, reported to the Secretary of State that Moule's system, which was then generally employed in the barracks, jails, hospitals, and public institutions of the three presidencies, had been found to be a great public benefit. I can, myself, bear testimony to the excellent results of the dry earth system where the closets are properly attended to—proper earth used—and the materials properly dried.

Sewage.

We now turn to water-carried sewage—its composition, value and treatment.

By the phrase "the sewage of a town" is implied:

(1.) The excreta (solid and liquid) of the population.

(2.) The refuse from kitchens, laundries, etc.

(3.) The drainings from stables, slaughter-houses, etc.

(4.) The liquid impurities resulting from various trade operations (breweries, dyehouses, fellmongeries, etc.)

(5.) The washings of public thoroughfares, etc.

(6.) Domestic and subsoil water.

To speak broadly, we may define sewage as "the refuse of communities—their habitations, streets and factories."

It is manifest, therefore, that it is not possible to define broadly what constitutes "average sewage." The quantity and quality of the sewage of a town will be influenced by the following amongst other conditions:

(1.) The number and nature of the manufactures and trade operations peculiar to the place, and which are drained into the sewers.

(2.) The existence of an excessive number of stables (such as result from the presence of barracks).

(3.) The volume of water supplied to the inhabitants.

(4.) The proportion of rain or surface water admitted into the sewers.

(5.) The quantity of subsoil water that leaks into the sewers.

(6.) The density and general habits of the people.

(7.) The season of the year.

(8.) The time of day.

Sewage may be subdivided into—

1. Domestic sewage.
2. Manufacturing refuse.
3. Rain and storm water.

We shall find, when we come to discuss the treatment of sewage, the first great difficulty is the large quantity to be dealt with. It has been suggested to meet this difficulty of quantity by adopting a duplicate set of sewers, the one for sewage proper (domestic and manufacturing), and the other for storm and rain water, or at any rate for the larger part of the rain water. For irrigation purposes, no doubt, it is desirable to have the domestic sewage as little diluted as possible, but for chemical treatment dilution within certain limits is not an evil. A separate system must be more expensive, besides which it robs the sewers of one means of natural and effective flushing, such as occurs after heavy rains. It also excludes from the sewage to be treated many materials (*e.g.*, road washings), that certainly need treatment as much as, if not more than, any sewage proper. To limit the water for removal of filth to its smallest quantity is a sound principle, but there is a danger in over-reduction. The most earnest advocates of the separate system scarcely see their way to exclude from the public sewers the rain falling on private property, as this would for the most part necessitate two sets of house drains. It may be admitted that both the separate and combined systems have their merits and defects, and that certain local conditions may determine the choice of the system.

The arguments used in favor of a separate system are:

(1.) Greater uniformity in the quantity of sewage conveyed.

(2.) The prevention of deposits, the dimensions of the pipes being capable of more accurate adjustment, permitting them to be daily filled to their maximum at the hour of maximum flow.

(3.) If the sewage has to be pumped, expense will be saved by the limitation of quantity.

(4.) Prevention of floodings from the capacity of the sewers being overtaxed, or from obstruction taking place in the surface channels during times of heavy rain, or on the occurrence of a rapid thaw after a long period of snow. Danger arising from the gases in the sewers being forced by the rush of water thus filling the sewer, being driven through the nearest outlet, and possibly through house connections, will be avoided.

(5.) Prevention of precipitation, and so of deposit in the sewers, from earthy matter (such as building lime) being carried in at storm time, together with road detritus, leaves, etc., and which, under ordinary conditions, might not be removed until the next heavy rain.

(6.) If obstruction occurs, a comparatively small volume of water will be sufficient to flush the sewers effectively on account of the relative smallness of pipe.

(7.) That with small pipes, good ventilation of the sewers may be more easily effected.

(8.) That the nuisance arising from organic matters being carried into the pipes at the time of storm, and putrefying on the upper portions of the sewer pipe, where, under normal conditions of flow, it forms a slimy coating and develops swarms of organisms, will be prevented, the sewers being filled daily to their maximum working capacity.

(9.) That the quantity of sewage to be dealt with would be greatly decreased.

On the other side it is urged that, however sound it may appear in theory to urge "the rainfall to the river, the sewage to the soil," there are manifest objections to the separate system:

1. That it is practically impossible thus to separate rain water and sewage, things that ought not to be in the rain water pipes being certain to get there.

2. That the road washings and filth, making the first wash of a heavy storm, is most often far more filthy than the very worst sewage, and, therefore specially requires treatment.

3. That storm water is the natural flush water for the sewers.

It may be said that the third objection may be met by automatic flush tanks; the second, by effective scavenging; the first by educating the people. We have not yet attained the ideal of sanitary work. A separate system would, I fear, mean the intermittent pollution of our water-courses. There are legal difficulties, too, in carrying it out, which I will not discuss.

I do not deal with the question of cost, except to say that the mere size of pipe is not the only, nor is it the main question to be considered in laying pipes, the excavation, paving, etc., being practically the same, whether pipes be large or small.

Composition of Sewage.

Sewage, we have said, is a complex fluid; no absolute average analysis can therefore be stated. It will, however, be a good starting point to regard the average sewage of London as a standard, and to speak of sewage of greater polluting power as a strong sewage, and of less polluting power, as a weak sewage.

A large number of samples of London sewage were examined by Dr. Frankland and myself between 1883 and 1884. The following are certain average details worthy of record. The results are stated in grains per gallon of 70,000 grains:

	Maximum.	Minimum.	Average.
Matters in solution...	49.77	28.42	45.213
Matters in suspension.	163.9	21.4	48.65
Ammonia............	6.527	2.515	3.012
Chlorine.............	8.33	5.67	7.21
Organic carbon......	3.847	2.118	3.069
Organic nitrogen.....	2.676	0.964	1.738

Average ratio of N to C — 1 : 1.77.

These results, however, take no note of true storm sewage.

Whilst an assistant of Dr. Letheby, I made, jointly with him, a very large series of analyses of sewage from ten of the large city sewers, the rate of flow being, on an average, 3,500 gallons per minute. The following are average details:

	Day Sewage.	Night Sewage.	Storm Sewage.
SOLUBLE MATTERS.......	55.74	65.09	70.26
(*a*) *Organic*............	15.08	7.42	14.75
Containing nitrogen.	5.44	5.19	7.26
(*b.*) *Mineral*............	40.66	57.67	55.71
Containing phosphoric acid...........	0.85	0.69	1.03
Containing potash...	1.21	1.15	1.61
SUSPENDED MATTERS.	38.15	13.99	31.88
(*a.*) *Organic*............	16.11	7.48	17.55
Containing nitrogen..	0.78	0.29	0.67
(*b.*) *Mineral*......... ...	22.04	6.51	14.33
Containing phosphoric acid............	0.89	0.64	0.98
Containing potash...	0.08	0.04	0.16

It may be of importance to record that at the time the samples were collected for analysis, 37.5 gallons (6 cubic feet) was contributed per head of the population. Of this, 80 per cent. was represented by the water supply. The following table exhibits, therefore, the weight in pounds of the chief constituents of 375,000 gallons of sewage (mid-day sewage being taken for comparison) furnished daily by 10,000 people, and its subdivision into excretal and non-excretal refuse:

Constituents of 375,000 gallons.	From excreta.	From refuse other than excreta.	Total.
	lbs.	lbs.	lbs.
SOLUBLE MATTERS	957	2029	2986
(*a.*) *Organic*............	733	75	808
Containing nitrogen .	200	91(?)	291
(*b.*) *Mineral*............	224	1954	2178
Containing phosphoric acid..........	30	16	46
Containing potash...	34	31	65
SUSPENDED MATTERS.....	316	1628	2044
(*a.*) *Organic*.... ...	356	507	863
Containing nitrogen .	23	19	42
(*b*) *Mineral*	60	1121	1181
Containing phosphoric acid....	21	27	48
Containing potash...	8	—	8

Putting these results in a few words, we may say every 10,000 persons in London contribute, on an average, 375,000 gallons of sewage daily, and that this includes about 1,671 lbs. of organic matter, containing 333 lbs. of nitrogen, and 335 lbs. of mineral matter, containing 94 lbs. of phosphoric acid and 69 lbs. of potash.

Of course the total quantity in any given town will depend on a variety of causes. It is certain to be as much as the water supply, but it may be a great deal more. In London, as we have said, it may be taken that 80 per cent. of the sewage is represented by the water supply.

Hofmann & Witt (1857) examined the sewage from the Savoy street sewer, an average sample being obtained by the admixture of samples taken hourly during the twenty-four hours. The results were as follows, stated in grains per gallon:

(*a.*)	*Organic*	30.70
	Containing nitrogen... ...	6.76
(*b.*)	*Mineral*..................	(?)
	Containing phosphoric acid	1.85
	" potash.........	1.03

A large number of sludge deposits (to which no precipitant was added) have been examined for the purpose of determining the ratio of organic nitrogen to organic carbon. The results are marked by a great want of uniformity, ranging from a ratio of 1 to 3.4, to a ratio of 1 to 9.1.

Major Scott, after a review of a large number of analyses, says: "We may assume that with each [one] part of the three fertilizers, nitrogen, phosphoric acid, and potash, there will be associated in the sewage sludge of London 20 parts, 25 parts, and 56 parts respectively, of organic matter."

Nitrogen to organic matter.........	1 : 20
Phosphoric acid to organic matter..	1 : 25
Potash to organic matter...........	1 : 56

It will be impossible for us to discuss the pollution from sources other than excreta, which, together, make up the complex fluid we designate sewage. With respect, however, to stable drainage, I would note that an average horse excretes thirteen times as much fæcal matter by weight, and about fifteen times as much urine, as an adult man. It may be noted further, that both horses and cows produce by respiration about thirteen or fourteen times as much carbonic acid as an adult man, and as a consequence vitiate the air in the same ratio. (Taking 1,200 cubic inches as the quantity of CO_2 produced per hour by a man, 14,750 inches is produced by a cow or horse.)

There is, however, a not unimportant consideration which occurs in considering the character of a town sewage, viz., the feeding of horses. The difficulty of dealing with the stable refuse where the horses have been fed upon maize, is far greater than where the animals have been fed on ordinary corn. In my own experience as a health officer I have had abundant evidence of the peculiarly offensive character of the manure in such cases.

In all inquiries respecting the sewage of a town, the nature and amount of the liquid refuse from manufacturing works (if admitted into the sewers) needs most careful consideration. Of these I may specially mention brewery refuse, the waste being of a singularly offensive nature. To add to the difficulty, a considerable quantity of yeast is discharged with the waste liquor, whilst the high temperature of the refuse intensifies the trouble of treatment. The refuse from certain dye works, etc., are also difficult to deal with.

As regards street washings, the following details may be worth noting: Granite roads were found at the time of a heavy shower to discharge water into the gulleys containing 800 grains of solid matter per gallon, of which 219 grains were in solution and 520 in suspension. The precise composition of the washings, will, however, depend on many conditions, such as extent of traffic, previous period of drought, etc. The water from wood paving, taken about the same time as the above, was found to contain 50 grains of solid matter per gallon, of which 40 was in solution and 10 in suspension. Some

20 samples of road washings taken from all kinds of roads, under circumstances as nearly as possible similar to the conditions named above, were mixed together. The water contained 280 grains of solid matter per gallon, of which 120 were in solution and 160 in suspension.

It would be outside my province to discuss the engineering details of a sewage scheme. Yet let me note that sanitary medicine must take cognizance of sewage in its progress through a town. There must be sufficient velocity, as well as an economy of scouring power, in order to prevent the solid matters from collecting. The ventilation of the sewers is again a question of importance upon which authorities differ, and no wonder, seeing how formidable are the difficulties.

Discharge of Crude Sewage into Rivers.

Nothing is more certain than that the discharge of crude sewage into a river is unadvisable. It is, in fact, a method of shifting a nuisance from the nuisance-producer to his immediate neighbor. The evils arising from such discharge depend mainly upon the suspended matter in the sewage. This, first of all, floats about near the outfall, certain portions of the organic matter combining with aluminous compounds from alluvial mud raised by tides and steamers. In time, deposition takes place. In the course of flow the various ingredients are found to deposit more or less in the order of their specific gravity. The first deposits are mainly mineral, with small quantities of organic matter carried down at the same time. The later deposits are mostly finely divided organic matter, along with a small quantity of mineral matter. Thus there occurs, as the result of flow, a natural sorting of the matters in suspension.

The organic impurities of the sewage in this manner collect in the bed of the river and ultimately putrefy. The gases developed and bottled up in time render the solids sufficiently buoyant to rise to the surface, where the gases of putrefaction (sulphur and phosphorus compounds for the most part) are given off, the solid matter again sinking to undergo fresh putrefactive changes.

Thus the nuisance from the discharge of sewage into the river may be far more offensive at a short distance from the outfall, than at the outfall itself. Further, at a point of slack water, the nuisance arising from these solids in suspension may be greatly aggravated.

As regards the matters in solution, provided the sewage be sufficiently diluted and allowed a certain flow, complete purification will be effected by oxidation. This fact is now-a-days admitted by nearly all chemists, and need not detain us further. The self-purification of running water is, however, not to be regarded as an argument in support of allowing crude sewage to be discharged into a river.

In 1875, a committee of the Local Government Board was appointed to make special inquiry into the practical efficiency of the chief systems of sewage disposals then in operation, and for which loans had been sanctioned by the

Board. It reported in 1876 (Sewage Disposal, Report of a Committee, 1876):—

"4. That most rivers and streams are polluted by a discharge into them of crude sewage, which practice is highly objectionable."

"5. That, as far as we have been able to ascertain, none of the existing modes of treating town sewage by deposition and by chemicals in tanks appear to effect much change beyond the separation of the solids, and the clarification of the liquid. That the treatment of sewage in this manner, however, effects a considerable improvement, and when carried to its greatest perfection, may in some cases be accepted."

"6. That, so far as our examinations extend, none of the manufactured manures made by manipulating town's refuse, with or without chemicals, pay the contingent costs of such modes of treatment; neither has any mode of dealing separately with excreta, so as to defray the cost of collection and preparation by a sale of the manure, been brought under our notice."

"7. That town sewage can best and most cheaply be disposed of and purified by the process of land irrigation for agricultural purposes, where local conditions are favorable to its application, but that the chemical value of sewage is greatly reduced to the farmer by the fact that it must be disposed of day by day throughout the entire year, and that its volume is generally greatest when it is of the least service to the land."

"8. That land irrigation is not practicable in all cases; and, therefore, other modes of dealing with sewage must be allowed."

This being the sewage with which we have to deal, our object is twofold:—

(1.) To make use of any valuable constituents that it may contain; and

(2.) To purify it.

Sanitary requirements, however, demand that no nuisance should result in the course of the operation of treatment.

The Value of Sewage.

The basis on which the theoretical

calculation of the value of sewage may be determined, is, authorities suggest, simplicity itself.

It may be conceded that the animal excreta are, practically, the only constituents of manurial value.

Having determined the value of the excreta of a mixed population, it is only necessary to know (1) the population of any given town, and (2) the quantity of sewage produced during the twenty-four hours, to estimate the manurial value of the sewage. It may appear strange, however, the question being one, we are told, of such simplicity, that authorities before the Select Committee of the House of Commons (1862) should have stated it so variously as from ½d. to 9d. per ton. Certain details upon which these money estimates were founded may be noticed.

The Rivers Pollution Commissioners, who fix its value at about 2d. per ton, say: "The money value of these constituents (combined nitrogen, phosphoric acid and salts of potash), dissolved in

100 tons of average sewage, is about 15s., whilst that of the suspended matters is about 2s. That is to say that 100 tons of average sewage are worth 17s., or about 2d. per ton."

Hofmann and Witt arrived at a similar conclusion. Six-sevenths, they say, of the valuable matters in sewage are in solution. Reckon that 700 tons of sewage contains one ton of solid matter, having a total money value of £6 0s. 3d. (£5 5s. for dissolved matters, and 15s. 3d. for suspended matters), it follows that the one ton of sewage is worth about 2d.

Lawes and Gilbert arrive at a similar conclusion. Reckoning the dry weather sewage of London as 24 gallons daily per head (= 40 tons per head per annum), and the ammonia as 10 lbs. per head per annum, the money value would be 2d. per ton, whilst if the ammonia be taken at 12½ lbs. per head per annum, it would be 2½d. per ton.

Take it, says another authority (Mr. Bailey Denton), that the fertilizing elements of one person (worth, let us say, 8s. 4d. per year) are diluted with 61 tons of water (an average quantity contributed by each individual to the outflow from towns), the value of sewage is 8s. 4d. divided by 61, or $1\frac{2}{3}$d. per ton.

Such are some of the estimates.

But there were those who desired to be still more precise in their calculations. Authorities who desired to be cautious valued the London sewage, when the population was 3,000,000, at £1,000,000 sterling, that is at the low estimate (ridiculous to many people) of 6s. 8d. as the annual value of each person's excreta. The two chairmen of parliamentary committees (Mr. Brady and Lord Robert Montagu), after a long inquiry, came to the conclusion that London sewage is equal in manurial value to 212,842 tons of Peruvian guano, with a market price of £2,890,000. Hofmann and Frankland considered that 1,250 tons of London sewage contained the fertilizing matters of one ton of Peruvian guano, whilst a very great authority indeed, one before whom the chemical world justly bows in admiration, would listen to nothing less as the annual value of the metropolitan sewage than £4,081,430.

Such being the teachings of science as to the value of sewage, nothing was more natural than to urge upon authorities its application to land. And here let me say at once, that I distinguish between utilization of the sewage and its purification. I consider them together, but they are totally different questions.

Science had its story to tell. The land acts, first, as a mechanical filter, and, secondly, as a chemical laboratory. As a filter, the larger insoluble particles are arrested on its surface, whilst the smaller are entrapped a few inches down. The water is absorbed, *i. e.*, each earth particle becomes covered with a liquid coating. Now follows the work of the chemical laboratory. The enormous surface of liquid thus formed is favorable to coercing the combination of oxygen with the organic impurities of this subdivided sewage water, carbonic acid and water together with nitric acid, oxidation being assisted possibly by the presence of certain micro-organisms resulting. The organic matters on the surface soon undergo slow burning. The nitric acid is your plant feeder.

The process of slow burning is the work of oxygen, whilst that of nitrification, as the researches of Pasteur and Warrington have shown, is due to the combined work of oxygen and of certain lower forms of life. Hence, to purify, you need not only a flow of sewage, but a flow of air, that is, constant movement regulated in its order. As regards the lower organisms, they may be already in the soil or be provided by the sewage. The purifying power of a soil, however, is peculiar to itself. You cannot completely control aeration, although drainage and loosening of soil will promote it, and an excess of irrigation stop it. In fact, the soil, as a purifying agent, is, to say the least, capricious.

Purification, the action of the soil, is greatly assisted by the action of vegetation. In winter time, when there is no vegetation, the soil only must do the work.

Enthusiasts full of faith were found to embark in private sewage farms, whilst local authorities, anxious to save the rates, offered the sewage to farmers in their neighborhood for a corresponding return.

It was not long, however, before a certain unpleasant awakening occurred, owing to the farmers declining even to accept the sewage.

Reasons for this were sought. Was it due, as was suggested, to the ignorance of farmers, and their blind attachment to old-fashioned ways? This contention was scarcely feasible, seeing how keenly they appreciate newly invented manures (*e. g.*, superphosphate, alkaline nitrates, etc.), new implements, new methods of subsoil drainage, etc.

Men began to suspect one of two things, either that there was (*a*) some obstacle to the agricultural use of sewage; or (*b*) that its theoretical value was very far from being its practical worth.

But other facts than those adduced by the mere working farmer, presented themselves in the failure of the farming attempts of enthusiastic irrigationists. Despite the statement of Mr. Edwin Chadwick, who, in 1844, propounded his views with the authority of the Board of Health, that liquid manure was at all times preferable to solid manure, and suitable for all crops and all soils, we have to record one long series of miserable failures in the attempt to find experimental proof of theoretical estimates. The failure of Mr. Smith's farm (Deanstone), of Mr. Neilson's farm, of Mr. Telfer's farm, of Mr. Kennedy's farm, (Myremill), of Mr. Huxtable's farm, of Mr. Chamberlain's farm, of Mr. Littledale's farm, and of Mr. Mechi's farm (all of which cases have at various times been held up as wonderful illustrations of the money success of irrigation) supply the unanswerable answer to Mr. Edwin Chadwick and his school.

The Rugby farm was pronounced "unremunerative" by its first manager, whilst it was abandoned by Mr. Congreve, and by Mr. Walker, who succeeded Mr. Campbell. The story of one and all sewage farms is a history of commercial failure.

The irrigationists, however, still pointed those who doubted the commercial success of sewage farming to the Craigentinny meadows in Edinburgh. We were told (correctly no doubt) that in good seasons £20 to £30 worth of green produce had been realized per acre (say £25 average). But it is no secret:

(1.) That in these meadows the quantity of sewage used has been from 10,000 to 13,000 tons per acre; in other words, taking the produce as worth £25, the sewage employed had a value, irrespective of rent and farming expenses, of less than ½d. a ton.

(2.) That the sewage was not used continuously, and when not wanted on the land, was diverted into the sea.

Nothing is more certain than that the theoretical value calculation of sewage, based on the supposition that the manurial elements of a sewage, extracted and dried, are their value in solution, must be regarded as an extravagant dream of enthusiasm. Such calculations have entirely overlooked the effects of dilution, and the presence of a mass of worthless material. Nay, more, the "profligate associates," as they have been called in sewage, are not merely worthless, but worse than worthless. Sewage in this respect is not singular. Thus, whilst rotten farmyard manure may have an estimated value of 15s., its practical value rarely exceeds one-half its theoretical. No doubt the enthusiasts of a few years ago have learnt a lesson at some cost. Mr. Bailey Denton, admitting the fallacy of old calculations, still clings with praiseworthy consistency to some of his old ideas of value. "Even," says he, "with such a greatly diminished value (*i. e.*, $1\frac{2}{3}$d. to $\frac{1}{4}$d. a ton), the country has a valuable property which it is our duty to preserve."

We are constantly reminded, moreover, of the success of irrigation in India, Egypt, Persia, etc. The simple application of water to the soil in dry and warm climates increases fertility. Moreover, we must admit that sewage has a higher manurial value than mere water. But the cases are not comparable; a climate having the temperature of our own with frequent rain (rain falling 150 days, on an average, out of 365), is not to be compared with one of tropical heat and of long continued drought. The sandy soil of Gennevilliers or of the Dantzic farm are no cases in point. Admitting as a fact a certain manurial value in sewage, the English farmer, it is certain, would sooner sacrifice the manurial value than be compelled always to have the water. For two difficulties stare him in the face (and a sanitary authority demands these conditions), first, to be compelled to take the sewage at all times (day and night, Sundays and week days) all the year round (summer and winter) whether his soil wants it or not, or whether he has any crops or not that can profitably use it, at all stages of their growth, seed time and harvest, and, secondly, so to utilize it as to produce an effluent which at all times, all the year round, shall neither produce a nuisance nor pollute a public watercourse. In times of frost—during the heavy rains of spring and autumn—the farmer finds he has no alternative (his land being practically impenetrable) but to let the sewage pass away unpurified into the nearest stream. He finds, too, that the use of sewage again is prejudicial during the maturity and ripening of the crops. These difficulties were grasped by the Parliamentary Committee of 1862, who reported that "it was desirable that those using sewage should have a full control over it, so that they might apply it when and in what quantities they may require."

Local authorities have, indeed, learnt the truth of these statements, since, when they adopt an irrigation scheme, they know that it is necessary for them to acquire land, and not trust to the farmers in the neighborhood.

I am aware that the difficulty of frost

is supposed to be met by the increased temperature of the sewage. If time, however, be allowed for the ground to be aerated, and the weather be so cold as to freeze it, some of the sewage at least must flow over frozen ground. This is the dilemma. Adopt means to aerate your ground, and it will become frozen. Neglect to aerate your ground, and it is useless, or practically so. The difficulty of storm water is said to be met by a certain portion of land being kept for storm sewage, and possibly planted with osiers. But this does not meet the case. Your osier beds can become water-logged as well as your farm. It is no doubt an advantage to have a reserve, but it only meets a part, and a very small part, of the real difficulty.

In considering the question of working cost, quite apart from the expense of preparing the land, it is stated on good authority (Local Government Board Report, p. 33), that sewaged land requires more horses and double the amount of manual labor than ordinary arable land. This means greater capital. "To properly stock (I am quoting from the report) and work a sewage farm upon which the main produce is consumed, quite five times the usual amount of money will be needed."

There is another point to be recorded, the enormous care needed in the management of a sewage farm. Dr. Carpenter understands this when he laments "how mischievous people often break down the carriers and other works, and let the sewage run where it ought not to go—in that way, getting into the effluent water."

We have admitted a certain manurial value in sewage. Before we proceed to consider the question of producing a good effluent, some other points bearing on its fertilizing powers come before us, viz.:

(1.) The methods of applying sewage to land.

(2.) The soil best suited for irrigation.

(3.) The crops most suitable for a sewage farm.

(4.) The value of the crops so grown.

I.—The Methods of Applying the Sewage to Land.

Various methods have been suggested, such as simple broad irrigation, as practiced at Milan, converting the field into a water meadow ; and subterranean irrigation, pipes being laid sufficiently deep to be beyond reach of the plow. This may be called upward irrigation. Both of these plans have been tried and abandoned. Irrigation by hose and jet is no doubt that method of applying sewage which yields the best results. (Smith of Deanstone, Chadwick, Mechi, Telfer, Kennedy.) Professor Way says: "If you ask me how to make, regardless of cost, the manurial ingredients of the sewage into the greatest amount of produce of any kind, I would put it on with pipes and hose in small quantities almost as I would in garden cultivation, as if I were watering it with watering pots, but it would never pay you to do it." And, apart from this, you would never be able to get on the land the quantity that would meet the sanitary difficulty. This failing, sewage has to be brought to the highest points of the land to be irrigated, conveyed by carriers of a more or less permanent character into some form of sewer channels. The open carriers, or surface channels, may be mere trenches, or, if it be desirable that they should be placed above the ground, constructed of concrete or of sheet iron, the sewage flowing in large or small volume, as required, upon the surface of theground. Sometimes movable troughs are used (Carlisle), but usually the sewage is run through open carriers, and merely the land more or less flooded by the carriers being dammed up at certain parts. Simple contrivances only are required to turn on or turn off the sewage as needed. The land must of course be so leveled and drained that the sewage may flow over different portions of ground, and not into hollows, where it would become stagnant, or pass away without undergoing the needful purification.

II.—The Soil Best Suited for Irrigation and Filtration.

We may distinguish three cases:—

1. Very porous soils. A pure sandy soil has had its advocates, on the ground that it becomes richer every year that sewage is applied to it, irrigation thus serving to convert poor into productive land (Way). Bagshot-heath has found favor as sewage land with some, on the ground of its porous, sandy, and sterile character (Lawes; Paxton). In such soils, however, the effluent is generally very impure. A coarse, gravelly soil may be "free," but it most certainly, as a rule, discharges the sewage imperfectly purified, on account of its non-retentive nature.

2. Heavy clay soils, or rather soils containing a notable proportion of clay, were approved by Liebig, on the ground that clay was the most effective soil for absorbing the valuable constituents of

sewage, viz.: the ammonia, phosphoric acid and potash. Liebig considered the success of the Craigentinny meadows to be dependent on the clay in the soil. It was his opinion that if the Maplin sands were to be used as irrigation land, 2,000,000 tons of clay would be needed to give them fertility to the depth of one inch.

A soil containing such a proportion of clay as to retard over-much the passage of the sewage through it, acts injuriously; in other words, it is over-retentive—the fact being that, to get the best effect of filtration, the filtration must not be too slow. The effluent is in such cases usually turbid and discolored.

A clay soil (*e. g.*, London clay, the stiff clay beds of the new red sandstone, and the boulder clay overlying the Oxford clay) are impervious to water. Such ground may be utilized by burning and mixing, although the cost of such treatment is considerable.

With clay, therefore, we may have either very slow filtration, the effluent being colored and turbid, or practically no filtration at all. Further, such soils are specially liable to crack and fissure, both by frost and extreme heat; in either case the sewage would run through the soil in an absolutely unpurified condition.

3. Soils intermediate between sand and clay. Perhaps a sandy loam, or a loam with a small portion of clay, is that soil best fitted to yield a good effluent where irrigation or filtration through land is practiced. Bailey Denton points out that the capacity of soils to absorb water (*e. g.*, a coarse, gravelly soil) is no criterion of its cleansing capability. On the contrary, he says, a loamy soil having sufficient sand to render it free and "to fill it with close interstitial spaces for aeration, will discharge a superior quality of purified water by the under drains." The best results I have myself seen are in the case of soils containing about 86 to 90 per cent. of sand with a little clay.

The value of a plant-bearing soil as an

absorbent, and possibly as an elaborator of plant food, is worth considering. Way supposed the absorbent action of a soil to be dependent on the chemical action of certain silicates of lime and alumina, which fixed the alkaline bases and allowed the acid constituents (phosphoric acid excepted) to pass in combination with lime. Liebig states that an acre of common clay soil, 4 inches deep, in the neighborhood of Munich, would absorb 2,076 lbs. of ammonia, 1,910 lbs. of potash, 888 lbs. of phosphoric acid, and that, like the stomach, which fitted food for the wants of the ani nal, such a soil fitted sewage for the wants of the plant. Clay, in his experiments, was the best soil for irrigation, sand the worst, turf and peat being intermèdiate. Voelcker found that clay absorbed potash salts and ammonia freely from its solution, but never completely, the ammonia absorbed being in great part but not entirely, capable of removal by washing. Sand absorbed ammonia and potash salts imperfectly. Chalky and marly soils absorbed and rendered insoluble the soluble phosphoric acid more powerfully than either clay or sand.

Voelcker's experiments on the action of various soils on ammonia show—

A.—As regards free ammonia :—

1. That all soils absorb ammonia from their solution, but that no soil absorbs it completely

2. That the stronger the ammonia solution, the larger the absolute quantity of ammonia absorbed, whilst the weaker the ammonia solution, the larger the relative quantity of ammonia absorbed.

3. That if after the saturation of a soil with a weak solution of ammonia, a strong solution be applied, the soil will absorb more ammonia from the strong solution.

B.—As regards salts of ammonia :—

1. That the soil absorbs the ammonia, the acid of the salt combining with the bases) lime, magnesia, etc.) present in the soil.

2. That absorption is greater with

strong solutions of ammonia salts than with weak solutions.

The ammonia absorbed by the soil may be partly removed by washing with water, but the quantity capable of being thus removed is always relatively less than that retained by the soil—in other words the absorptive power of the soil to absorb ammonia is relatively less than the solvent power of water to redissolve it.

These remarkable results are chiefly dependent on the alumina and hydrated oxide of iron in the soil, and in lesser degree on the presence of lime and other bases.

I wish to remark on the immense advantage in an irrigation farm of ferruginous earth. I have seen a case where a very good effluent was obtained by the accidental circumstances of a small area (small, that is, in comparison to the entire farm) containing a large quantity of an iron deposit.

The composition of irrigated as compared with non-irrigated soils has been on many occasions contentious matter in our courts, and the subject of numerous investigations. The top few inches of an irrigated farm presents no doubt a very marked difference from the underlying soil, such difference being dependent partly on the nature of the soil, partly on the method of irrigation, but more particularly upon how far the suspended matters have been removed before the application of the sewage to land, and the extent to which intermittency of action has been practiced. If, however, the top inch of the land be carefully scraped off, the difference of the composition of sewaged and non-sewaged ground will probably be found to be small. As regards nitrates, phosphates and chlorides, the difference is, as a rule, absolutely *nil*. Perhaps there may be a slightly increased amount of oxidizable organic matter, but even this is by no means invariable, whilst at a depth of eighteen inches, it is a very rare thing to find any marked alteration of composition. It is certain, therefore, that given land of ever so suitable a character as a sewage purifier, its powers are not those, agriculturally, of a storage battery.

Any excess of sewage over that which the plant can utilize at the time is, so far as commercial profit is concerned, wasted, passing off into the subsoil drainage partially or wholly purified. As a fact, the land does not store in any quantity the manurial elements for the use of future crops. The fertility of a given area is not 10 times greater by the application of the sewage of 1,000 persons, than it would be by the application of the sewage of 100. In fact, it is no better and no worse. The difference is to be sought in the effluent, not in the land. The Craigentinny meadows are still sandy and poor, despite of all the sewage put upon them. The land, notwithstanding all that has been done for it, still contains less than fifteen parts of organic matter in a thousand.

But how far is absorption dependent on the strength of the manurial fluid applied? Voelcker's investigations on this point have been referred to in detail. His experiments show that when manurial elements in a weak solution like sewage is applied to the soil, it merely oxidizes the nitrogen and strains the fluid, the resulting nitrates flowing away, unless vegetation is growing at the time, when the elements of the sewage may be appropriated. But more than this, his experiments show that a weak sewage may actually remove from a soil upon which there is no vegetation, the manurial ingredients already present in it.

That the total soluble nitrogen of sewage may be found in the effluent as nitrates when the sewage is applied to land where there is no vegetation or where vegetation is inactive, I have many times verified by analysis.

III.—Crops Most Suitable for Irrigation.

Nearly all agree that the most profitable application of sewage is to pasture land, osiers, and Italian rye grass. Way says that its application to grass land is the only profitable way of dealing with it—in other words, by feeding it into milk or flesh, and so getting a manageable manure.

Bailey Denton holds a different view, considering that "the less the sewage farmer has to do with stock the better." He is of opinion that the cultivation of grass is unprofitable.

And here I may refer to the greediness with which cattle feed on sewage-irrigated pasture. Mechi states that cattle will follow the hose and feed on the grass wet with sewage. Many who gave evidence before the Parliamentary Committee on the sewage of towns testified to the same effect, the committee reporting that "the evidence proves that cattle of all sorts appear to prefer sewaged grass to all others, and will eat it within a few hours of its being dressed with sewage." And I beg your attention to this fact in passing, for I shall refer to it again when I speak of the dangers incident to eating the meat of animals fed on sewage produce.

I would note, too, that there is evidence to show that a damp and sodden condition of ground, such as is common in a sewage farm, is peculiarly favorable for the production of the "liver fluke" of sheep (*Diatoma hepaticum*), a disease occasioning great fatality. This danger of irrigation is not undeserving of attention.

Roots.—Some have advocated irrigation for root crops in dry weather (Campbell, of Rugby). The mangold-wurtzel does well in a sewage farm.

Miller, of Edinburgh, is against the use of sewage for roots, since he found it made furrows and channels in arable land, and washed the roots of plants bare.

Bailey Denton advocates the growing of roots (mangolds, beets, turnips, carrots, parsnips, potatoes and onions) as better crops for sewage land than the cultivation of grass.

Cereals.—Some consider sewage suitable for wheat. Mechi advocated its use, although not directly to the land so used (otherwise the wheat grows too luxuriantly and fills too easily) but to a preceding grass, root, or clover crop.

The majority of authorities disapprove of its application to arable land, or of its use for cereals, roots, etc. Voelcker says, "It is quite unfit for cereals after the grassy state, because of its forming straw instead of grain, and checking the ripening process." Lawes, Way, Congreve (of Rugby), have expressed themselves to much the same effect.

Its application to corn crops was tried at Watford, Rugby and Alnwick, but abandoned.

Bailey Denton advocates the production of straw upon a sewage farm as advantageous for feeding stock, although the quantity of grain is small.

Voelcker condemns its use for market produce, "as it clogs the soil and kills the plant."

Bailey Denton specially advocates the cultivation of cabbages on sewage farms. I remember being told that they had tried growing rhubarb at Aldershot, but that they abandoned it because nobody would eat it a second time, owing to its rank sewage flavor.

At the Brussels International Congress (1876) a collection of vegetables were shown, said to have been grown in fields irrigated by the sewage of Paris. There was a curious silence as to the cost of production.

Liebig, arguing on the quantities of ammonia and phosphoric acid in sewage, in comparison to the quantity of potash, considers sewage less adapted for grass crops than for pasture land. Say 4 tons of good hay (= 12 tons of grass) is grown on an acre of land per annum. This 4 tons abstracts from the land :—

Nitrogen.......	141.6 lbs.	(=ammonia 172 lbs.)
Phosphoric acid	72 "	
Potash	124 "	

To get 124 lbs. of potash you must have 2,400 tons of sewage. This contains :—

Nitrogen.......	451.07 lbs.	(=ammonia
Phosphoric acid	109.6 "	547.73 lbs.)
Potash.........	124 "	

Now in accordance with the law that "the effect of all the constituents of a manure is but the effect of that one of them which, in comparison with the wants of the plant, is present in the smallest quantity," it follows that 375.73 lbs of ammonia, and 37.6 lbs. of phosphoric acid, are not merely wasted, but act injuriously by clogging the soil and killing the plants. On this ground he advocates adding to the sewage potash and phosphoric acid in proportion to the requirements of the crop, thus lessening the sewage required, and increasing general fertility. Thus Liebig argues that sewage should always be used in conjunction with richer manures, guano being rich in phosphates and ammonia, but poor in potash; farmyard manure being rich in potash but poor in phosphates and ammonia; sewage occupying an intermediate position. The following table will serve to illustrate his views:—

	Potash lbs.	Phosphoric acid lbs.	Ammonia lbs.
193 tons of sewage yield.....	10 .	8.8 .	44.1
2,023 lbs. of farmyard manure.	10 .	9.0 .	14.9
1,672 lbs. of Peruvian guano	10 .	200.5 .	142.3

Voelcker scarcely endorses these views, for he says if the soil itself contains the elements of fertility, sewage has no more value than so much water; but if it be poor and barren then the application of sewage will produce crops of grass when nothing else of any agricultural value will grow upon it.

IV.—Value of Crops Grown on Sewage-Irrigated Farms.

It must be admitted that the size and weight of roots and succulent vegetables grown on a sewage farm are often considerable. Thus enormous cabbages, turnips, celery, etc., are often shown as sewage-grown. But sewage produce is best described as dropsical, *i. e.*, the percentage of moisture in sewage-grown produce is far higher than in the case of ordinary market produce. (This fact was proved by Lawes in his experiments at Rugby Farm.) This being the case, sewage produce is difficult to dry, and prone to decompose. It must be consumed fresh, and on the spot, for it will not stand being carried any distance to market. Dr. Voelcker is definite on this point. Irrigated land, it is certain, does not yield so nutritious a product as natural pastures. If you want good produce, you must be content with small quantity.

PERCENTAGE COMPOSITION OF DRY SUBSTANCES.

	Plot I. No sewage plot.	Plot II. 3,000 tons sewage per acre.	Plot III. 6,000 tons sewage per acre.	Plot IV. 9,000 tons sewage per acre.
Nitrogenous substances..	11.16	17.58	18.37	19.66
Fatty matter (ether extracts)	3.41	4.13	3.95	4.04
Woody fiber.	29.08	28.21	28.32	28.13
Other non-nitrogenous matters...............	46.73	39.09	38.08	36.91
Mineral matter (ash)....	9.62	10.99	11.28	11.26

Passing to the solid matter itself, a larger proportion of nitrogen was found in the sewaged than in the unsewaged produce, and the larger the quantity of sewage applied, the larger became the nitrogenous constituents of the vegetation.

But here arises the important question, "Are nitrogenous constituents the true measure of the nutritive quality of a produce?" To this Voelcker replies, "No." On the contrary, nutritive properties depend on proper maturation, whilst an excessive quantity of nitrogenous produce indicates unripeness, *i. e.*, a deficiency of sugar.

I have thus far limited myself almost entirely to a consideration of the manurial value of sewage. We must now consider, in connection with manurial value, the second condition of effective sewage treatment, viz.: the production of a good effluent.

There now arises the important question, how much sewage can properly (*quâ* agricultural success) and safely (*quâ* sanitary success) be applied to a given area of land.

There are two ways of applying sewage to land—

1. Surface irrigation, or the distribution of sewage over as many acres as it will wet, having in view a maximum plant growth.

2. Intermittent downward filtration.

I.—Surface Irrigation.

And here one fact is certain, the agricultural and the sanitary aspects of the question are not in accord. To realize an agricultural success, the farmer says, apply at proper times and seasons a large quantity of sewage (and within reason the larger the better) to your land. To realize a sanitary success, the sanitarian says, apply continuously as small a quantity as possible. If sewage be put upon a soil in larger volume than 1,500 tons per acre per annum, even when there is actively growing rye grass upon it, the subsoil water is certain to pass away foul

(Way). It was found at the Anerley School farm that the same crop of grass was obtained when 1,500 tons of sewage per acre was applied by hose and jet, as when 8,000 to 9,000 tons were supplied by open carriers; but that in the latter case the effluent water was almost as foul as the sewage (Westwood). At Rugby, it was recorded that with 3,000 tons of sewage per acre, a yield of 22 tons of grass was obtained, whilst with 6,000 tons of sewage a yield of 28 tons of grass, and with 9,000 tons of sewage a yield of 32 tons of grass only was obtained (Lawes). The conclusion is irresistible. There is a limit to the quantity of manurial elements that the soil and plants are capable of appropriating. Exceed this limit, and any quantity in excess must pass away in a more or less unoxidized form.

As regards the quantity of sewage that is safe and proper to apply to land, I find authorities differ between 100 tons and 40,000 tons per acre per annum; a difference, in other words, between 2 and 800 persons per acre. Thus an authority "of great weight" expresses an opinion that 300 tons of sewage per acre per annum would accomplish as much as the 10,000 tons he had applied. Another authority considered the Rugby farm inferior to the Edinburgh meadows, because in the former from 3 to 9,000 tons of sewage per acre only was applied, whereas in the latter 10 to 12,000, and even 30 to 40,000 tons have been used. Mr. George Shepperd and Mr. Mechi considered 100 tons of sewage per acre per annum sufficient (or the manure of two persons). The latter lived to find his estimate erroneous, increasing his quantities at first to 500, and finally to 2,000 tons per acre for green crops. Miles, of Bristol, reported that two persons per acre gave good results, whilst Mr. Thomas Ellis considered (and in this Mr. Brady, the chairman of the Select Committee on Sewage, agreed) 600 tons of sewage (or the produce of a dozen people) advisable.

Mr. W. Hope and Mr. Westwood, of

the school farm at Anerley, considered an acre of land was required for every twenty or thirty people (1,000 to 1,500 tons of sewage per annum), for, said Mr. Westwood, "if more than this be used, it runs away into the drains and fouls the stream." This he found to be the case when 8,000 or 9,000 tons per acre was applied to land cultivated with rye grass. Liebig considered 2,430 tons of sewage sufficient for meadow land to yield 12 tons of grass (4 tons of hay) per acre. He adds, a soil saturated with manure not only fails to increase the crop, but, in the case of roots, is positively hurtful. The Earl of Essex (Chairman of the Commission to inquire into the best method of utilizing sewage) after many trials at Watford, decided that 5,000 to 6,000 tons a year was desirable to each acre for Italian rye grass, but that 600 tons to each acre was sufficient in the case of meadow land. Voelcker fixes 2,000 to 4,000 tons per acre for better kind of lands, and 8,000 to 10,000 tons for sandy soils, stating "that he has nowhere seen such small quantities as 300 or 400 tons per acre produce any remunerative effect." Way likewise fixes 100 persons to the acre, provided the land be grass land, estimating that 30,000 acres of land would be required if the sewage of 3,000,000 people had to be dealt with.

Sir R. Rawlinson states the case thus:—

"The means which have been found in practice to answer are as under stated, namely, for flood irrigation about one statute acre to 100 of population of a fully water-closeted town, but there cannot be any hard and fast rule."

In nineteen irrigated towns, according to Professor Robinson, there is an average of 137 persons to each acre (= to 5,128 gallons per acre per day, or 38 gallons of sewage per head of the population per day). Mr. McKie, of Carlisle, records the average of 53 towns as 98 persons to each acre (= to 3,826 gallons of sewage per acre per day).

Lawes and Rawlinson also agree that an acre of land is required for every 100 people (or 5,000 tons of sewage per year), a view agreed to in the main by Bailey Denton, who fixes 100 to 150 people, according to the porosity of the soil, lighter soil taking the sewage more freely than heavy. In Bailey Denton's opinion, however, extra land is needed for giving rest, and for permitting alternate cropping.

The difficulties, it will be seen, are tremendous. For commercial profit the sewage must not be less than 5,000 tons per acre—for sanitary efficiency (*i. e.*, to prevent nuisance), the quantity must not exceed 1,500—*i. e.*, a minimum of 100 is necessary to pay—whilst 30 is the maximum to escape prosecution.

II.—Intermittent Downward Filtration.

The difficulty of securing efficient land for surface or broad irrigation pressed hard on the irrigationists. Dr. Frankland and others saw that the larger the population of a town, not only the less land there was within a reasonable distance, but the more costly such land became. Irrigation was doomed unless the land difficulty could be overcome, and some method adopted whereby a large volume of sewage could be concentrated on a small area.

Dr. Frankland's laboratory experiments of 1870, with known quantities of different soils, gave birth to the process known as "Intermittent Downward Filtration." For this purpose it was stated to be necessary—(1) to have a suitably constituted soil which will act as a filter; that is, a soil not too open, so that anything may pass through, but not too close, so that nothing may pass through. (2.) To have the land deeply drained, say at a depth of 6 feet, so as to allow a considerable distance for percolation. This constituted filtration as opposed to irrigation. The land becomes an oxidizing instrument, to burn the impurities, and so transform them into harmless gases, rather than a mere separating machine. To obtain the best effects of oxidation, and to keep the land in the most effective condition, the sewage must be applied intermittently, *i. e.*, with regulated intervals of rest, to give time for air to go into the ground as the water runs out, thus fitting it for a fresh dose of sewage. Intermittent filtration, Dr. Frankland would say, is a copy of nature in the lung action of respiration, alternately receiving and expelling air. This intermittent work avoids, he would contend, the clogging of the soil, and secures its efficient and frequent aeration. By such means Dr. Frankland stated that the sewage of 3,300 people could be treated on one acre of land.

Let me endeavor to give an illustration of the method of working the intermittent downward filtration system.

Suppose a population of 9,900, with three acres of suitable land suitably drained. Each acre, for purposes of work, is subdivided into four parts, the sewage of 3,300 being placed successively for a period of six hours on each quarter acre. Thus each quarter acre receives the sewage of 3,300 people for six hours, eighteen hours rest being allowed before it receives another dose. Some have suggested, in further development of the idea of intermittency, that one of the three acres might be used per year for the 9,900, so that each acre would have two years during which it might the more perfectly recover itself, whilst each quarter acre of the one acre in use for the year would have eighteen hours rest out of the twenty-four. It is no misnomer to call this "intensified irrigation."

But Dr. Frankland's arguments were based on laboratory experiments. The varying effects of the varying qualities of sewage on the one hand, and the enormous differences in land, as regards its capability of absorption and filtration, on the other, seem to have been very imperfectly considered. Nor were the difficulties arising from subsoil water taken into calculation, nor the density of the soil in the laboratory experiments, as compared with its density in the natural state. I am fully aware that Dr. Frankland would say that the estimate of 3,300 to an acre supposes proper land—properly drained—properly leveled.

It is right, too, we should note that Dr. Frankland has from the first insisted that intermittent downward filtration involved the sacrifice of the manurial value of the sewage, the area of ground being too small, and the quantity of sewage too large, to make it pay. This view, however, Mr. Bailey Denton in no way endorses; on the contrary, he considers that the system of the intermittent application of sewage to land in no way interferes with, but actually assists, farming operations.

Both Dr. Frankland and Mr. Bailey Denton agree in considering the removal of the suspended matter in the sewage before its application to the land to be unnecessary. Mr. Bailey Denton, however, advocates the use of furrows (rather than flooding the land), partly as a means of preventing the clinging of solid sewage matter to the stalks and leaves of plants, and partly with the object of bringing the sewage into contact with the roots, which are the active abstracting agents of manurial worth. Indeed, Bailey Denton goes so far as to say that the presence of the suspended sludge in the sewage is an advantage rather than a bar to its application to land. By making some furrows of greater depth than others, he renders these the receptacles of the solid matters. The sludge, he says, "consists of vegetable and animal substances which are perishable, mixed with earthy and mineral substances, which are not perishable." It is only necessary to remember this "to realize the fact that they cannot possibly clog the land when dry. The most minute particles consist of fine road sand which floats on in the liquid after the heavier detritus has deposited itself. When these perishable and imperishable substances find their way into the soil, they must each, from their nature, obviously add to its porosity, inasmuch as the perishable substances leave open spaces as they decay, whilst the imperishable substances from their gritty nature necessarily help to increase its filtering capabilities. So long as the sludge is wet it impedes absorption to a certain extent, but when once dried, and the land broken up by the plow, it not only ceases to uphold the liquid, but naturally and permanently helps to let it into and through the soil." In other words, by digging the sludge into the soil, Mr. Denton contends that the soil is rendered more percolative than before. There may be something in this view. But how often have we seen, in practical working, sewage being applied to land, clogged by large masses of black albumenous matters, the result of previous irrigations, closely adhering to the soil, impeding absorption, and lessening the surface through which the water can pass into the ground. Mr. Denton says, "the sludge must then be allowed to dry, and when in a fit condition dug in." But in the act of drying comes the nuisance. In hot weather it means putrefaction (Mr. Denton calls it decomposition of perishable substances), and with putrefaction comes a stink, besides which it is in the act of evaporation that dangers occur from detrimental matters being carried bodily into the air. In filter beds, we know full well that the surface of the filter bed is that part most affected, and further that, for efficiency, the surface of the filter bed needs frequent removal and cleansing, whilst irrigated land shows neither to the eye nor to chemical analysis much indication of any excess of organic impurity a few inches from the surface.

I admit to the full the power of soil to purify sewage by oxidation. I admit, moreover, the advantage of intermittency of action, *i. e.*, of intervals of rest alternating with intervals of work. The entire success of the process, however, depends on perfect aeration during rest, to fit the soil for its next period of work. My experiments lead me to doubt the efficiency of a rest of 18 hours only, even when the sewage has had the solids in suspension removed. But of this I am certain, that when the suspended solids have been allowed to remain in the sewage, the glutinous constituents of the sewage, together with the *papier maché* material in solution, clogs the ground with an impervious covering, whereby the entrance of air is very much retarded. Further, the sewage, when applied after the period of rest, cannot flow through the ground on the surface readily, on account of the glutinous layer and *papier maché* film. Thus, as a result, the period of rest fails to become, *quâ* the soil, a period of aeration. This condition will be aggravated should the effluent water, from any circumstance, not flow freely away. Thus the very condition of success may be, and as I know often is, thwarted during the period of rest, as the result of the preceding period of work.

Difficulties of a practical nature crowd upon us in considering this method of treatment. Three, at any rate, may be noted:

1. The cost of preparing the land for the work.

2. The difficulty of securing proper land, or of ensuring its effective working

at all times, in all weathers, with all kinds of sewage, and under all circumstances.

3. The fact that much of the solid filth of the sewage will, unless previously removed, accumulate on the surface, where it undergoes decomposition and becomes, especially in hot weather, a formidable nuisance.

Intermittent downward filtration had its birthplace in the laboratory. Whether the earth used were cube feet or yards, or six foot tubes, many details besides this mere statement of the work accomplished are necessary. Was the earth used surface earth? How was the sewage collected? Was the earth exposed to the modifying influence of wind, light and rain? How long was the earth used—a week, a month, a year, or longer? It is to be feared that a new birth in sewage treatment needs a less cramped cradle than a London laboratory. You cannot learn how to direct an army in the field by practicing with toy soldiers. No laboratory experiment pure and simple can teach sewage treatment.

We now turn to the hygienic aspect of sewage irrigation. I shall speak of three classes of effects rendering sewage irrigation dangerous to the public health:

1. Offensive and injurious emanations.
2. Pollution of subsoil water.
3. Distribution of undefecated sewage containing the ova of entozoa.

I.—Offensive and Injurious Emanations.

Of such emanations, the evidence is ample. The River Pollution Commissioners admit that odors do arise with land irrigated with sewage, day after day, for years. The Craigentinny meadows, near Edinburgh, can only be described as filthy, emitting a stink hardly endurable. The surgeon to the barrack adjoining the meadows, described the stench (1868) as "sickening." Of the Croydon Sewage Farm, at Beddington, Dr. Creasy, Surgeon to the Orphan Asylum at Beddington, stated that "typhoid fever had been in every cottage on the estate "—every disease, in fact, assuming a particular type, accompanied by what is called a "sewage tongue." In fact, the stink of sewage-irrigated ground, and the malarious effects of the sewer gases evolved, are matters of frequent complaint and litigation. Dr. Clouston traced an outbreak of dysentery in the Cumberland and Westmoreland Asylum to the effluvia from a sewage farm.

There is, too, a remarkable statement by Copland, that the effects of sewer gases are never so bad as when emitted from sewage spread out upon the land. This statement is worthy of consideration. Solid matter is given off during evaporation. As the turpentine in lead paint is evaporating, solid lead carbonate is carried into the air, and produces lead poisoning amongst the inmates of the freshly painted house. This cannot result from any volatility of the lead, but merely from the mechanical dislodgment of lead particles during the evaporation of the volatile constituents of the paint. For when the smell has gone, the danger has passed. The sanitarian recognizes the importance of defecating the excreta of the typhoid patient as soon as evacuated, and of removing it from the sick room without delay. And why? To prevent the *materies morbi* being carried into the air during the evaporation of the liquid portion. It must, therefore, be an unscientific method to spread the sewage of a mixed population over the land, thereby increasing the area of evaporation. Mr. Hawksley's words may be quoted here. They are the record of one whose unique experience is only rivaled by his acute powers of observation: "Water irrigation carried on in warm weather is exceedingly unhealthy. I can speak positively to it from repeated observation in different places, that the odor, particularly at night and particularly upon still damp evenings in autumn, is very sickly indeed, and that in all these cases a great deal of disease prevails. The sewage forms a deposit on the surface of the ground, that deposit forms a cake of organic matter, and organic matter when it is in a damp state, as it usually is, gives off in warm weather a most odious stench."

There is yet another point to be considered. That a district saturated with moisture, and more particularly if along with the moisture there is an excess of organic matter (I am excluding specific morbid emanations), is unhealthy and malarious, the fens of Lincolnshire and the rice fields of China, not to speak of other places, supply abundant evidence. Buchanan, in a masterly research, has shown that phthisis is more prevalent where there is a wet atmosphere than where there is a dry one, whilst Pettenkofer, of Munich, regards fever and cholera as dependent on fluctuations in the level of ground water charged with sewage. The case is serious. Saturate—be continually saturating—a large area with sewage water, and as a consequence be continually raising the subsoil water, an increased humidity of atmosphere must result, and conditions favorable to malaria, fever, and phthisis.

Dr. Sturge, in 1879, in a paper before the Institution of Surveyors, gave some important details respecting the sewage of Paris. 70 per cent. of the Parisian houses have cesspools, but even of the remaining 30 per cent., the solid excrement is not allowed to enter the sewers. Some analyses of Paris sewage were given (respecting which, however, I speak with caution) showing 56 grains of organic, and 123 grains of inorganic matter per gallon.

Of the total 60,000,000 gallons daily of Paris sewage, 10,000,000 are treated on 914 acres of land at Gennevilliers. This land has about five inches of alluvial soil resting on ten feet of sand and gravel. I omit all reference to the agricultural success or non-success of the Gennevilliers farm, but it must be noted that authorities consider that the value of building land in the neighborhood has decreased, and the health of the inhabitants suffered from a rise in the level of the subsoil water. I quote Dr. Sturge's words (p. 153): "Great complaints have been made that since the introduction of the irrigation, ague has become far more common than it was before, and more deaths occur from diarrhœa and dysentery."

One thing is abundantly evident, even to any untrained observer, viz., that it is impossible to insure a pure effluent by an irrigation process. The land which is covered with an active crop of vigorous vegetation, is a totally different purifying area from the same land upon which no rye grass or other vegetation is growing. The land under the influence of summer warmth and active evaporation is entirely different from what it is at times of frost or snow. The land flooded with heavy rains is different land from what it is in dry weather. Inequality of purification, uncertainty of action—at one time good, at another doubtful, at another absolutely useless—is the record I have to give from personal observation, and that on no limited scale, of irrigation as a method of purifying sewage. The sewage comes every day to be treated, and no earthly power can say whether your farm is or will be in a condition to deal with it. And more than this—the very condition that increases the quantity of the sewage to be dealt with (such as heavy rain), is the very condition that renders your land temporarily disabled. And yet further still, the very condition that increases the bulk of your sewage, or at any rate its polluting character—the population—is that condition which renders costly the land in the neighborhood, and probably makes it altogether impossible to procure at any price. I give on p. 1151 certain analyses of sewage effluents from different farms.

II.—Pollution of Subsoil Water, and of Running Streams.

The select committee on the sewage of towns, although champions of irrigation, admit that if the power of the soil be overtaxed (that is if too much sewage be applied) there must of necessity be injury to wells and running streams.

III.—Distribution of Undefecated Sewage containing the Ova of Entozoa.

The fact has always been recognized that entozoic diseases have an external origin—*i. e.*, that the ova or parasites come from without, and are not generated within, the human body. Millions of ova are voided with every segment discharged by the person afflicted with tapeworm, each ovum being capable of producing a measle in the flesh of an animal, and each measle a tapeworm in the body of the man.

Here, then, are two serious consequences of irrigation worth considering: I have seen watercresses and celery grown on sewage ground, having a quantity of dried sewage matter deposited on the stems. I have, with more than a cook's patience, tried to wash this matter off, but the tenacity with which it sticks upon the surface of the vegetable when once dry is perfectly astounding.

Be it remembered that watercresses and celery are eaten uncooked. I have seen cabbages and turnips, not merely grown on sewage ground, but carefully prepared arrangements made for a weekly flooding with sewage, the market produce being placed in a kind of reservoir permitting sufficient raw sewage to flow into it, so that it may completely cover the vegetation.

The grass covered with sewage, eaten, as it is with rapacity by the cattle, infect their bodies with the larval parasite. Thus the meat is measly, and measly meat, except for efficient cooking, means tapeworm to the human subject. Perhaps a similar story might be told of trichina, with its ten times greater danger. No doubt, as an accident, the danger is constant, but sewage irrigation would practically render it an affair of certainty. In other words, sewage always contains excremental ova. The farm, therefore, that receives sewage must be more liable to produce measly meat than the farm that does not receive it.

"May we not, indeed," says Dr. Cobbold, "but too reasonably conjecture that the wholesale distribution of tapeworm eggs, by the utilization of sewage on a stupendous scale, will tend to spread abroad a class of diseases some of which are severely formidable? So convinced am I of the truth embodied in an affirmative reply to this latter query, so certain am I that parasites are propagated in this particular way, so surely do I see unpleasant results if no steps are taken to counteract the evil, that I feel myself bound to speak out boldly, and to produce no uncertain sound in the matter, which most closely concerns humanity. The whole question is, in truth, of vast hygienic importance."

Let us review our facts. We have dilute sewage to deal with. We desire to be sanitarians, viz., to purify our sewage so that it shall not pollute our watercourses, nor cause nuisance. We desire to be economists, viz., to get out of the sewage all that is valuable in it. In a word, we desire to achieve, by one and the same operation, a sanitary success and a commercial profit. In sewage treatment, as in other things, you cannot combine the impossible. Achieve your commercial success, and you must abandon sanitary considerations. You must, as at Edinburgh, flood your land with your thousands of tons of sewage per acre, until your farm is a stinking morass, and your effluent water so impure that you must take it directly into the sea lest you foul your watercourses. Achieve your sanitary success, sprinkle your 300 tons per acre per annum on your land with hose and jet, and away goes your agricultural profit. Try a compromise between the extremes of the 300 and 10,000, and you get the difficulties of both with the advantages of neither. I admit possible exceptions: a small population; cheap land removed from human habitation; a porous soil admitting free percolation; happy gradients not requiring steam power; proximity to the sea, so that extreme purity of effluent need not be demanded; proximity to a town, so that a ready sale for the sewage grass for dairy purposes can be secured. But the difficulties are enormous. I must have enough land—and the greater the population with whose sewage I have to deal, the greater the quantity of land required, and the larger probably its price. I must have proper land—sufficiently porous, but not too porous, properly leveled and drained. If the level of my land be above the sewer outfall, I require costly motive power. The larger the quantity of sewage (as in wet weather) with which I have to deal, the less able is the already over-loaded ground to cope with it. Frost or snow, the work has still to be done. At all times the effluent must be sufficiently pure, lest litigants be aroused. At all times the operations must be conducted without offensive smells from an over-sodden state of soil, and without polluting the air by rendering it abnormally damp or polluted by sewage effluvia, the prolific source of typhoid. The subsoil water must be so diverted, that neighboring wells shall not be polluted. Grant all these difficulties overcome, and there remains as the produce of my farm a grass only fit for dairy purposes, and even then likely to be a source of entozoic infection to man and animals.

Straining, Filtration, and Subsidence.

Many attempts have been made not only to strain and filter sewage, but also to allow the deposition of the larger pieces of the suspended matters in tanks, with or without straining. As a fact, it is impossible to strain sewage efficiently, or to effect deposition without previous treatment. If the straining material be of fine texture, such as of wire, it soon clogs, whilst if it be of coarse texture, it is of no use. If fine gauze, or an iron grate be used, the albuminous matters soon choke it, and prevent further action. In Baldwin Latham's self-cleansing extractor (an ingenious contrivance in use at Dantzic, Croydon, Coventry, etc.), and consisting of a vertical strainer rotating about a horizontal axis, the solid matter being raised from a central receptacle by an Archimedean screw, the most that can be said is that the grosser matters are removed. But even here, a considerable play of water upon the gauze is required to ensure its action. It was formerly a common practice to strain the sewage through wooden planks perforated with ¾-inch apertures, before applying it to land, a proceeding that reduced the suspended matters some 9 or 10 per cent.

A combined system of subsidence and filtration has been attempted on many occasions. This method was formerly adopted at Birmingham, where the sewage was conveyed through a series of tanks, the passage occupying about two hours. Two sets of tanks were employed, each set being worked continuously for about a fortnight, when the sludge was removed and consolidated by evaporation and soakage in properly prepared pits. The effluent water was found to be offensive, and the works a nuisance.

Coventry formerly adopted a similar process, a coarse gravel filter running the whole length of one tank being employed, through which it passed into a second, and again into a third tank of small gravel. The purification proved very inefficient.

At St. Thomas, adjoining Exeter, a similar method of defecation by subsiding ranks, iron strainers, and gravel filters (forming the tank boundaries) was adopted, although in this case a little lime and about 0.75 gallon of carbolic acid to 200.000 gallons of sewage were added. The carbolic acid proved valuable.

At Uxbridge again, a combined system of subsidence, straining through a grating, and filtration through charcoal, is adopted, before the sewage is discharged into the Colne. It is, however, quite certain that mere subsidence and filtration, as methods of sewage treatment, are failures.

We may here mention the suggestion of Strang, of Glasgow, of treating the sewage discharged from a water closet, by upward filtration through a box containing the refuse ashes of the house. By this means the solid matter is retained in the lower part of the vessel, and the liquid matter passes through the ashes. Dr. Anderson, of Glasgow, reports well of the apparatus. Mr. Austin, late of the Local Government Board Office, was of opinion that sewage might be dealt with by placing a series of portable filters in the sewers. (Society of Arts Conference, 1877, p. 14.) By this means much of the kitchen stuff could be kept out of the sewers, which, it is true, is often as objectionable as, if not more objectionable than, the sewage itself.

Whatever filtering material you use, be it sand, gravel or charcoal, two difficulties are inevitable:—(1) That the filter soon becomes choked, when it fails to act, or acts inefficiently; (2) that the matters deposited on the surface of the filter cause an insufferable nuisance. It may be said, as regards the first objection, you have only to recharge your filters and to utilize the old material for manure. The answer is, the cost of material and of labor, and the difficulty of securing a sale for your refuse. To meet the second objection it is said, "Cultivate the surface of your filter beds, whereby vegetation can be made to use up the obnoxious matters." In practice, however, this is not successful, whilst it is impossible to secure a crop all the year round.

I know of no place where filtration alone has proved a success hygienically. Of course intermittent downward filtration is practically land filtration. The objections urged to general filtration apply equally to land filtration.

Some interesting details respecting the filtration of the foul water of the River Plate is given by Mr. George Higgin ("Proc. Inst. Civil Engineers," vol. lvii.) They show the extreme difficulty of filtering this impure water, a difficulty which is nothing compared to that of filtering sewage.

Discharge of Sewage into the Sea.

Seeing sewage is worth so little, it is no wonder that local authorities have been desirous, where possible, to get rid of it by permitting its discharge into the sea (see Hawksley's Social Science Address 1876, p. 28). This has been done at Weston-Super-Mare, St. Leonards, Torquay, Eastbourne, Llandudno, Dover, Carnarvon, Brighton, Margate, and Ramsgate. There is much to be said in favor of this method. No doubt it appears wasteful, but nature is certain to utilize in due course in her own way what we fail to utilize in ours. But it must be noted that a nuisance is possible if the sewage be discharged into the sea too near land, from the foul matters in suspension being brought back again by the tide to putrefy on the shore during low water. This was said to have occurred at Dover ("Proc. Inst. Civil Engineers," vol. xliii. p. 221) and at Carnarvon. A stink may result, moreover, from the reduction of the sulphates of sea water to sulphides by the organic matter in the sewage, and the evolution of sulphuretted hydrogen by the action of carbonic acid on the sulphides so formed. Possibly to some such cause the smells and unsanitary condition of the Bay of Naples, the Port of Marseilles, the Bay of Cadiz, the West Coast of Africa, and other places owe their origin. This difficulty is worth considering, moreover, more particularly in those cases where a town extends down to the water's edge. No doubt further sewage matters, flocculent materials, corks, etc., have a special tendency to float on sea water, continuous decomposition resulting. Difficulties have arisen at Margate, Ramsgate, and Brighton, from these several causes.

Evils resulting from the discharge of sewage into tidal rivers containing sea water have occurred at Glasgow and towns adjacent, where the sewage was taken into the Clyde, and were investigated by Sir John Hawkshaw in 1874, who recommended its discharge into the Firth of Clyde at Farland Head. The discharge of sewage into the Thames was also a subject of inquiry by a Royal Commission, and was discussed by Professor Stanley Jevons in a letter to the *Times* of December 2, 1878. I need only point out that the discharge of sewage into a tidal river involves cost for dredging.

Regarding sewage (which I do) as a thing to be got rid of, and for which we must be prepared to pay to be rid of it, there are manifest advantages in taking it out to sea or estuary. It should, however, in such cases, be discharged in deep water, at a considerable distance from land below the line of low water, and where there is a well-ascertained current to carry it permanently seaward. Careful tidal observations are needed before deciding on the point of discharge. A spot where there is an oscillating action resulting in a return of sewage matter, either in the neighborhood of the discharge, or at distant places to which the tide carries it, must be avoided—in other words, we must not allow a turn of the tide to carry one person's refuse to somebody else. It is difficult to imagine a nuisance resulting under carefully considered conditions, more particularly if the discharge pipe be some distance from the town, and the town itself well above the sea level. Still, even in all cases, it is worth considering whether or not some process of clarification may not be advisable.

It is worthy of note that chloride of magnesium is itself a precipitating agent for sewage. Again, sea water, owing to the common salt present in it, has a tendency to reduce the ease with which organic matter is oxidized. Thus the oxidation of the organic impurity of the sewage is less rapid when it is discharged into salt water, than it is when discharged into fresh.

In the "mud inquiry," the Conservators of the Thames contended that certain sewage banks in the river were caused by the sewage outfalls at Barking and Crossness. In time, these sewage deposits putrefy, rise to the surface, give off offensive gases, ultimately sinking to undergo fresh putrefactive changes. It is certain that in a tidal salt river, foul banks of sewage mud may form, which in ordinary rivers would not be produced. Of course, I admit that a strong tidal current might carry these masses away, but in the absence of such current, they subside and mingle with the sand and mud of the beach.

Precipitation Processes.

By "chemical precipitation," or "the chemical treatment of sewage," is implied the addition of certain chemicals to the sewage, whereby the deposition of the solid suspended matters and some of the dissolved matter from the formation of insoluble compounds, together with the deodorization of the offensive constituents precipitated or dissolved, is effected. The general features of a chemical process for sewage may be thus described:

To the sewage (from which the grosser suspended matters may or may not be removed) chemicals are added, either suspended in water, or, if soluble, dissolved in water. After this treatment, the sewage is allowed to flow into subsidence tanks, where either it is allowed perfect rest for a few hours or is passed through a series of tanks continuously, in order in either case to allow the deposition of the sludge—that is, of the matters in suspension. The clear effluent is then allowed to flow either directly into a watercourse, or over land, previously to its discharge. The black fluid or sludge in the tank (of which 90 per cent. is water) is then all that remains to be dealt with.

The precipitants to be employed have been subject matters of numerous patents. Of these we shall note the most important.

I.—Processes involving the use of Lime as the Chief Precipitating Agent.

Lime.—The use of lime for disinfecting excreta was the subject of a patent in 1802 (Estienne). In 1844 lime was used to purify the Manchester sewage before discharge into the River Medlock.

This was done at the suggestion of Dr. Clark, of Aberdeen, who at that time was at work at his process for softening water by the use of lime, and as the result of which, he was led to suggest its use for sewage precipitation. It was abandoned for a time at Manchester on the ground of cost (a ton of lime being required daily), but was re-adopted in 1854, at the suggestion of Crace Calvert, who advised, after the addition of two or three grains of lime per gallon, complete rest of the liquid so treated in subsidence tanks, his report stating that the precipitate subsides rapidly, the supernatant water being clear, colorless, and inoffensive.

In 1846, Mr. William Higgs took out his patent for the treatment of sewage in subsiding tanks or reservoirs by means of chemical agents. For the purpose of precipitating the solid animal and vegetable matters contained therein, hydrate of lime (commonly termed slack lime) was preferred. In 1851, Mr. Thomas Wicksteed patented a process for manufacturing manure from sewage, etc., by admixture with lime, collecting the deposit and submitting it to certain centrifugal drying machinery, thus obtaining, to use his own words, " the manure as fertilizing material in a state commodious for transport."

Action of Lime.—When lime is added to raw sewage, a carbonate of lime is first formed. This acts as a weighting material, whereby, if the opportunity be afforded, the light flocculent suspended matters will be carried down along with the precipitated carbonate. In addition to this, however, a certain proportion of dissolved organic matter is also precipitated, the lime forming with the organic matter a compound of uncertain chemical composition.

Crace Calvert, operating on the Manchester sewage, gives the following as the average results of five days' treatment by lime:

	Matters in Solution.		
	Total solids.	Mineral.	Organic.
Raw sewage..	32.00	23.46	8.54
Effluent......	25.76	22.26	3.50

	Matters in Suspension. Total solids.	Mineral.	Organic.
Raw sewage..	6.65 ..	3.08 ..	3.57
Effluent......	0 ..	0 ..	0

The action of lime on London sewage was the subject of a prolonged investigation by Dr. Letheby during the time I acted as his assistant.

In Calvert's experiments on Manchester sewage the lime effected the entire removal of the suspended matter (mineral and organic), and more than 50 per cent. of the dissolved organic matter. In Letheby's and my own experiments, the removal of all the suspended matter was effected, and about one-fourth of the dissolved organic matter.

The action of lime was further investigated and reported on by Hofmann and Witt, as one of the most promising of the many processes for obtaining a deposit from sewage, which, when dry, might be employed as manure. Operating on London sewage with 20 grains of lime per gallon (800 grains of lime to 40 gallons of sewage), the following results were obtained:

	Matters in Solution. Total solids.	Organic.	Mineral.
Raw sewage	107.6	52.36	55.24
Effluent	96.02	40.34	55.68

	Matters in Suspension. Total solids.	Organic.	Mineral.
Raw sewage	52.49	36.4	16.09
Effluent	traces.	traces.	traces.

In other words, 20 grains of lime removed all the suspended matter, and more than one-fourth the dissolved organic matter.

After the addition of the lime a flocculent precipitate is formed. This settles at the rate of about one-fourth part the bulk of the liquid in one hour. The clear supernatant liquor is colorless, clean, and comparatively odorless. Hygienically, the process is successful—commercially, it is not successful, because the precipitate is mainly carbonate of lime and non-nitrogenous organic matter.

These laboratory experiments are confirmed by practical working. Thus Higgs' process was used at Tottenham in 1857, the results being so satisfactory that the Local Board of Health gave a testimonial certifying to its efficiency (sewage treated 175,000 gallons daily, or sewage of 10,000 persons—12 grains of lime added per gallon (1 ton per week) —dry precipitate obtained was four to five times the weight of the lime used). That the success was no mere accident is proved by the high eulogium passed on the process by Normandy and Miller in the action brought by Higgs against the Hitchin Local Board for an infringement of his patent.

Why, then, was not this hygienic success continued? The reason is obvious–the

TOTTENHAM.

	Matters in Solution.			
	Total solids.	Organic.	Mineral.	Am'onia.
Raw sewage.	54.50	9.49	45.01	2.60
Effluent	48.99	8.01	45.98	2.84

	Matters in Suspension.		
	Total solids.	Organic.	Mineral.
Raw sewage..	39.99	14.53	25.46
Effluent	1.69	0.37	1.32

manure was found to be of so little value that the commercial result proved a failure, Mr. Higgs transferred his expensive works for a merely nominal sum to the local authority, who (in spite of their testimonial showing the capabilities of the process) so neglected them, that shortly after the transference, an injunction was obtained by the trustees of the River Lea, to prevent foul undefecated sewage being discharged from the works. Carelessness and parsimony are certain to ruin the best of processes.

Wicksteed's process was adopted at Leicester in 1855, the works, which cost £30,000 to £40,000, being managed in the first instance with marked success. [Sewage treated (1858), 2,000,000 gallons daily, or the sewage of 65,000 persons, 3 to 16 grains of lime were added per gallon. Sludge (dry) was 3 to 4 times the weight of the lime used.]

Very high was the commendation passed on this process by Aitkin and Taylor, after a minute investigation in 1851. But the Corporation shirked the lime, and neglected the works. No wonder that the River Soar, into which the effluent is discharged, became foul, a result

LEICESTER.

Constituents per gallon.	Matters in Solution. Total solids.	Organic.	Mineral.	Am'onia.
Raw sewage	70.00	13.49	56.51	2.52
Effluent	66.99	10.65	56.34	2.61

Constituents per gallon.	Matters in Suspension. Total solids.	Organic.	Mineral.
Raw sewage	19.15	5.50	13 65
Effluent	1.40	0.49	0.91

which is certain to be attributed by partisans to failure of the lime process rather than to its true cause, viz., the miserable carelessness and false economy of those to whom the management was entrusted.

The value of the sludge precipitated by lime has been variously estimated as from 15s. 6d. to 29s. 6d. per ton. Voelcker, who fixed 15s. 5d., gives the following as its composition:

		Value per ton.
Moisture	10.52	—
Organic matter	12.46	£1
Phosphate of lime	2.27	7
Mineral matter	54.75	—
	100.00	
Nitrogen	0.60	—
Ammonia	0.72	56

No doubt, as an agricultural article, this manure is worth very little indeed compared to the extravagant views entertained of its fertilizing power by the earlier patentees. Local authorities have to learn that to treat sewage means outlay, and that cost is no excuse for neglect.

I conclude by laying down certain essentials for the successful treatment of sewage with lime:

1. The lime used should be in a perfectly caustic state, and before admixture with the sewage should be thoroughly slaked and mixed with sufficient water to render it the consistency of a thick cream.

2. That the quantity added should not be less than ten grains per gallon, to a sewage that does not exceed thirty gallons per head of the population.

3. That very complete agitation of the lime with the sewage is advisable in order to secure perfect admixture of the lime and flocculation of the precipitate, thus rendering the after subsidence more rapid. This admixture is effected pre-

ferably by means of a paddle-wheel mixer, the axis of which is at the water line of the well in which the mixing process is effected.

4. That after precipitation the defecated sewage should flow over an apron into a tank, which should be at least 4 ft. deep, and capable of holding at least one hour's sewage, and from this into a second tank over a weir placed half an inch below the surface and at the opposite end to the apron over which the sewage enters, this second tank being capable of holding at least four hours' sewage.

5. Or, if this continuous process be not adopted, the defecated sewage should then be allowed to remain at rest in a tank for at least one hour.

6. That the sludge should be removed in summer time once in 48 hours, and after removal be pressed, or otherwise consolidated and dried with all reasonable speed.

The frequent removal of the sludge is a matter of importance. If this be not done, it putrefies, rises in large flakes, and promotes the decomposition of the supernatant water. It is not difficult by the operation of a dirty tank to undo all the good done by chemical treatment. It will be manifest that a double set of tanks is necessary for successful working.

Lime and Chloride of Lime.

At Hertford, in 1866, about 8¼ bushels of lime and 150 lbs. of chloride of lime were used daily in the treatment of 1,640,000 gallons of sewage per day (=lime 2 grains, chloride of lime 0.64 grains per gallon). At this time the population was 7,000, showing the great quantity of subsoil water that must have mixed with the sewage in its transit to the works (= 234 gallons per head). The lime (as cream of lime) added, was apportioned to the rate of flow by little buckets attached to a water wheel. The treated sewage was now discharged into a depositing tank. The tanks are in duplicate, each tank being worked three days, where it remained about forty minutes, a period too short for complete subsidence. The tank was divided under the water line by a cross wall, the sediment being thus kept back, the supernatant water being then filtered through 6 or 7 inches of coarse gravel and 3 inches of fine sand. The filter required cleansing daily. From the filter beds it passed into an effluent channel about a mile long, to be discharged into the River Lea at Ware Mill. About 12 cwt. of sludge was removed daily. After flowing along the outfall channel for a quarter of a mile, it became clear, fish and vegetation being found in the water in abundance.

In 1866 the following analyses were obtained:

Date.	Matters in solution.			Matters in suspension.		
	Total solids.	Organic.	Mineral.	Total solids.	Organic.	Mineral.
Raw sewage, August 26	26.95	1.70	22.25	2.45	1.05	1.0
Effluent, "	26.00	1.00	25.00	0.85	0.35	0.5
Raw sewage, August 31	29.30	1.95	27.35	6.30	3.25	3.1
Effluent, "	27.25	1.20	26.05	1.30	0.60	0 7
Raw sewage, December 13	30.33	5.35	24.98	5.39	0.71	4 68
Effluent, "	27.00	2.51	24.49	0.74	0.24	0.50

In 1867, 3.43 grains of lime and 0.33 grains of chloride of lime were used per gallon, and the analysis (November) was as follows:

	Matters in solution.				Matters in suspension.		
	Total solids.	Organic.	Ammonia.	Oxygen to Oxidize.	Total.	Organic.	Mineral.
Raw sewage	25.0	2.50	0.34	.296	1.42	0.72	0.70
Effluent	28.33	1.25	0.45	.281	0.43	0.17	0.26

The chloride of lime, although only one third of a grain per gallon, not only disinfected the sewage, but prevented the growth of the sewage fungus.

My experience enables me to speak favorably of the employment of chloride of lime with lime, especially in hot weather. About 56 lbs. per 1,000,000 gallons will be found, as a rule, fully sufficient for a sewage represented by thirty gallons per head of the population.

Lime and Sulphate of Soda.

Fulda's Process. This process was tried on a small scale at Pratt's cloth mills (Yeadon, near Leeds), and at Barnsley Union Workhouse in 1873. The process was abandoned, the effluent not proving satisfactory.

Salts of Magnesium with Tar and Lime.

Fritz Hillé's Process.—The process of Fritz Hillé (patented 1870) was to be used as follows: A mixture of lime (100 lbs.), gas tar (3 lbs.), chemical salts, viz., chloride of magnesium (17 lbs.), were made into a paste with 180 lbs. of water. Hillé, however, does not bind himself to these exact quantities, varying them according to the composition, strength, and quality of the sewage to be treated. From the decomposition of the magnesium chloride by the lime, a bulky precipitate is formed, which carries down the suspended matter.

The exact quantity of paste to be added must also be a matter of experiment. It will vary from $\frac{1}{4}$ lb. to 1 lb per 100 gallons, or from 10,000 lbs. (=4 tons, 9 cwt., 1 qr., 4 lbs.) to 2,500 lbs. (= 1 ton, 2 cwt., 1 qr., 8 lbs.) per million gallons. This quantity, however, supposes subsequent filtration.

Hillé suggests that the sludge may be advantageously used again as a precipitant for fresh sewage, employing for this purpose a mixture of from two to five parts of sludge with one part of the paste. Further, he considers that depositing tanks are not essential, but that the sewage after treatment may with advantage be applied directly to the land.

If tanks be employed, they should not be used for more than three days at a time.

Salts of Alumina.

Numberless patents have been taken out for treating sewage by means of compounds of alumina.

If sulphate of alumina only be used, the ammonia of the sewage would in time effect its decomposition, resulting in the precipitation of alumina. The action of alumina thus set free is to combine with the soluble organic matter, with which it forms an insoluble compound. Thus it is used as a mordant or fixing agent for colors when applied to fabrics, and to precipitate coloring matters from their solutions, forming insoluble compounds called "lakes." Ammonia and phosphoric acid are also fixed by aluminous compounds.

Stothert (1852) patented a mixture of sulphate of alumina (or sulphate of zinc), caustic lime and charcoal (obtained from sewage or night soil), as a precipitant for sewage. The quantities suggested were 73.5 grains respectively of sulphate of alumina and charcoal, 3.5 grains of sulphate of zinc, and 22 grains of slaked lime per gallon. The lime was to be added first, and then the mixture of charcoal with sulphate of alumina. Hofmann and Witt report (1857) the following results produced with 5 ozs. of lime and 10 ozs. of the alumina mixture to 40 gallons of London sewage:

	Matters in Solution.		
	Total solids.	Organic.	Mineral.
Raw sewage	107.6	52.36	55.24
Effluent	87.73	37.56	50 17

	Matters in Suspension.		
	Total solids.	Organic.	Mineral.
Raw sewage	52.49	36.4	16.09
Effluent	none.	—	—

They record that the addition of the alumina caused a marked increase of suspended matter, as well as a largely increased flocculation and rapidity of subsidence.

Stothert claims that a ton of the materials, costing 30s., will make two tons of manure worth £2 2s. per ton, containing, when dried, 1.44 per cent. of ammonia, 8.6 per cent. of phosphate of lime, and 34 per cent. of organic matter.

I do not know of this process having been employed on a large scale.

Lenk's deodorizing liquid (patent, 1865), was a solution of alum cake (crude sulphate of alumina) containing 12 per cent. of alumina. In the case of London sewage, 25 grs. by weight of the solution sufficed to defecate a gallon efficiently, a very flocculent precipitate forming, which required about 30 minutes to subside.

This process was tried at Tottenham in 1858 for about one week, one ton of solution (value £6 10s.) being used to treat 4,900,000 gallons (700,000 daily). The following results were obtained:

	Matters in Solution.			
	Total solids.	Ammonia	Organic.	Phosphoric acid.
Raw sewage	91.10	9.76	42.30	3.77
Effluent	63.39	4.23	9.70	trace

	Matters in Suspension.		
	Total solids.	Organic.	Mineral.
Raw sewage	367.7	225.6	142.1
Effluent	3.01	0.77	2.24

The precipitation was very successful. Voelcker reported that "the effluent might be poured into any watercourse without causing a nuisance." He valued the dry deposit at from 25s. to 30s. per ton.

A curious history is here presented of a local authority, guardians of the public health, and moreover, under an injunction not to pollute the Lea, trying a process for one week, which they admitted gave "fair results," and which others know to have been more than fair, and then abandoning it, whether from carelessness or parsimony I do not know.

Manning (1853) suggested as a sewage precipitant, a mixture of animal charcoal, alum carbonate of soda, and gypsum, some caustic lime in addition being also advised. The use of alum, on account of its expense, was afterwards dispensed with (patent, 1854), by the employment of a waste obtained in the course of the alum manufacture from the rough liquors (called soft sludge, consisting of sulphates of iron and alumina), and afterwards (patent, 1855), by the use of various aluminous minerals and earths (alum slate, &c.), treated much in the same way as that adopted in the preparation of alum.

The sewage was to be treated as follows: The aluminous preparation was to be added to the sewage, and the whole agitated, the unslaked lime with animal charcoal being introduced during the mixing. The treated sewage was then to be allowed to subside in proper tanks.

This process was favorably spoken of by Penny, of Glasgow, who gives the two following analyses of the sludge:

	Per cent.		Per cent.
Ammonia..........	2.22	..	0.884
Phosphate of lime..	2.05	..	13.57
Organic matter.....	43.72	..	31.74

The former he regards as of the estimated value of £1 16s. 5½d., and the latter of £1 15s. per ton.

Compounds of Iron and Alumina (Sulphated Clay).

Bird's Process. Six cwt. of powdered

clay is treated with 120 lbs. of sulphuric acid, and the mixture allowed to stand for a week.

The following are places where the process has been used:

Stroud (*Gloucestershire*). This solution of sulphate of alumina and iron is used in quantity equal to 28 to 37 grs. of mixed sulphates per gallon, at Stroud (population 8,000) in Gloucestershire, to defecate 200,000 gallons of sewage. The treated sewage is allowed to run into settling tanks passing from one to another through straw filters, and finally filtered through coke filters. The sludge is dried, and made into a manure by admixture with sulphate of ammonia and phosphate of lime.

The Stroud sewage was examined and reported on by the Rivers Pollution Commissioners in 1868, when a solution containing 6 cwt. of pulverized clay acted on by 120 lbs. of sulphuric acid was added to 200,000 gallons of sewage. They record the effluent as inodorous, but not of a high degree of purity. (See 1st Report, 1868, p. 58.)

Cheltenham. Bird's process was adopted at Cheltenham in 1868. It was said not to be a success.

Northampton. In 1872, Northampton sewage, which was then 1,000,000 gallons a day, was defecated with crude sulphate of alumina and iron, made by the action of sulphuric acid on a ferruginous clay. Three cwt. of chamber sulphuric acid were added to 2 tons of clay in a wooden trough, and allowed to remain in contact for a week. The solution was generally found to contain about 15 cwt. of a sulphated ferruginous compound. There were six of these troughs in use—the entire soluble contents of one trough being used daily. The flocculation was imperfect from the want of an efficient stirring apparatus. Moreover, the acid of the chemicals caused effervescence with the carbonates present, a scum being formed from the rise of the suspended matters. This, however, was kept back in the first tank by cross-bars. The sewage then flowed into a second tank, and finally over a weir into a channel a mile in length, when it was discharged into the river. The river itself was clean, the aquatic vegetation healthy, and fish abundant.

The samples given below are averages of many samples taken over 24 hours. The effluents generally were clear and inoffensive.

	Matters in Solution.		
	Total solids.	Oxygen required to oxidize.	Ammonia.
Raw sewage	73.60	2.265	4.98
Effluent, 1st tank	70.16	1.980	4.19
Effluent, 2d tank	70.65	1.243	3.247

	Matters in Suspension.		
	Total solids.	Organic.	Mineral.
Raw sewage	13.83	8.48	5.37
Effluent, 1st tank	4.97	2.91	2.06
Effluent, 2d tank	1.74	1.11	0.63

About 400 tons of sludge were removed per week. This was mixed with sifted ashes (48 tons) and burnt refuse (20 tons), and found a market at 3s. per ton.

In 1875, the proprietors of Bird's process brought an action against the proprietors of the Coventry process for infringement, in which they were unsuccessful.

A process (*Cobley's* patent) similar to the one just described (the precipitants being said to consist of iron, alumina and carbon) is in use at Crewkerne, the precipitant being placed in a box with perforated sides, the sewage being allowed to flow through the box by which contact with the precipitant was secured. There is no stirrer, but sufficient mixing is said to be effected by the means described. The patentee states that the precipitant can be supplied (exclusive of a small royalty) at £2 per ton. A good effluent, which does not undergo putrefactive change by keeping, is stated to be produced.

At Hertford (population 9,000) the sewage is treated with a solution of sulphate of iron (1 part), lime (2 parts), and sulphate of alumina (2½ parts). It flows into subsidence tanks (7 in all, 5 being used continuously), and finally through a coke filter.

Lime and Salts of Alumina (Coventry Process).

Anderson, of Coventry, suggested the use of lime and an aluminous compound, prepared by adding 1 part of common sulphuric acid, mixed with its own bulk of water, to 2 parts of clay (shale having also been used). The mixture is to be set aside in a warm place until it appears white on the surface.

One pound of this mixture is to be well agitated with 100 gallons of sewage, and a $\frac{1}{4}$ lb. of lime (as cream of lime) afterwards added. He advises that the defecated sewage be allowed absolute rest for twenty-four hours, the clear effluent being then drawn off, and the sludge removed.

Odling gives the following results by this process:

	Matters in Solution.		
	Total solids.	Organic matter.	Ammonia.
Raw sewage..	42.77	8.33	0.77
Effluent	56.28	6.30	0.84

	Matters in Suspension.		
	Total solids.	Organic.	Mineral.
Raw sewage..	89.74	51.66	38.08
Effluent	1.61	0.91	0.70

Both Odling and Voelcker reported highly of this effluent, as thoroughly deprived of noxious qualities.

The sludge is valued by Voelcker at 30s. a ton. He gives the following analyses:

Moisture...........	12.01	..	15.70
Organic matter.....	26.89	..	31.86
Phosphate of lime..	2.60	..	2.55
Mineral salt........	6.61	..	10.33
Silica, etc..........	51.89	..	39.56
	100.00	..	100.00
Ammonia........=	1.39	..	1.22

At Coventry the use of this process was commenced in 1874. It has been ably supervised for many years by Mr. Melliss, C. E. There are, at the present time, four precipitating tanks worked on the continuous principle. The effluent flows through filter beds occupying 9 acres, used intermittently, and is ultimately discharged into the River Sherbourne.

The sewage of Coventry is about 2,000,000 gallons daily, very foul, and much colored with dye refuse, etc. It needs far more chemicals than average sewage. The sludge produced is about 25 tons per day (90 per cent. moisture).

About 2 tons of crude sulphate of alumina (but of which 2-5ths, being insoluble in water, is not put into the sewage), and 10 cwt. of lime are used daily. The cost for chemicals is said to be £1 14s. per 1,000,000 gallons, and the entire cost (including rent, capital on works, management, etc.) about £4 14s. per 1,000,000 (= 1.8½ per head).

Formerly, one portion of the sludge was got rid of in a semi-dry condition at 7s. per ton, whilst another portion, dried and reduced to a portable condition, fetched £2 per ton. Some of the sludge was also "fortified" by added chemicals, and fetched from £5 to £6 per ton.

A similar process was also in use at Nuneaton from 1872 to 1876, when the arrangements between the Local Board and the General Sewage and Manure Company fell through, from some misunderstanding respecting the average daily flow. Nuneaton sewage is offensive, owing to the presence of manufacturing refuse. From 400,000 to 500,000 gallons were treated daily. The effluent was filtered through 2 acres of land. The yield of manure was about 1 ton daily. The cost was as nearly as possible the same as at Coventry.

The A B C Process—The Native Guano Company.

The patent of the Messrs. Sillars and Wigner (1868) claim the use of alum, blood, and clay (hence termed the A B C process), with other agents, viz., compounds of manganese and magnesium, chloride of sodium, animal and vegetable charcoal, with the object

(1.) Of deodorizing and purifying sewage by means of these chemical subtances, and so obtaining a sediment which may be used as manure.

(2.) The deodorizing and purifying sewage by means of the mud already precipitated from sewage as above described.

(3.) The addition of an acid to the mud in order to retain ammonia, and so fit it for use as a manure.

The precise composition of the precipitating material has been changed from time to time. When first used at Leicester, in 1868, the precipitating mixture consisted of :

	Parts.
Alum	600
Blood	1
Clay	1,900
Magnesia	5
Manganate of potash	10
Burnt clay	25
Chloride of sodium	10
Animal charcoal	15
Vegetable charcoal	20
Magnesian limestone	2

These were mixed with water, and added to the sewage, until no further precipitate resulted. About 4 lbs. of the mixture were required to every 1,000 gallons of sewage (= 28 grs. per gallon). The treated sewage then flowed into subsidence tanks, where the sediment was allowed to deposit. This sediment was used five or six times over as a precipitant, until its power in this respect was exhausted. After the sludge had been dried, a small quantity of acid (preferably sulphuric acid) was added to fix the ammonia, in which state it was claimed to be a valuable manure.

In 1869, the process was worked at Leamington, the composition of the precipitating mixture being:

	Parts.
Alum	259
Clay	896
Charcoal	56
Clay blood.	40
Carbonates of soda and potash	6
Previous precipitate	14
Perchloride of iron solution	1 pint.

This mixture was added in the proportion of about 51 grs. per gallon, at a cost of £15 18s. per million gallons of sewage.

The mixture used at Leamington in 1870 was as follows:

	Parts.
Ammonia alum	336
Clay	672
Animal charcoal.	15
Vegetable charcoal	20
Sulphate of magnesium	20
Clay blood	4

Of this composition 56 grains per gallon was found to be necessary.

1873, the process was used for a short time at Crossness for the treatment of 500,000 gallons daily of the sewage at the Southern Metropolitan Outfall. The mixture used had the following composition :

	Parts.
Sulphate of alumina............	5
Charcoal.	29
Clay............................	26
Mixed with a little blood.	

This was added in the proportion of 224 grains per gallon, and yielded 12.33 tons of manure per million gallons of sewage (5.25 tons from sewage, and 7.08 tons from the added chemicals), the ingredients costing £24 9s. 8d.

Tottenham, Hastings, Bolton (1872), Southampton, and Leeds afterwards adopted the process, but in all it was abandoned on the ground of cost. At Southampton a contract to deal with the sewage was canceled after £10,000 had been spent on works, owing to some erroneous expectations respecting profits.

At Bolton, 1872-1873, the chemicals used were as follows:

	Parts.
Sulphate of alumina	71
Clay	132
Carbon (waste from prussiate of potash factory)	81
Blood, small quantity.	

This mixture was added at the rate of about 90 grains per gallon. The quantity of sewage treated was 2,500,000 gallons daily. The process was abandoned on the ground of expense.

At Leeds in 1870 (sewage 9,000,000 gallons daily, of which the A B C Company were to deal with 2,000,000) the precipitating mixture employed was:

	Parts.
Alum	5,964
Carbon (refuse from prussiate of potash factory)	4,480
Clay	7,460
Blood mixture	56
Lime	186

About 120 grains per gallon of this mixture was employed. The cost for chemicals per million gallons was £7 5s. The Company abandoned the works on June 1st, 1873. In June, 1875, however, they again treated the Leeds sewage for one week with the following precipitating mixture :

	Parts.
Lime	15,990
Animal carbon	13,556
Alum	8,076
Clay	16,848
Carbolic acid	28

About forty grains of this mixture was used per gallon of sewage, at a cost of £2 8s. 10d. per 1,000,000 gallons.

Another trial was made for one week in January, 1876, when the cost of chemicals was found to be £3 5s. 9d. per million gallons.

The process, as carried out at Leamington (population 20,000, sewage 600,000 gallons daily in dry weather), was successful. The A B C mixture was stirred into the sewage in a circular tank, from which it passed into two settling tanks, each set being used for one week, there being three sets of tanks for alternate working. The effluent then flowed into a channel 850 feet in length, 10 feet wide, 4 feet deep, the last third of which was converted into a filter of sand and animal charcoal, having a superficial area of 3,000 square feet. The sludge was converted into paste by centrifugal machines, revolving 1,500 times per minute, and afterwards further dried by exposure to air. It was then sprinkled with dilute sulphuric acid (1 of acid to 6 water), the acid being used in the proportion of one per cent. of the manure. It was afterwards heaped for a fortnight, during which time it heated considerably, forming a rotten compost, which was further dried and sold for manure.

About 28 grains per gallon of the A B C mixture was employed, whilst the dried precipitate, containing 20 per cent. of moisture, weighed about 80 grains. Analyses of the effluent at Leamington, as reported on by Dr. Letheby, are as follows:

Date, etc.		Dissolved matters per gallon.						Suspended do.	
		Total.	Chloride sodium	Organic matter.	Ammonia.		Oxygen required.	Total.	Organic.
					Free from organic matter.				
		grains.	grains.	grains.	grains.	grains.	grains.	grains.	grains.
Dec. 11, 1869	Raw sewage....	66.13	11.04	14.43	2.543	0.220	1.830	113.60	39.92
	Effluent water..	67.27	9 68	11.27	1.892	0.109	0.951	7.64	2.86
	Ditto filtered....	60.97	7.21	7.50	0.954	0.093	0.488	3.08	1.12
Jan. 29, 1870	Raw sewage...	67.81	14.64	11.09	3.769	0.200	1.804	43.44	14.72
	Effluent water..	51.33	6.01	7.61	0.315	0 060	0.406	1.04	0.30
April 20, 1870	Raw sewage ...	94.10	18.76	19.25	3.200	0.352	2.400	50.14	29.06
	Effluent water..	72.27	12.52	13.70	3.840	0.200	1.600	2.26	1.12
July 14,'70	Effluent water..	72.33	9.20	6.15	2.520	0.114	0.252	0.60	0.12
Sept. 20, 1870	Raw sewage....	86.67	16.52	17.30	4.125	0 711	3.512	34.64	22.12
	Effluent water..	74.93	11.57	13.10	3.467	0.150	1.023	1.54	0.52
Sept 21, 1870	Raw sewage....	81.10	15.58	15.70	5.120	0.440	3.159	29.50	18.14
	Effluent water..	69.30	8.03	8.70	0.690	0.060	0 320	0.16	0.10
Sept. 30, 1870	Raw sewage...	95.67	18.17	19.50	10.160	0.320	2.708	7.84	5.64
	Effluent water..	69 67	8.26	7.40	0.971	0.008	0.204	0.00	0.00
Average	Raw sewage....	81 91	15.79	16.21	4.819	0.374	2.569	46.53	21.40
	Effluent water..	67.26	8.97	9.17	1.822	0.098	0.613	1.24	0.76

It will be noted in these analyses that the chloride of sodium in the effluent is less than that of the original sewage. This may be partly explained by its dilution with subsoil water, and also by the fact shown by Voelcker and Way that marly soils possess the power of removing alkaline chlorides from their solutions.

At Hastings the works were situate on the seashore. The A B C material was agitated by a machine mixer with the sewage, and after flowing through subsiding tanks, was discharged into the sea.

The A B C process depends in great measure on the alumina as a precipitating agent. It is doubtful whether the blood is of any service, as it can scarcely be urged that in the quantity in which it is added, the fibrin can be of much value as an agent for entangling suspended matter. The clay is mainly a weighting agent, to assist the rapid subsidence of the suspended impurities.

Of course the quality of the manure

must depend on the quality of the sewage. Hence, as we should expect, its composition is not absolutely constant. Against the valuations of authorities we have the indisputable fact that it is being sold continuously for about £3 10s. per ton.

Phosphoric Acid, Magnesia and Lime.

Herapath's Process—Blythe's Process.—

The object of this mixture as a sewage precipitant is to fix the ammonia (as an insoluble ammonio-phosphate of magnesia) which in the employment of lime, or iron and alumina salts, remains in solution in the effluent, and consequently is lost. The lime, however (in common with iron and alumina salts) precipitates the phosphoric acid in the sewage. The use of sulphate or chloride of magnesium as a precipitant, in order to form the insoluble ammonio-phosphate of magnesia, was first suggested by Sir James Murray. Herapath, in 1853, patented a process for the use of magnesia or one of its compounds, in order to precipitate the ammonia and phosphoric acid "at or about the same time as the deodorization of the same sewage is effected by the addition of some chemical agent which will not decompose ammonia or its salts."

With this object he employed a mixture of 1 part of sulphate of iron, and 4 parts of burnt magnesian limestone. The process was tried at the sewage Works of St. Thomas, near Exeter, but proving unremunerative, was abandoned.

Murray and *Herapath's* process did not meet with the approval of Hofmann and Witt, on the ground that 1 part of the ammonio-phosphate of magnesia is soluble in 45,000 parts of water containing free ammonia and in 15,000 parts of pure water, whilst in a water containing a salt of ammonia, it was soluble to the extent of 1 in 7,000 parts.

In 1858, *Blythe* (Consulting Chemist of the Board of Health) patented the use of a solution of phosphate of magnesia in combination with lime or other precipitating agent.

The following is his description of the process:

" Superphosphate of magnesia is first to be prepared by the mutual decomposition of superphosphate of lime and a salt of magnesia, the superphosphate of lime being obtained from bones, bone-ash, apatite, phosphorite, coprolite, phosphate of alumina, phosphate of iron, phosphate of copper, or any other substance containing phosphoric acid, by the aid of sulphuric or muriatic acid, or other acid, the proportions being, in the case of phosphate of lime, one ton of phosphate to half a ton of sulphuric acid of commerce, previously mixed with three times its weight of water, or three-quarters of a ton of hydrochloric acid of commerce diluted with twice its weight of water. These are allowed to stand together for two or three days, being frequently stirred, and then they are mixed with a ton of sulphate of magnesia, dissolved in a small quantity of water, say a little more than its own weight. Powdered charcoal is then added in sufficient quantity (about one ton) to bring the mixture into a solid and convenient form for transport. When used for the purification of sewage, it is to be dissolved in water, and added to the sewage in the proportion of five parts of the phosphate to every 100 parts of solid matter in a gallon of the sewage. The whole is then to be well mixed and thoroughly incorporated by means of an agitator. If the sewage does not contain enough free ammonia or other alkali to neutralize and precipitate all the superphosphate of magnesia, lime is to be added, in the form of milk of lime, until the sewage is faintly alkaline to test paper. By this means the ammonia-phosphate of magnesia is thrown down as a flocculent precipitate, which carries with it, after the manner of a clarifier, any insoluble impurities suspended in the liquid. In like manner, instead of lime, he claims the use of any other alkali or alkaline earth, as potash, soda, magnesia or magnesian limestone, or alumina. He thus produces a valuable manure, containing, as he supposed, the ammonia, as well as the nitrogenous organic matter of the sewage, and the phosphoric acid employed; 'while the supernatant liquor being freed from ammonia and nitrogenous matter, liable to undergo putrefaction, becomes deodorized, and may be either applied to the irrigation of land, or run off into the ordinary channels of drainage without fear of creating any nuisance or offense.'"

Way, in 1861, in the second report of the Commission to inquire into the best mode of distributing the sewage of towns, condemned the process as the most costly of all the plans that have been proposed, but on grounds that scarcely commend themselves to our judgment. I am ready to admit that the process may fail in removing the ammonia to the extent indicated by the patentee, but how it can possibly fail in removing the phosphoric acid (I am arguing now on chemical grounds), as Way's analyses show is beyond comprehension. The only explanation can be that Mr. Way did not use sufficient lime.

Many experiments were made with Blythe's mixture, of which the following are illustrations. Superphosphate of magnesia was added, in the proportion of 10.3 grains of phosphoric acid per gallon, and then an excess of lime until the sewage was faintly alkaline.

	Matter in Solution.			
	Total solids.	Phosphoric acid.	Ammonia.	Oxygen required.
Metropolitan.				
Raw sewage.	68.33	.64	6.33	2.54
Effluent	90.02	.60	6.24	1.41
Coventry.				
Raw sewage.	46.61	.53	1.16	.78
Effluent	68 07	.05	1.06	.43

	Matters in Suspension.		
	Total solids.	Organic.	Mineral.
Metropolitan.			
Raw sewage	47.42	27.51	19.91
Effluent	0	0	0
Coventry.			
Raw sewage	21.11	8.87	12.24
Effluent	0	0	0

The dried precipitates had the following percentage composition:

Organic matter	28.06	12.16
Phosphate of lime	27.11	32.65
Earthy matters	35.30	45.60
Sand, etc.	9.53	9.59
	100.00	100.00
Nitrogen equal to ammonia	1.61	0.99

The process purified the sewage successfully. One ton 3 cwt. of the superphosphate compound and 4 cwt. of lime was found on an average to be required for 1,000,000 gallons. This produces 3 tons 1 cwt. of a manure valued at £3 14s. per ton, the chemicals and labor to produce which cost £1 15s., leaving a net profit of £1 19s.

Blythe's later experiments showed that the magnesian compound might be omitted, and that the precipitated phosphate of lime was as valuable for plants as the original superphosphate.

Arrangements had been made to try the process at Southampton and Leicester, but fell through, owing to the death of the patentee.

Phosphoric Acid, Lime, and Alumina.—Phosphate Sewage Process.

The patent of Mr. *David Forbes*, F. R. S., and of Dr. *Astley Paston Price* was taken out in 1870. It consisted in the use of an acid solution (sulphuric acid being generally employed) of natural phosphate of alumina, with or without lime or carbonate of lime. The object was to employ a precipitant of manurial value, in order to obtain a compost of high fertilizing power.

The phosphate of alumina was obtained from the West Indies, where it occurs in such enormous quantities that on one island alone the deposit is estimated at 9,000,000 tons. It contains about 38 per cent. of phosphoric acid and 25 per cent. of alumina, with about 2.5 per cent. of peroxide of iron. It was formerly supposed to be phosphate of lime, but analysis shows that the material does not contain more than 2 per cent. of lime.

Experiments with London and Coventry sewage, in which was added 33 grains per gallon of the phosphatic material (= 10.38 grains of phosphoric acid) dissolved in its own weight of commercial sulphuric acid, gave results as follows:

	Matters in Solution.			
	Total solids.	Phosphoric acid.	Ammonia.	Oxygen required.
London.				
Raw sewage.	68.33	0.64	6.33	2.54
Effluent	100.07	0.68	5.70	1.44
Coventry.				
Raw sewage.	46.61	0.53	1.16	0.78
Effluent	82.59	0.60	1.04	0.47

	Matters in Suspension.			
	Total solids.	Organic.	Mineral.	Phosphoric acid.
London.				
Raw sewage	47.42	27.51	19.33	0.68
Effluent	0	0	0	0
Coventry.				
Raw sewage	21.11	8.87	11.96	0.28
Effluent	0	0	0	0

The dried precipitate gave as follows:

	London sewage.	Covent'y sewage.
Organic matter	24.80	10.40
Phosphate of lime	16.82	22.11
Carbonate of lime and magnesia	49.39	58.14
Silica, etc	8 99	9.34
	100.00	100.00
Nitrogen equal to ammonia	1.41	0.91

The effluent was clear and without smell, much soluble organic matter being removed. The process, however, is peculiar in this respect, that if no lime be added after the precipitating material, much soluble phosphate will remain in solution. The effluent may then be used for irrigation, no nuisance being likely to result from the use of the clarified water, the manurial value of which will be considerable. In other words, we strengthen (the patentees would say) the manurial value of the sewage, and purify it by the same operation.

If lime be used, the deposit may be made to contain any proportion of phosphate of lime (indeed it may be rendered almost pure bone earth), necessary to pay its cost of carriage to a distance. Thus to effect a good sanitary result a small quantity only of precipitating matter is required, whilst a commercial success may be effected by the use of a large quantity of the precipitant. Thus, if two tons of the phosphate be added to every 1,000,000 gallons of London sewage, it would yield four or five tons of manure, containing 15 to 18 per cent. of phosphoric acid, whilst if three tons be added per million, a manure would be obtained worth, according to Voelcker, £7 7s. per ton, and having a composition as follows:

	Per cent.
Moisture.........	3.98
Organic matters..	20.11
Phosphoric acid..	28.52=62.26 tribasic phosphoric of lime.

	Per cent.
Lime...........	13.09
Alumina, etc.....	29.95
Sand, etc........	4.35
	100.00

Nitrogen 0.57=to ammonia 0.69.

The only place where the process was worked to which we need refer is *Hertford*, where the process was in operation for two years (1876-1877). The results were good, but no details are given as to cost. The company paid £100 per year rent for the works, and received £300 per year as a subsidy from the corporation, *i.e.*, at the rate of 7d. per head of the population.

Whitthread's Process (1872). — The patentee employs superphosphate with a little milk of lime, the object being to recover the phosphoric acid in the sludge.

Dugald Campbell's Process. (1872).— The patentee employs superphosphate and some lime. It was tried at Tottenham in 1872 for six days on 3,500,000 gallons, at a cost for chemicals of £16 6s. 5d. per million gallons, yielding 6.3 tons of manure per million, valued at £5 per ton.

It was also tried experimentally (1873 to 1875) on the metropolitan sewage, when the chemicals required to produce a good effluent were found to cost at the rate of £22 6s. per million gallons. The dry manure was valued at from £3 15s. to £4 15s. per ton.

Salts of Iron.

Brown (Feb. 1847) patented the use of the sulphates and chlorides of iron as sewage disinfectants, and *Ellerman* (Oct. 1847) the use of the chlorides and pyrolynates (acetates) of iron. Ellerman's fluid (price 1s. 6d. a quart retail, 9d. wholesale), contained from 24 to 43 per cent. of the iron salts named, and had a specific gravity of from 1336 to 1443.

Dale's fluid (sp. gr. 1450, price 6d. per gallon) was a strong solution of perchloride of iron, and was proposed by Hofmann, Frankland, and Miller, for deodorizing the Thames during the hot summers of 1857 and 1860, on the ground that it compared favorably, as regards cost, with lime or chloride of lime. Thus they said 1,000,000 gallons of London sewage required for deodorization the following quantities of the several ingredients named:

		Cost.		
		£	s.	d.
86	gallons of Dale's fluid....	1	13	0
400	lbs. of chloride of lime..	2	2	10½
132½	bushels of lime..........	3	6	6

They remark that the sewage treated with lime became offensive after three days—with chloride of lime after four days–whilst that treated with perchloride of iron did not become offensive even after nine days. The use, however, of the iron was objected to by Odling and Letheby, both urging that a black mud would form in the river, which, after a time, would undergo putrefactive changes, and be more unsightly than even the sewage. Letheby also urged the quantity of arsenic in the perchloride as an unanswerable objection to its employment as a precipitant where the sludge is not removed before the treated sewage is allowed to escape into the river.

Dale's liquid (130 gallons to 1,000,000) was used at Croydon in 1852 and 1860. The results were not satisfactory, because the suspended matter was imperfectly removed, the iron sulphide giving the effluent a black and polluted appearance.

Dover's patent (1851) claims the use of acids with iron filings or oxide of iron and protosulphate of iron, the defecated sewage being afterwards filtered through charcoal, peat, etc.

Mudie's disinfectant, a preparation of dry copperas, is valuable for the deodorization of drains, etc., owing to its property of absorbing ammonia and sulphuretted hydrogen. It is hardly suited for the defecation of sewage, although it acts well as a general disinfectant, for which purpose it is largely used in the French slaughter-houses.

Lime, Sulphate of Iron, and Coal Dust.—Holden's Process.

This mixture, as a sewage precipitant, was patented by Jules Houzeau and Devedeix (1866), and was used at Bradford by Mr. Holden (hence known as *Holden's Process*). The sulphate of iron was to be added first, and afterwards milk of lime mixed with coal dust. The use of clay is also mentioned in Holden's patent. The treated sewage then flows into subsiding tanks. A clear and inodorous effluent can be obtained, about one-half of the dissolved organic matter being precipitated. The manure is of little value.

Bradford.—The process was tried in 1868 on 130,000 gallons daily. It was reported against by the Rivers Pollution Commissioners, as giving a clear effluent, but of a quality worse than the original sewage, founding their opinion on the quantity of organic nitrogen present. They supposed that the putrescible organic matters in suspension passed into solution by this treatment. Further, they considered the hardness of the effluent an objection to its being allowed to pass into water-courses.

Marsden and Collins' Process consists in the use of lime, carbon waste from the prussiate manufacture, house ashes, soda, and perchloride of iron.

This process was used in 1874 at *Bolton*, in dealing with one sixth of the sewage (population, 93,000). The cost of chemicals was given at £1 7s. 3d. per million gallons of sewage. the total cost being £7 14s. 5½d. per million.

Hanson's Process (1875) employs lime, black ash (tank waste, or refuse from alkali works, containing sulphides of calcium and sodium), and red hæmatite treated with sulphuric acid.

This process was tried at Leeds, the chemicals used being in the proportion of:

	Tons.	Cwts.
Lime......	20	0
Black ash.....................	4	0
Red hæmatite and oil of vitriol..	1	6

Two tons 16 cwt. and 1 qr. were added to every 1,000,000 gallons, at a cost of £2 5s. 8d. per million. The effluent was said to be good. Its use was discontinued in April, 1876.

A modification of this process is now

in use at Leyton. The process was adopted in 1882 by the Golcar Local Board.

Goodall's Process (1875) employs lime, animal charcoal, ashes, and iron liquor (solution of sulphate of iron).

LIME AND AN IRON SALT.

At Ealing the lime (20 cwt. per week to 3,000,000 gallons) is added to the sewage in the course of its transit to the subsidence tanks. These tanks, each measuring 64 ft. × 10 ft. × 10 ft. deep, are divided into five compartments by cross planks, where the lime precipitate subsides. In the last subdivision of the tanks, the defecated sewage is treated with an iron solution (crude sulphate 15 cwt. to 3,000,000 weekly). The sewage then flows upwards through two filter beds (No 1, gravel, 30 ft. × 10 ft. × 2 ft. thick; No. 2, sand, 60 ft. × 10 ft. × 2ft. thick), the effluent being clear and inoffensive when discharged.

At Northampton, in 1862, lime (as milk of lime) and chloride of iron (in solution) were used as sewage precipitants. The constituents were mixed together, and so decomposed, before they were added to the sewage [60 lbs. of solid chloride of iron, 12 bushels of lime to 400,000 gallons of sewage daily]. There was no mechanical contrivance to mix the sewage with the chemicals. The sewage after treatment passed into two subsiding tanks (40 ft. × 30 ft. and 60 ft. × 30 ft., each 5 ft. deep), from the second of which it flowed over a weir into an outfall channel a mile in length, being ultimately discharged into the River Nene. The tanks were worked for a fortnight, when the sludge was conveyed into pits, and mixed with the town refuse, the manure realizing 1s. 9d. per load.

Letheby recommended adding the iron salt to the sewage first and the lime afterwards, and that some mechanical contrivance for stirring the treated sewage both after the addition of the iron and the lime should be adopted. He considered 4.5 grains of chloride of iron and 15 grains of lime per gallon was needed. These details were adopted, and the results obtained were excellent.

Some difficulty having occurred in procuring the chloride of iron, a solution was prepared on the works of 9.400 grains per gallon. A fit of economy then led the authorities to reduce the quantity to 0.006 grain of chloride of iron and 5.88 grains of lime per gallon, quantities manifestly insufficient, under which treatment it was seen and reported on by the Rivers Pollution Commissioners.

For a short period combinations of lime and salts of iron were used both at Clifton and Cheltenham.

Having now dealt with the various precipitants suggested, to throw down the suspended matter and coagulate a part of the dissolved slimy organic matter of sewage, let me note that these precipitants, for practical purposes, are lime, chloride of magnesium, sulphate and phosphate of alumina, and salts of iron, alone or in conjunction with each other.

In addition to these, clay and other

weighting bodies, together with charcoal and other absorbent substances, have been added under various patents.

In selecting a chemical precipitant, five main points present themselves to us:

1. That, consistently with purity of effluent, the chemicals used should be cheap.

2. That the precipitant should act as a deodorizer and disinfectant as well as a precipitant.

3. That the precipitated matters should subside rapidly.

4. That the maximum purity should be obtained with the minimum of deposit, in other words, with the smallest quantity possible of chemicals.

5. That the sludge should part with its water readily.

I now approach the really practical question, asked all over the country, from every sanitary authority, often in tones of painful despair, viz., *How shall we deal with our sewage?*

And here let me say there is no one answer that can be given to this question. The adviser, to advise fairly, must be prepared to sink his hobby, be it the hobby of precipitation or the hobby of irrigation, remembering that whilst conditions favorable to his hobby may exist at one place, conditions absolutely unfavorable may exist at another. Further, it is of no use telling how some pet plan, say, of irrigation or of precipitation, has succeeded at some one place or another, persuading local authorities to undertake a pilgrimage of inspection (although they are usually ready enough to do so), and arguing that because such and such plan has succeeded at A, therefore it will succeed at B. There is no universal remedy for the sewage difficulty, and no one plan of treatment to be laid down.

When people say, "The whole thing is easy enough, only do this or do that," be certain they have not grasped the difficulties of the subject, and, I fear, know little about it.

Let me attempt, however, to suggest certain fundamental propositions that may serve as a starting point in advising local authorities:—

1. Towns must be prepared to pay to be clean. You will never be able to make your sewage pay your rates;—on the contrary, experience shows that you must purify your sewage at the expense of the rates.

2. That health demands that your sewage should be got rid of, and purified at any cost. Minimize the cost, but pay you must for purification. Hence you must be prepared not only to borrow money to erect works, but for an annual expenditure after the works have been erected.

3. That no matter how perfect your works, your sewage will require constant attention, Sunday as well as week-day, night as well as day.

4. That to let unpurified sewage pass into a stream means passing your filth on to your neighbors. Sewage ought to be treated where the sewage is produced, as far as it is possible. And considering this aspect of the subject, let

me add, litigation is a more expensive luxury than sewage treatment, and breeds, if possible (although on this I admit a doubt), more ill-will.

5. That although our duty is to do our work well, at as small a cost as possible, we neither require (*quâ* the effluent) to produce a drinking water, nor (*quâ* the sludge) to produce Peruvian guano.

Our sewage has to be treated. We shall necessarily inquire how much sewage there is to treat, and what kind of sewage it is.

Let me suppose that our first thought is the possibility of an irrigation scheme.

Far be it from me to say that irrigation may not prove successful. But it is fair to note that, to attain the end of a sanitary authority, experience has shown that the sanitary authority must itself be the proprietor of the land. If you give the sewage to the farmers (supposing they would accept your gift) the interests of the local authority and of the farmers are opposite. For it is manifest that the interest of the farmer is his crops, whilst the interest of the local authority is the purification of their sewage. The local authority, as a sanitary authority, must demand a pure effluent at all times, in winter and in wet seasons as well as in summer and in dry seasons. Between these divided interests of farmer and sanitary authority, the question of purity of effluent may, and in our experience usually does, fall to the ground. Hence, if irrigation is to be adopted, the local authority must provide its own land for the purpose.

Sundry questions at once arise:—

1. Is it practicable to obtain *sufficient* land, and land *properly constituted* as regards general character, level, etc., for irrigation purposes? Let me note that the word "sufficient" is not capable of precise definition. What is sufficient in the case of one kind of land is insufficient in the case of another. What is sufficient land with one kind of engineering treatment, and with one kind of sewage, would prove insufficient with

another kind of engineering treatment and another kind of sewage.

2. Is this properly constituted land reasonably *near* to the town, so that the cost of conveying the sewage to the land will not be excessive, but at the same time reasonably *distant*, so that the town may not derive injury from the nuisance likely (we might almost say certain) at times to result?

3. Is the land of such a level as to necessitate pumping? Is it near a water-course, canal, railway, etc.?

Let me suppose these questions answered satisfactorily. A very serious further question has now to be considered, viz., where is the effluent to be discharged?

The importance of the question is this. In all irrigation schemes, of whatever nature, we are dependent for effective purification, on effective land, in effective order. The action of land may become ineffective from circumstances over which we have no control, viz., *frost*, where the ground may become absolutely impenetrable, and *water-logging*, in times of heavy rains, when the sewage is in far greater quantity than normal, and for a time at least more foul than normal, from flushing of the sewers.

Hence, if the outfall is into a river where considerable purity, and unfailing continuity of purity, is demanded, an irrigation scheme is, to say the least, unsafe. If, however, the discharge be into the sea, or into a tidal estuary, or into a stream where the occasional discharge of a little doubtful water is unimportant, an irrigation scheme, pure and simple, may pass muster.

To secure land for a sewage farm (even after the proper land has been found) is not an easy matter. It often means a fancy price. It means, too, a mass of opposition from adjoining property holders, who suddenly discover that all the fields in the vicinity of the land selected are building ground.

I do not mean this as an objection peculiar to land required for irrigation purposes.

Another matter has to be considered. If land be taken on lease for a sewage farm, its renewal may prove difficult. The lease of the Croydon farm expires in 1892.

I will at once admit that my own experience has led me to the opinion that greater advantages result from a combined process of precipitation and irrigation than can be obtained by either method independently, admitting as I do to the full, that a good effluent may be obtained by a precipitation process alone, nearly as good, in fact, as any effluent that can be obtained by irrigation. A precipitation scheme by itself has these two enormous advantages over irrigation, viz. (1) its efficient working is totally independent of weather, and (2) that, if sufficiently large works be erected, any emergency of quantity can be met. Precipitation has had its greatest enemies in its most earnest advocates. Extravagant advantages have been claimed for it. The sludge has been advertised as of enormous manurial value. Patents by the hundred have been taken out. Precipitation advocates have been for the most part advocates of a system in which they are interested. And there is no wonder that distrust in precipitation schemes have arisen, when the *claims* put forth by enthusiasts and patent-mongers have been weighed in the balance against the *facts*, and found wanting.

Supposing, then, we determine on a precipitation process, there arises the first great question, *what precipitant shall be used?* Here two points must be considered. At any rate it will not be disputed:—

1. That, consistently with efficiency and purity of effluent, the chemicals should be cheap.

2. That the smallest quantity of chemicals that experience proves is capable of doing the work properly should be added to the sewage, so as to minimize the quantity of sludge formed.

I am anxious to be in no sense the advocate of any one system of precipitation. I will admit, however—the process now is not a patent, and if it were I should speak with greater caution—that the A B C turns out the best effluent with which I am acquainted. My own experience leads me to speak very highly indeed of the combined use of lime and sulphate of alumina. The quantity of lime which is to be added first should be such as to render the sewage faintly alkaline. Probably at the rate of from five to seven grains per gallon will be needed for this purpose. It should be added as milk of lime, and should be thoroughly stirred in by means of a paddle-wheel, or other efficient mixer. A flow of a few yards should now be allowed, to permit the aggregation of the precipitate. This having taken place, a solution of crude sulphate of alumina, in the proportion of about five grains of sulphate of alumnia, is to be added, and the sewage again actively stirred. In the alkaline condition of the sewage, the alumina will be precipitated, and will then combine with a portion of the organic matter, forming together an insoluble precipitate. Thus treated, the sewage should be allowed to flow into tanks for the precipitated matters to collect.

Let me attempt to indicate the effects of such treatment. A portion of the lime will be at once converted into carbonate of lime, by combining with the carbonic acid present in the sewage, and serve as a weighting material to aid in the deposition of the lighter flocculent materials. This mechanical action of the lime carbonate is of great importance. The flocculent suspended matter is no doubt one of the most important materials to remove, because it is that ingredient of the sewage which readily putrefies, and in this way causes a nuisance. It is, moreover, so light that, unless weighted, it is difficult to precipitate. A second portion of the lime combines with some of the organic matter in solution, producing an insoluble precipitate (of uncertain composition) of a compound of lime and organic matter, the subsidence of which is again assisted by the formation of the carbonate of lime previously described. A third portion of the lime renders the sewage slightly alkaline.

The alumina salt is now to be added. The alumina is precipitated, owing to the alkalinity effected by the slight excess of lime. This alumina combines with some of the organic matter in solution, not precipitated by the action of the lime. The power of alumina in combining with dissolved organic matter, and so removing it from solution, is taken advantage of in many commercial processes.

Respecting the iron salts, one strong objection to their use is, that if the effluent be discharged into a river, the stream is liable to be blackened from the formation of a sulphide of iron, a condition likely to be mistaken by the general public for a sewage deposit. I have, therefore, of late, admitting the value of iron compounds as precipitants, hesitated to recommend their use, save under very exceptional circumstances. As regards the use of phosphates as precipitants, the effluent is almost certain to contain some phosphoric acid, which greatly aids the growth of low forms of fungoid growths, amongst which may be included the so-called sewage fungus.

It is advisable that the effluent, before its discharge into a stream, be at least neutral and preferably slightly acid. This condition is easily brought about by the addition of a small quantity of acid to the effluent before its escape.

The effluent, after treatment, will no doubt have a slight odor. This is not, however, a sewage smell. If in this condition of comparative purity—indicated by absence of color and freedom from suspended matter—it be allowed to flow over and through a small area of land (a loamy sand or gravel by preference) to serve as a chemical filter, high degree of purity may be obtained, and the finer finishing touches of purification effected.

The evils of irrigation under such circumstances do not arise. Such a filtration of the effluent (1) cannot produce a nuisance, because it contains no foul suspended matters to collect on the surface and putrefy; (2) it cannot clog the ground because the gelatinous and *papier maché* matters in solution have been removed; whilst (3) it has a certain manurial value, the quantity of ammonia in solution being not much less than that of the original sewage.

Again I may quote from Dr. Monro's paper, who, it will be remembered, doubts the advisability of ordinary irrigation as a general process, on account of impervious deposits choking the pores of the land. He says, "The removal of the suspended matter, however, from the sewage, renders irrigation much more practicable. With a clear effluent and a porous soil, the nitrifying power brought into play is enormous, and a moderate area of soil, whether of grass land or arable, can deal with large and almost continuous doses of sewage water." Dr. Monro points out that the presence of objectionable organic matter is as destructive to nitrification as the clogging of the pores of the soil, or a great lowering of temperature.

The following table will give some idea of the cost of chemical treatment of water-carried sewage.

I may be asked what quantity of land is needed where sewage has been efficiently precipitated. Again the answer will depend on the nature of the land. But if I say an acre to every 5,000 to 7,000 people, I am well within the results of my experience.

Sewage works of the kind I have mentioned can be carried out without the slightest nuisance. The mixing should be done in closed wells. The mixture, as it flows into the tanks, should, if sufficient chemicals have been used, be as free from odor, at the distance of a few feet from the mixer, as common water. The land cannot possibly produce noxious effluvia or poisonous vapors, because the sewage has already been treated with antiseptic precipitants.

Of course all depends on the treatment having been efficient. Success in the treatment of sewage obeys the same laws in this respect as success in anything else.

TABLE showing that the Cost of Chemical Treatment of Water-carried Sewage at the outfall varies according to the foulness of the Sewage operated upon, and that such cost is influenced by the number of Water Closets in use. It will be observed that Water Closets increase the cost of Chemicals at the outfall and lessen the cost of cleansing Privies, Pails, or Middens, but that this increased cost of Chemicals is less than that thrown on the rates by the cleansing and removal of the contents of Privies, Pails, or Middens.

Name of Process.	Where used.	Population.	Number of water closets in use.	Number of privies or middens, etc., in use.	Quantity of refuse removed yearly from privies, middens, etc.	Annual cost of emptying privies, middens. etc.	Cost per Million Gallons for Chemicals.	Cost per head per annum for chemicals.	Cost per head per annum for emptying privies, etc.	Tot. cost per head per an. for chemicals and emptying privies, etc.
						£	s. d.	d.	d.	d.
Alumina, iron, etc...	Coventry	42,000	6,000	150	7,000 loads	1,050	19 10	4½	6	10½
Alumina, iron, etc. sewage if dye were absent..	Coventry	42,000	6,000	150	7,000 loads	1,050	12 6	3	6	9
Precipitation by Lime and Coke Filtration.... ...	Bradford	197,000	10 per ct.	90 per ct.	56,200 tons	8,000	11 0	2	9¾	11¾
Lime process........	Leeds	320,000	13,720	43,000	80,000 loads	12,333	10 9	1½	9½	11

From the above table it will be seen that if the proportion of water closets at Bradford and Leeds was larger, the cost of chemicals at the outfall must be considerably increased. If on the other hand the proportion of water closets at Coventry was as low as it is at Bradford and Leeds, the cost of chemicals could be considerably reduced, and would probably not exceed 8s. or 9s. per million gallons. From this it will be seen that alumina treatment, such as that employed at Coventry, is cheaper than lime treatment; and it has already been shown by official investigations, that lime treatment and its modifications are not as efficient as, or equal in sanitary results to, alumina treatment. It is, moreover, still more expensive than is shown in this table, because of the fact that it produces twice the quantity of sludge as alumina treatment does, the dealing with and disposal of which is a very costly matter, particularly as it is practically useless as a manure, and not so readily saleable as that produced by alumina treatment.

I am desirous here of pointing out certain details of treatment essential for the success of a precipitation process:—

1. It is necessary that the sewage treated should be *fresh*—by which I mean sewage in which active putrefactive changes have not taken place. Perhaps, speaking generally, the sewage should not be more than 48 hours old for effective precipitation. But it is certain that, with a sewage of not more than 24 hours old, a far better result, with a smaller amount of chemicals, can be obtained. In fixing, however, the time, a certain elasticity must be allowed, an elasticity by way of extension in winter and of compression in summer. I have said the treatment should be effected *before* active putrefaction commences. In sewage, the decomposition of the different constituents takes place at different times, in some cases the periods of active change being separated by periods of practical rest. Thus a certain alteration in sewage takes place almost immediately. This results (amongst

other changes) in the breaking up of the urea, and the formation from it of carbonate of ammonia. It is a rare thing indeed for any sewage, when it reaches the sewage works, to contain more than a trace of urea. No nuisance results from this change of the urea. A considerable interval occurs before any other putrefactive stage occurs, and it is during this interval when the precipitation should be effected. If this period be allowed to pass, increased difficulty in working results.

2. The straining of the sewage before treatment, in order to remove rags, corks, and the various *et ceteras*, such as dead rats, walking sticks, etc., that come down along with the sewage, is advisable but not essential, in order to prevent accumulations on the surface of the tanks. Fixed wire gratings are objectionable, on the ground of their becoming so easily choked. Baldwin Latham's extractor is employed in several places with success.

3. It is essential that sufficient chemicals be employed to effect complete pre-

cipitation, disinfection, and deodorization of the sewage.

No greater mistake can be committed than to starve the chemicals. To this must be attributed many cases where a precipitation process has proved a failure. A local authority will spend a large sum in erecting works, perfect in architectural detail, excellent for sewage treatment, whilst they shirk a small annual payment for the necessary chemicals. I need scarcely point out that efficient works will not purify sewage. They are but the means to an end. It is better to calculate the amount of chemicals to be used on the population than on the quantity of sewage.

4. It is essential that after the chemicals are added, the mixture should be well stirred. The chemist understands the value of the stirring rod in order to effect perfect chemical contact. My own experience is that the chemicals added to sewage are often wasted from insufficient stirring. Not only is it the case that they do not precipitate so much as they

might, but the process of flocculation is imperfect, and the difficulty of obtaining a clear effluent correspondingly great.

5. It is essential that there should be sufficient tank accommodation. Let me note sufficiency of tank accommodation is necessary for two reasons—(1) That the precipitate may subside perfectly, and leave a clear colorless effluent. Shallow tanks, with considerable velocity of sewage through them, or insufficient tank accommodation, means imperfect subsidence. Imperfect subsidence means the discharge of a certain quantity of flocculent organic matter in the effluent (the mineral matter being more likely to be deposited from its greater specific gravity), and which flocculent matter is likely to occasion nuisance from its decomposition. The treated sewage should flow through at least two subsiding tanks in series, the first being capable of holding one hour's flow, and the second not less than four hours' flow. The tanks should be at least four feet deep, and the overflow of the defecated sewage should be

over a weir, not more than an inch below the surface. There should be a double set of tanks for successful working.

(2) Sufficiency of tank accommodation is also important, so that the sludge may be frequently removed, otherwise the freshly precipitated sewage may be contaminated by the decomposing materials of a previous precipitation, or a nuisance result from a collection of decomposing matter. Many a good effluent is spoilt by foul materials being allowed to collect in the subsiding tanks. These materials undergo putrefaction, the gases given off contaminating the effluent. The solid matters, becoming specifically lighter than the liquid by the gases of putrefaction developed in and amongst them, rise to the surface, the floating black masses presenting an objectionable appearance, and discharging offensive products into the air. After a time these black masses sink, and thus, by constant commotion of the precipitated matters, a turbid effluent, with a more or less foul smell, results.

6. That the defecated water should flow through a shallow open conduit of not less than a quarter of a mile before being discharged into the stream.

7. The stream into which the effluent is discharged should have a free run, and in volume be not less than eight times the volume of the defecated sewage.

8. That the tanks themselves should not only be emptied of the sludge, but thoroughly cleansed before being refilled.

The extent of tank accommodation needful will depend a good deal on the dilution of the sewage to be dealt with, either by subsoil or surface waters, or by both, and whether the treatment employed be intermittent or continuous. The following gives the tank capacity provided at certain successful works:—

PRECIPITATION TANK CAPACITY.

Place.	Treatment.	Population.	No. of tanks.	Capacity in gallons.	Gallons per head.
Bradford..	Intermittent................	200,000	34	612,000	3.06
Coventry..	Intermittent and continuous.	45,000	8	1,000,000	.22
Hertford..	Continuous.......	7,747	6	318,000	.41
Leyton ...	Continuous.................	40,000	4	1,000,000	.25

The most suitable depth for tanks is from 5 to 6 feet.

It may be worth noting the rate at which the precipitated matters deposit when the treatment with lime and sulphate of alumina is efficient, and the sewage collected in tanks of 5 feet 6 inches. The water begins to clear a few minutes after the cessation of agitation. In thirty minutes it clears to a depth of 3 feet, with 8 inches precipitate, while after two hours the precipitate will measure 4½ inches only.

All this accomplished, two questions remain: (1.) Have you produced such an effluent that it will not pollute the watercourses? (2.) Is not the sludge certain to cause a nuisance?

That a clear, colorless, non-frothing effluent can be produced by mere chemical precipitation, is not a matter of opinion, but of fact. That an effluent absolutely without smell can be produced, I doubt. The smell, however, of the effluent from properly treated sewage is not the odor of sewage. I have never, I candidly confess, found an effluent without a certain smell. I have heard a well-known authority ascribe it to the presence of minute traces of essential oils or strong smelling bodies (*e.g.*, onions), difficult of removal by precipitants. If the effluent is to be discharged into the sea, or into a tidal or large river (say 200 or 300 times the volume of the effluent), this odor is absolutely immaterial; but where great purity is required, *e.g.*, when the effluent has to be discharged into a small stream or into a river employed at a short distance from the outfall for drinking purposes, some further treatment is called for.

Such further treatment consists either (1) in the use of artificially prepared filter beds, such as are used for the filtration of water, or (2) by filtration through a small area of land.

Of these two methods, I prefer the latter. After careful consideration, I consider that for this purpose an acre to every 5,000 to 7,000 people (as I have before noted) is abundant. I shall not discuss any question of manurial value, although I may point out that the ammonia of sewage is not appreciably affected by ordinary chemical precipitants.

(2.) Is not the sludge an inevitable cause of nuisance? I confess it may be, and often has been. Allowing the sludge to accumulate week after week in the depositing tanks, is not only an evil (as I have pointed out) so far as our endeavors to procure a good effluent is concerned, but an unmitigated nuisance, so far as relates to the sludge. Further, the old method of emptying the sludge into open sludge pits, where the liquid portion was allowed to drain away and to evaporate, has proved a constant cause of just complaint, more especially in warm weather. I am not sure whether the sludge, under these conditions, was not sometimes a greater nuisance after being taken out of the sewage than when left in it. Until lately the difficulty of the disposal of the sludge was one inherent to all precipitation works. Until lately I said—because now the difficulty is overcome.

It is essential, both in the interests of the effluent and of the sludge, that it should be frequently removed from the tanks—I mean that the sludge should be removed before putrefactive decomposition sets in. This frequent removal is necessary (1) so that the effluent may not be polluted, and (2) so that no nuisance may result during the removal of the sludge and the cleansing of the tank. For here I must express a strong opinion that it is not enough merely to empty the tank of sludge, but it is imperative that, after being emptied, and before being refilled, the tank should be well cleansed—in other words, that the matters which stick to the sides of the tank should be completely and efficiently removed to prevent nuisance or fouling by subsequent decomposition.

It would be outside my province to deal with the methods of raising the sludge out of the tanks. This is a purely mechanical question. The sludge is a thick black liquid, which may be pumped out of the tanks or lifted out by bucket pumps into troughs, which serve to convey it wherever it may be wanted.

I am indebted for the table on page 199 to the manager of a sewage works in a residential neighborhood of a population of 18,000. The process used is lime and sulphate of alumina. The sewage is pressed in one of Johnson's presses:

The record of sludge begins on February 16, 1885, and ends on February 16, 1886. The wet sludge is got by a series of eighty different actual measurements on various days throughout the year. The pressed sludge is got by keeping a record of the number of times the presses were emptied on every day in the year. A cubic yard of wet sludge is taken as weighing .98 of a ton, and a cubic yard of pressed sludge as weighing .75 of a ton (actual determinations).

The following details are taken from Mr. Lacey's report to the Brentford Local Board, on "The Disposal of Sewage Sludge." (See page 200.)

Sludge.	Amount per day in tons.	Amount per annum in tons.	Amount per million gallons of sewage in tons.	Amount per million gallons of sewage proper in tons.	Amount per head of population per annum in cwts.	Cost per ton.
Wet......	33 75	12,319	44.53	67.5	13.7	10d.
Pressed...	6.04	2,205	8	12	2.45	4s. 7d.

THE DISPOSAL OF THE SLUDGE AT VARIOUS TOWNS.

I. Left to dry in open pits, and given or sold to farmers.	II. Run on land, or dug in and deposited.	III. Mixed with house refuse and given to farmers, or used on own land	IV. Partly air dried, and burnt in kiln.	V. Dried, and made into cement.	VI. Pressed in filter presses.	VII. Mixed with house refuse and burnt in destructor.
Atherton, 12,602.* Bacup, 25,034 Burton-on-Trent, 41,500. Chester, 37,000. Ely, 8,171. Derby, 89,690. Leicester, 130,000. Luton, 28,000. Over Darwin, 36,000. Twickenham, 13,200. Taunton.	† Birmingham, 605,000. Redditch, 10,500. Royal Leamington Spa, 24,000. Walthamstow, 30,000. Windsor, 12,500.	Epsom, 8,000. Northampton, 55,000. Wellingborough, 14,000.	Salford, 180,000.	Burnley, 68,000.	‡ Croydon Rural, 25,000. § Coventry, 47,000. ‖ Leyton, 38,000 ¶ Wimbledon, 20,000. **Chiswick	Ealing, 18,000.

* The number after each town is the estimated population.
† 479 cubic yards daily; 1 acre of land used weekly; treatment repeated every third year.
‡ Sold at 1s. 6d. per ton.
§ Cost of pressing per ton of cake 2s. 6d. Sold at 2s. 6d. per ton.
‖ Cost of pressing per ton of cake 1s. 8d. Cleared free of cost.
¶ Cost of pressing per ton of cake 3s. 6d. to 3s. 9d. Sold at 1s. per ton.
** Cost of pressing per ton of cake 3s. 4d.

It will be convenient at this point to consider the amount of sludge produced, its value as a manurial agent, and the method suggested for its disposal.

I.—Amount of Sludge.

The quantity of sludge varies enormously, according to the amount of sewage, and the precipitants employed. Thus, at Coventry the sludge from 1,000,000 gallons is about 12.5 tons, whereas at Birmingham it varies from 25 to 33 tons.

The quantity of sludge produced from a given quantity of sewage will vary according to local circumstances and conditions; such for instance as the character of the soil, the condition of the streets and roads, whether surface water be wholly or in part admitted to or excluded from the sewers, whether manufacturing refuse is included in the sewage to be treated, whether or no the w. c. be in general use, and whether the process of precipitation be complete and efficient or only partial.

In a town where w.c.'s are in general use, where the soil is of gravel and sand, where surface water is partially admitted into the sewers, where there are no manufactories, and where precipitation is well and efficiently done with chemicals of modern bulk, the proportion of pressed sludge containing 50 per cent. of moisture, may be taken at .6 (six tenths) of a pound per head per day, or about 2 tons, 14 cwt., daily per 10,000 of the population.

The principle is right:—Consistent with efficiency, produce as little sludge as practicable; and this for two reasons —(1) that if it has any value, you secure its maximum value; whilst (2) if it has no value, you have the less to get rid of. Thus with some precipitants you get a large volume of valueless sludge. With sulphate of alumina you get comparatively little sludge, but a material of greater value. Of course it may be argued that the more sludge you obtain, the more perfect has been the removal of the impurities of the sewage. This may or may not be true.

II.—Composition and Value of Sludge.

I am anxious at once to say that I place no intrinsic value on the sludge whatsoever. An estimate of the value of sludge from different places has been given on high authority, but it is better to regard the sludge as a thing to be got rid of, and as a thing which, to be got rid of, must cost money and may not bring money. The following table of the analyses of sludge from various places, and by various methods of precipitation, have been given by Dr. Wallace as follows:

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	Lime. 2	Lime & 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, etc	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	.75	1.21	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	1.97	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	99.16	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
Calculated value per ton	s. 33	s. d. 10 9	s. d. 11 5	s. d. 13 4	s. d. 15 1	s. d. 15 4	s. 20	s. d. 27 2	s. d. 14 2	s. d. 17 2	s. d. 21 7	s. d. 11 5

A table by Dr. Voelcker on the estimated and market values of one ton of sludge from places stated is here given:

ESTIMATED AND MARKET VALUES OF ONE TON OF SLUDGE FROM PLACES STATED (VOELCKER).

	Estimated or theoretical value.*	Practical or market value.†
	£ s. d.	s. d. s. d.
1. Bolton sludge (M and C process)	0 9 8½	3 3 to 4 10
2. Bolton sludge, 15 per cent. of moisture	1 1 1	7 0 to 10 6
3. Bradford sludge before lime was added	0 11 0½	3 8 to 5 6
4. Bradford sludge with 15 per cent. of moisture	0 19 3	6 5 to 9 6
5. Bradford sludge after treatment with lime	0 4 8	1 6 to 2 4
6. Bradford sludge with 15 per cent. of moisture	1 0 0½	6 8 to 10 0
7. Aylesbury, A B C sludge	0 8 4½	2 9 to 4 2
8. Aylesbury, A B C sludge with 15 per cent. of moisture	0 16 8½	5 6 to 8 4
9. Coventry sludge of General Sewage Manure Co.	0 16 9½	5 6 to 8 4
11. Rochdale Manure	0 15 11¼	5 4 to 8 0
12. Halifax manure by Goux's process	0 17 7	5 10 to 8 9

* Calculated on the supposition that phosphate of lime is worth 1d. per lb.; potash, 2d., and nitrogen (as ammonia) at 8d.

† By this is implied its value as compared with good farmyard manure, which has a theoretical value of 15s. 7d., its market value being from 5s. to 7s. 6d. per ton.

The old system consisted in merely placing the sludge in pits, and allowing it to air-dry. In this condition it was sold or given to the farmers. I may mention here that a sludge containing 90 per cent. of moisture can be reduced to 80 per cent. by forty-eight hours' draining, to 75 per cent. by three days' draining, and to 71 per cent. after a week's draining. After this, air drying is comparatively slow, although no doubt the admixture of porous substances would render drying more rapid and more complete.

III.—Disposal of the Sludge.

1. *Johnson's Process.*—By this process the liquid portion of the sludge is extracted by pressure in a series of compartments. Each compartment is provided with a canvas cloth, which acts as a strainer, and retains the solids as the liquid passes through. The sludge is driven into the compartments by compressed air, 100 to 120 lbs. per square inch, until they can hold no more. On

opening the press, a solid cake of compressed sludge is found in each compartment. The cake is compact, easily handled, and practically has no smell. It has a certain manurial value.

It is worth while to consider a few details of pressing. The sludge, as precipitated, contains on an average 90 per cent. of water, whilst the pressed sludge cake contains 50 per cent. By simple air drying, the 50 per cent. of moisture may be reduced to less than 20 per cent. Thus in every ton (2,240 lbs.) of unpressed sludge, 2,016 lbs. is moisture, and 224 lbs. solid matter. After pressure, the 224 lbs. of solid matter holds about 224 lbs. of moisture, the removal of 1,792 lbs., or about 179 gallons, of water having been effected. The time occupied in the compression of 5 tons is about one hour. The sludge cake, according to Monro, contains from 0.6 to 0.9 per cent. of nitrogen, and over 1 per cent. of phosphoric acid. It has been the practice to run back the liquid expressed from the sludge into the sewer, to be retreated. Professor Dewar and myself have pointed out that this course is unadvisable. The liquid thus expressed is exceedingly foul, although perfectly clear, and does not readily lend itself to ordinary chemical precipitation. I will merely note that it requires separate treatment, and that our experiments indicate that chloride of lime or perchloride of iron in larger amount than is required for ordinary sewage may be rendered effective for the purpose.

The manurial value of the pressed sludge cake from Coventry, Leyton and West Ham, has been the subject of careful investigation by Dr. Monro, from whom I have abstracted the percentage details of experiments on the dried sludge given in the following table:

PERCENTAGE DETAILS OF EXPERIMENTS ON THE DRIED SLUDGE.

	Coventry sludge dried. Precipitants, lime and sulphates of alumina and iron (filtration).	Leyton sludge dried. (Precipitants like Coventry.)	West Ham sludge dried. (Precipitants sulphate of alumina and lime.)
Organic matter	26.14	26.08	40.32
Containing nitrogen	1.36	1.35	1.82
Potash	0.30	0.34	0.22
Total P_2O_5	2.43	2.04	2.57
Soluble P_2O_5	1.37	1.69	1.24

The phosphoric acid in sewage sludge is chiefly in combination with alumina. Dr. Monro notes that whilst Coventry sewage contains much manufacturing refuse from dye-works, and West Ham sewage the refuse from industries of a most varied and polluting character, Leyton is a rural and suburban district, having no manufactures of any kind contributing to the sewage.

Dr. Monro has practically tested the agricultural value of these pressed sludge cakes, for the details of which the reader is referred to his original paper. Good crops of swedes were obtained. The three sludges gave almost identical results as regards yield. The following were the results obtained by him with different dressings for comparison:

RESULTS PER ACRE.

	Tons.	Cwt.
1. 10 to s farmyard manure.......	13	11½
2. 4 cwt. superphosphate.........	11	2¼
3. 5 tons Leyton sludge...	10	4
4. 5 tons farmyard manure........	10	1½
5. 5 tons West Ham sludge.......	9	8½
6. 5 tons Coventry sludge.........	9	6½
7. 2 cwt. superphosphate with 2 cwt. of nitrate..............	9	5¼
8. 2 cwt. superphosphate....	9	4¼
9. 2 cwt. coprolite................	8	15½
10. 4 cwt. coprolite....	7	10
11. Unmanured..................	5	18

From these details it is evident that the air-dried filter-pressed cake has a certain manurial value—at any rate, about equal to farmyard manure—which possibly, considering how easily it may be stored without causing a nuisance, may be worthy of being considered more fully than it has at present. It is worth noting that although the newly pressed cake is richer in nitrogen than farmyard manure, and contains more than double the amount of phosphoric acid, still that the manurial value is not greater, weight for weight. This Dr. Monro explains by differences of physical condition, viz., the loose texture of farmyard manure compared with the compact condition of the sludge cake; the physical state of the one being as favorable to rapid oxidation and disintegration as that of the other is unfavorable. To overcome this difficulty, Dr. Monro suggests the reduction of the cake to a fine state of subdivision.

The cost of procuring the sludge is stated by Mr. Hutchinson (to whose excellent paper I must refer) as from 2s. to 2s. 6d. per ton at Coventry. I have no records as to what the further cost of grinding would involve.

The Johnson process is at work at Croyden Rural, High Wycombe, Coventry, Leyton, Blackburn, and Aylesbury.

(2.) *Major-General Scott's Process.*—This is adopted at Burnley. The lime precipitated sludge (*i. e.*, lime and organic matter) is drained until it contains about 65 per cent. of moisture. The sludge at this stage is tested as to the amount of lime present, more being added if necessary. The mass is now dried by heat, and finally burnt in kilns. The residual clinker is ground, and used as an hydraulic cement (Portland cement). The cement is said to have a tensile strength of 350 lbs. per square inch after immersion in water for seven days, and to be worth 35s. per ton.

It is evident that the composition of sewage sludge varies not only in different towns, but in the same town at different times. It is not quite clear how far this process can be worked so as to secure that which engineers know to be so important, viz., a cement of constant character. (See paper by Granville Cole, Ph.D., Society of Arts Conference, 1879, p. 137.)

The cost of drying is 7s. per ton. The coke employed for burning averages 1s. 4d. per ton, and the labor, etc., 15s. per ton.

Major Scott has suggested that in the case of the London sewage both a manure and a cement might be prepared.

In the *Journal of the Society of Arts*, November 28, 1879, he suggests, in the treatment of sewage, that the primary separation of the coarser mineral suspended matter should be effected in a first tank, a sufficient period of rest being afterwards allowed for the subsidence (not the artificial precipitation) of the lighter suspended matters in a second tank. The sludge of this second tank (*i. e.*, after the watery portion has been drawn off) is to be treated with about two-thirds its weight of milk of lime, sufficient superphosphate being afterwards added nearly to neutralize the lime. (The superphosphate is to be prepared by mixing 20 cwt. of Cambridge coprolites with 17 cwt. of brown sulphuric acid, sufficient water being added to render the mixture almost fluid). By this treatment the mixture (he states) becomes surprisingly inodorous, and dries with rapidity. The cost of chemicals he values at 16s. 6d. per ton of prepared manure, its removal from the tanks and subsequent drying being 3s. 6d. He considers it worth £3 10s. per ton. The sewage or liquid portion of the second tank, from which the organic matter has been recovered, is then to be treated with lime, and the precipitate thus obtained made into a cement.

Major Scott seems to have overlooked the difficulty of effecting precipitation of the suspended matters of sewage (such as he is desirous of obtaining in the second tank) without the use of precipitants. Further, a limed sludge, when dried, is certain to lose ammonia, in other words, is certain to lose manurial value.

The deposit in the first tank Major Scott proposed should be burnt in a destructor with waste cinders, and be used to reclaim a portion of the marshes. At any rate (he justly considers) it ought not to be allowed to pass into the river.

(3.) *Destructor.*—The destructor has been carried to its greatest state of perfection at Ealing, under the ingenious and careful management of Mr. Charles Jones. In this case, however, the ashes of the district are mixed with the sludge. The chemicals used for precipitation are 11.5 grains of clay and about 10 grains of lime per gallon, a little iron and alumina being also used. The sewage treated comes from a population of about 18,000, and is equal to 600,000 gallons daily. About 157 cubic yards of sludge are obtained per week. This is mixed with about 100 cubic yards of ashes and house refuse. Before the mass is burnt in the destructor, about 25 per cent. of the liquid portion is allowed to drain away.

It may be advisable here to note the

difficulties that have been met with generally in the use of destructors:

1. An escape of vapors that prove more or less offensive at a considerable distance from the shaft. This depends on the materials having undergone incomplete burning, in other words, that the materials in the destructor have been subjected to destructive distillation (in which case the products, consisting of various empyreumatic vapors, are offensive), rather than combustion, in which case the products would be simply water and carbonic acid, and inoffensive. No doubt, until lately, the escape of unburnt and partially burnt vapors, a very small quantity of which sufficed to cause a nuisance, have proved a serious objection to the use of destructors.

2. The escape from the shaft of unburnt or partially charred paper, fine sand, etc., at certain stages of the process.

I do not hesitate to say that both of these difficulties are met in Jones' destructor. This has been done by mixing the sludge with the house ashes, thus assisting effective combustion. Mr. Jones lays down that every town supplies sufficient house refuse to burn its sludge. The main point, however, on which he relies, is the construction of a muffle furnace (a fume destroyer, as he calls it) between the furnace and the main shaft. As a result, not only is a greatly increased draught secured, but the combustion of unburnt vapors discharged from the furnace in which the sludge is placed is secured. I may add that Mr. Jones informs me that the muffle furnace is kept going at a cost of 1s. 6d. per day, but that this, in addition, gives 10 lbs. of steam for engine purposes. He obtains, as a residuum from the furnace, 25 per cent. of hard clinker, which is utilized in various ways, viz., for artificial stone, road-making, etc.

Various suggestions for what may be called fortifying the sludge have been suggested. Thus, Colonel Jones, of Wrexham, after drying the sludge to 20 per cent. of moisture, adds to every 12 parts 7 parts of raw bone meal and one part of sulphate of ammonia.

I do not propose discussing other suggestions for the disposal of sludge, such as the separation of the water by centrifugal machines—converting the sludge into a fuel by admixture with other waste products—its conversion into a combustible gas—making it into bricks, etc. (Monson). These suggestions are scarcely practical.

The question of cost must be considered in conjunction with (1) the quantity of the sewage, (2) the quality of the sewage (that is, the nature of the sewage other than mere excreta), (3) the flow per head, and (4) the standard of excellence required.

As regards quantity, I wish to say that you cannot apply the cost of treating small volumes of sewage to the cost of treating large volumes, the treatment of the former being more easily effected than the latter.

Prices of Chemicals.

Green copperas or proto-sulphate of iron can be obtained for about 20s. per ton.

Lime can be obtained from 10s. to 15s. per ton.

Sulphate of alumina can be obtained from 46s. 6d. per ton, as per following analysis :—

Moisture	5.94
Crystallized sulphate of alumina	77.44
" sulphate of iron	4.00
Sulphates of alkalies and sulphuric acid	6.82
Insoluble iron and alumina	5.80
	100.00

The annual cost of thoroughly and efficiently treating the sewage of Coventry, pressing the whole of the sludge etc., exclusive of interest on plant, land, and depreciation—the population contributing being 45,000 persons, and the sewage containing large quantities of dye and manufacturing refuse—is £2,800 per annum, an amount equal to 1s. 3d. per head.

The cost at Hertford, where the sludge is not pressed, and manufacturing refuse is absent, with a population of 7,747, is £570 per annum, equal to 1s. 5½d. per head.

A few words only on the analysis of sewage. No single analysis of a sewage effluent is satisfactory as proof of good or of inefficient working. Knowing as we do that sewage varies from hour to hour, no accurate conclusion can be drawn as to the composition of the raw sewage or of the effluent, except by collecting half hourly, or at least hourly, samples during one entire period of twenty-four hours, and the various samples mixed in the proportion of the fluid. The analysis of a sample of raw sewage and of an effluent taken about the same time are not comparable, because the passage of the sewage through the tanks is commonly the work of some hours. Supposing, for example, I collect a sample of twelve o'clock sewage and a sample of effluent at the same time, the twelve o'clock sewage may be the very strongest sewage of the day, whilst the effluent sample is the effluent of the very weakest sewage. Precisely the opposite condition may occur, viz., that I may compare the effluent of the strongest sewage with the weakest raw sewage delivered.

Further, in all cases where analyses are made for test purposes, the weather should be noted, the rainfall and the flow being compared with the average flow. For accurate purposes a normal condition of flow should be selected, and comparison made between the average of twenty-four hours' sewage and twenty-four hours' effluent.

As regards the analysis of sewage, it is advisable to estimate the quantity of the matters in suspension, and in these the amount of mineral and organic (with volatile) matters. In addition to this, I have of late adopted the system of estimating the organic carbon and nitrogen, and the oxygen required to oxidize the organic matter in the effluent without removing the suspended matter. Seeing that the real issue is the condition of the effluent, I consider this method preferable to an analysis of the clear effluent after the removal of the suspended matter.

I propose the following form as one which conveys the best information that chemistry can afford as to the chemical composition of a sewage and of an effluent:—

The results are stated in grains per imperial gallon of 70,000 *grains.*

Matters in Suspension—Total....
(α) Organic and volatile....
(β) Mineral................

The following details have been obtained from the effluent without the removal of the suspended matters:—

Total solids (suspended and dissolved)
Ammonia..........................
Chlorine...........................
=Chloride of sodium........
Nitrogen (as nitrites and nitrates)....
Oxygen required to oxidize organic matter..........................
Organic carbon.....................
Organic nitrogen..................

To get rid of execretal filth with the least possible delay is no doubt the teaching of sanitary science. The advocates of the water closet urge that water as a vehicle to carry the refuse commends itself to us on the ground of convenience, cleanliness and cheapness. They would compare, with plausible argument, the natural power of gravitation (such as is made use of in the water closet) with an organization of men and carts (such as is required by the dry earth system). The advantages, at first sight, seem all on one side. Facts, however, point in an opposite direction. Dilution with water is the best known method of rendering practically useless whatever is valuable in sewage—indeed, worse than useless, an ungovernable nuisance. The excreta of animals are no doubt intended for the food of plants, and for our use through their intervention. Of course, do what we will, nature will assert herself and her plans. But nature is embarrassed by our meddlesomeness. The nutritive food of the plant we drown in water, our ingenuity failing when we attempt to deal with the filthy mixture. We cannot utilize it, unless we abandon all sanitary precautions; it pollutes our air, renders our ground a stinking morass, and defiles our watercourses. Thirty gallons of water daily per head is brought to us who live in London, from pure sources, at great cost, and with great engineering skill; filtered, often refiltered, with extraordinary care; stored with scrupulous anxiety; analyzed by one chemist after another. It is, however, a striking fact that only 1-90th part of the entire water supply is used for drinking purposes, a large quantity being destined to become the diluent of our sewage, to perplex us by its quantity, to bother us by its uselessness, and to steal our health by the perpetual nuisance it occasions.

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