GRAHAM FAIRBANK, CECIL FRASER, WYNDHAM HARRY PAYNE GALLWEY, THOMAS HARRY HOUGHTON, EDWARD MAYNE, WILLIAM FRANK PETTIGREW, JOHN PRICE, Jun., PETLEY LLOYD AUGUSTUS PRICE, ROBERT HENRY READ, JONAS MOLESWORTH STAWELL, HENRY WESLEY VOYSEY, ERNEST FREDERICK WELCH, FRANCIS SAMUEL WILDE, and JAMES WILLIAM WYATT.

No. 1,506.—"The Sewage Question."[1] By C. NORMAN BAZALGETTE, Barrister-at-Law.

THE object of this Paper is twofold. First, to limit and define the proper application of the various systems which have from time to time been introduced, as a more or less efficient means of dealing with the sewage of towns. Secondly, to direct attention to certain subordinate questions arising upon the practical operation of these systems.

The Sewage Question has not made much progress, so far as discovery and invention are concerned, during the last quarter of a century, nor does there seem to be much prospect of any new or startling light being thrown upon it in the future. The fact is the field of investigation is nearly exhausted. Earth, air, fire and water have all been resorted to, and the relative merits of processes based upon them are pretty well known, while the resources of chemistry have been ransacked in turn. And yet even now many sanitary authorities stand in an attitude of doubt and expectation, as though, distrustful of the present, they waited for the advent of some miraculous invention which was to supplant all previous doctrine and set the whole question at rest. The causes of such hesitation are doubtless, first, the introduction by empirics of numerous processes which, professing to deal with sewage at a profit, have little or no real value. Secondly, the division among experts themselves, arising from the tendency to study and elaborate special crotchets to the exclusion of a comprehensive form of practice, adapted to the varying conditions and necessities of different localities. Thirdly, the proneness of every

[1] Since the draft of this Paper was placed in the hands of the Secretary of the Institution, a report upon the same subject by Messrs. Read, Rawlinson, and Smith has been made, of which a notice appeared in the "Builder" of December 2nd, 1876. The Author is gratified to observe that the conclusions in that report, so far as they trench upon his views, appear generally to confirm their soundness and accuracy.

The discussion upon this Paper extended over five evenings.

inventor to overrate the merits and exaggerate the capacity of his own invention. The most recent and conspicuous illustration of this latter defect may be found in the pretensions of Intermittent Downward Filtration, as put forward by the Rivers Pollution Commissioners.

The following classification of the various systems has been adopted for the purposes of this Paper:—

I. Treatment with chemicals.
II. Application of sewage to land, including irrigation and intermittent downward filtration.
III. The dry earth system.
IV. The Liernur or pneumatic system.
V. Seaboard and tidal outfalls.

I. Treatment with Chemicals.

This category may be taken to include all those multifarious processes which, by the admixture of chemicals, have sought the purification of sewage by the precipitation of the dissolved and suspended impurities it contains, and the ultimate realisation of the precipitate in the form of manure. It would be beyond the province of this Paper to attempt even the most meagre summary of the various methods which have been suggested for the accomplishment of these objects. More than a century has elapsed since the first experiments were instituted at Paris, with a view to the extraction of the manurial elements of sewage in a compact form; and since that time, more than sixty permutations and combinations of the original idea of treatment by chemicals have seen the light. But although minute criticism of their comparative merits is impossible, it will still be necessary, for the purpose of defining their appropriate application, that some reference should be made to a few of the more conspicuous modern processes.

Before proceeding to their separate consideration, it may be stated that no chemical process can unaided effectually deal with sewage, but that its application must be ancillary to some other process, as, for instance, the disposal of sewage upon land. This partial incapacity of chemical reagents is attributable to the well-established fact that, in the adoption of any process, one of two results is inevitable; either purification must be purchased at the cost of insolvency, or solvency must be preserved at the sacrifice of purification; in other words, any chemical process to effect puri-

fication must be worked at a loss. For, conceding even that some of the agents employed can produce a fairly satisfactory effluent, there is no instance upon record where such a result has been obtained concurrently with a commercial profit, or even without a positive loss, although there is abundant evidence to the contrary. This failure must be mainly ascribed to the cost of the chemicals; for while to secure purification it is absolutely necessary that they should not be stinted, the only set off against their cost is the return derivable from the sale of the precipitate as manure. Experience has proved that sewage manures are unmarketable; and even assuming that this were not the fact, still, inasmuch as the value of the manure is pretty nearly in a direct ratio to the chemicals introduced into it, it is clear that, making allowance for waste, there must be an inevitable deficit. Apart, however, from this financial objection, there is a formidable practical difficulty attaching to the use of these processes, which up to the present time has proved an almost fatal bar to their efficient operation, namely, the difficulty of dealing with the enormous quantity of sludge developed by the employment of precipitants. From time to time a number of expedients have been suggested (the most recent by General Scott, R.E., Assoc. Inst. C.E.), to reduce this sludge into a manageable and inoffensive form. But hitherto the success attending the application of these expedients has been so partial, and the difficulty has been so insuperable, that in most cases, where treatment by chemicals has been or is practised, a limited manipulation only has been attempted, and the great bulk of the sewage residuum has been allowed to go to waste. Accordingly, even the doubtful return derivable from the sale of manure, when considered as recoupment for the cost of chemicals, must be subjected first of all to a liberal discount in respect of the difficulty of extracting it in a saleable form. Thus there are three urgent objections to the general adoption of any precipitating process as a means of dealing with sewage. First, it is so costly that purification can only be effected at a serious pecuniary loss; secondly, the extreme difficulty of manipulating the sludge and extracting the manure; and, lastly, the unmarketable character of the extract. A conviction of the truth of these conclusions is steadily forcing itself upon the public mind, and the various companies who are working chemical sewage patents begin to find bankruptcy as one alternative, or abandonment of purification as the other.

As long ago as 1865, Mr. Rawlinson, C.B., M. Inst. C.E., in the Third Report of the Sewage of Towns Commission, epitomised the results gained up to that time, and stated that experience, so far

as carried, proved that fluid sewage could not be manipulated into a solid manure so as to pay. It remains to be seen whether the results he cited have been substantially varied by subsequent practice.

1. *The Lime Process* may be considered as the progenitor of most chemical methods of treatment in this country, having been adopted more than twenty years ago at Leicester. Its comparative efficiency is proved by the fact that its use survives in some of the more conspicuous instances of modern practice. It was included in the condemnation pronounced by Mr. Rawlinson in 1865; and the opinion then expressed has been confirmed by the Rivers Pollution Commissioners in their first report, 1870. They say (p. 52), referring to the operation of the lime process at Leicester, Tottenham, and Blackburn, "In all these places the plan has been a conspicuous failure, whether as regards the manufacture of valuable manure, or the purification of the offensive liquid;" and again, "the method obviously failed in the purification of the sewage to such an extent as to render it admissible into a river." So far as Leicester is concerned, the accuracy of these statements has been verified by a personal inspection which the Author made of the works in the spring of 1876. The river Soar was then in a state of active pollution, although the most serious effect was observable at a point comparatively remote from the outfall works; but this apparent anomaly was easily accounted for by the fact, that a certain time must elapse before the effluent undergoes complete putrefaction, and it is thus enabled to flow some distance down the stream before arriving at its most offensive condition. About 300 tons of semi-solid sludge were being produced weekly, the estimated value of which was 6*d.* per ton, and yet even at this nominal price it could only command a market among the farmers to the extent of from 400 to 500 tons per annum, or something less than a fortnight's supply, while the remainder had to be got rid of upon 500 acres of drying ground, to the admitted nuisance of the adjacent cottages. The estimated cost for works incurred in respect of this process at Leicester, exclusive of sewerage works, is about £40,000, and the result is a complete failure, both as regards purification and the profitable extraction of a manurial compound. As Leicester is about to abandon the lime process for irrigation, it is unnecessary to dwell further upon the unsatisfactory effect of its adoption there.

At Birmingham the history of the lime process is perhaps more curious, and scarcely less instructive. Previous to 1871, the sewage there was allowed to subside in tanks, before being passed

into the rivers Rea and Tame. In that year the Town Council, being alive to the defects of the system, and having an additional stimulus to action in a couple of injunctions obtained against them, appointed a committee to report upon the best means of dealing with the sewage of the town. This committee in the course of the same year presented a valuable and exhaustive report, in which (p. 44), after describing the *modus operandi* of the lime process, they pass the following opinion upon its merits:—

"The deposit, in the form of a highly putrescible mud, is taken out, dried, and sold for manure; the process of drying being tedious and offensive, and in winter almost impossible. This process is the simplest and least costly of any, but according to the report of the Rivers Pollution Commissioners, the effluent water, though clarified, is not purified or fit to be admitted into a running stream, since it still contains about one-half of the putrescible organic matter, which is precisely what is most important to keep out. Moreover, as the effluent water still contains most of the valuable constituents, the manure is of little value, and it is difficult, and on a large scale might be impossible, to dispose of it."

Bearing in mind that this stricture on the lime process was pronounced as recently as 1871, it is noteworthy that this process has since been selected and applied by Mr. Hawksley, Past-President Inst. C.E., for the purpose of dealing with the sewage of the town. Judging from the information obtained by a personal inspection of the works in the spring of 1876, the Town Council appear to have spared neither pains nor expense to verify the conclusions previously expressed by their Sewage Committee. The population contributing sewage is about 354,000; and, although it is not easy to ascertain the exact expenditure upon land and works at the outfall, yet, approximately, £38,000 must have been paid for 115½ acres of land, then there is the lease of 105 acres, while the cost of the old and new tanks may be calculated at £18,000 and £30,000 respectively, so that the outlay in round numbers has probably exceeded £100,000. On arrival at the works the sewage is treated daily with about 15 tons of lime. It is next passed through eighteen depositing tanks, in which the accumulation of sewage residuum varies in amount and density in proportion to the distance of the tanks from the sewer outfall. The clarified effluent is then allowed to pass by various outlet sluices into the Rea or the Tame, or is disposed of by irrigation on the Corporation land. The amount of sludge produced daily is about 500 tons, an infinitesimal portion of which is converted into

cement by General Scott's process. At the time of the Author's visit only three men were engaged in the manufacture of this cement. This will afford some criterion of the limited quantity of sludge dealt with. The residue of this enormous bulk of sewage matter, with the exception of a few boat loads, sold to the farmers at £1 a boat load, has to be dug into drying beds covering a large acreage, which is being continually extended. But although the operation of digging it into the ground is incessant, the accumulation of sludge is so enormous as to be almost unmanageable, even the large area at the disposal of the Corporation being insufficient for present requirements—the soil, in many parts to a considerable depth, being saturated and sodden with the impurities which it contains. Such a condition of things, in the neighbourhood of a populous and important town, cannot be too seriously deprecated, both as tending to prejudice the health of the inhabitants and to depreciate the value of property. The machinery by which the process is applied is costly, ingenious, and elaborate, but the result from a sanitary point of view, except as a temporary expedient, can only be regarded as a calamitous failure.

The Corporation of Birmingham have, it is true, been exceptionally unfortunate in their efforts to deal with the sewage difficulty. In 1872, through an extraordinary exercise of land-owning influence, they lost a Bill, the object of which was an irrigation scheme, by a narrow majority upon third reading, after it had previously received the sanction of a Parliamentary Committee. It is to be hoped that the lime process, as practised at Birmingham, is merely a temporary means, pending the adoption of some more substantial and efficient mode, although the permanent and expensive character of the works rather tends to preclude so sanguine an expectation. But it is not only in the creation of this cumbersome mass of sewage mud that the process fails at Birmingham, for the effluent water, to reiterate the expression of the Sewage Committee, "though clarified, is not purified, or fit to be admitted into a running stream." Indeed, at the time of the Author's visit, some of the Corporation land was actually under irrigation by the effluent, and the attendant remarked naively enough, that for this purpose they preferred the effluent to the raw sewage. In that simple remark lay the confession of the practical inefficiency of the whole system; for it proved that the effluent still contained the putrescible organic matter which while the most fertilising is also the most actively polluting property of sewage, and which, therefore, should be

most jealously excluded from the stream. It may perhaps be argued, that the effect of some of these chemical processes is not only to purify the sewage, but to give to the effluent water a manurial principle non-polluting in itself. This, however, is not the case, at all events with the lime process, for the fertilising power of the effluent is not due to any innocuous manurial principle which is added, but rather to the presence of the nitrogenous organic matter which it has failed to abstract. This view is confirmed by the Rivers Pollution Commissioners in their first report, p. 55, where, in speaking of the lime and Sillar's processes, they say: "The material, however, which it is of the greatest importance to remove from the dissolved constituents of sewage, is nitrogenous organic matter, because it is this kind of organic matter which enters rapidly into putrefaction, and becomes an active agent in the pollution of rivers. This material is represented in the analytical results by organic nitrogen. It is precisely here that both processes signally fail (although the lime process is slightly superior to the other) in accomplishing such an amount of purification as would render the sewage admissible into an open watercourse."

The lime process must therefore be taken to have failed at Birmingham as at Leicester, and if it has failed at Birmingham it will never succeed elsewhere, for all that experience can suggest or skill effect, in providing appropriate mechanical apparatus has been accomplished there. Yet it has failed in the first requirement of any process, namely, to produce a sufficient purification of the treated sewage. Moreover, an enormous amount of comparatively worthless sewage mud is being continually accumulated, the disposal of which is both difficult and offensive.

2. *The A B C, or Sillar's Process* (as worked by the Native Guano Company) claims a Mosaical origin, but it has been more sensational than successful in its public career.

The Rivers Pollution Commissioners, in their first report (p. 57), placed the A B C process, as a purifier of sewage, upon a par with the lime process, but condemned both as failing to purify to such an extent as to render sewage admissible into running waters. In a subsequent Report of 1870, after detailing their investigations, extending over a period of nearly two years, the Commissioners (p. 18) present certain summarised conclusions which may be shortly paraphrased as follows:—1. On no occasion has the purification been sufficiently complete to render the effluent admissible into running water: 2. The effluent is little better than what can be obtained by mere subsidence: 3. The manure

has a low market value, and cannot repay the cost of production: 4. The manipulations incident to the process are nauseous and offensive.

These conclusions are based upon irrefragable evidence, which is set out in the Report. It may be instructive to extract an answer from the evidence of Dr. Odling, who was examined as an independent witness before the Commissioners, and whose evidence is appended to their Report: *Q.* 51, p. 34 (by Dr. Frankland), "Looking at the whole result of the experiments, do you consider that this is a process to be recommended for the purification of town sewage?—*A.* Certainly not. No doubt this method, like all other methods of precipitation, does keep out a considerable proportion of filth from the river, but there was a great deal of putrescible matter in the effluent liquid, and in comparing this mode of precipitation with others, it did not seem to me that its alleged superiority had any foundation. As regards its superior defecation of sewage, and the high value of the product yielded, I came to the conclusion that it was simply a juggle."

To the sweeping condemnation expressed in this report, one invariable plea has been put forward by the promoters of the process, to the effect that, upon each occasion when the test experiments were made, there was some abnormal cause in operation, which unfortunately disturbed the accuracy of the results obtained, and therefore precluded their adoption as a basis upon which a judgment could be formed as to its general merits and capabilities. But the Commissioners (p. 20, same Report), referring to the failure of the process, completely dispose of this allegation, for they say, "And if this failure be charged upon any alleged unfairness in the conditions under which the experiments took place at Leicester and at Leamington, it must be pointed out in reply, that when the experiment was tried in the laboratory under circumstances which excluded all possible sources of error, the same result was still more unmistakable."

But a still more practical answer was soon afforded. On the 29th of January, 1871, the sanction of the Metropolitan Board of Works was obtained by the Native Guano Company to a proposal that experiments should be instituted at Crossness, in order to illustrate the efficacy of the A B C process. On the 11th of January, 1873, or two years subsequently, Sir Joseph Bazalgette, C.B., M. Inst. C.E., the Engineer, and Mr. Keates, the Chemist, of the Metropolitan Board, respectively presented reports upon the results observed and recorded during that period, the

gist of which may be shortly stated. The Engineer reported that the cost of producing a manure amounted to £6 6*s.* 4*d.* per ton. The Chemist put the net value of the manure at 20*s.* a ton, but reported "That the effluent water was, on the whole, very good. The A B C treatment so far clarified and defecated the sewage that, looking solely to the physical condition and chemical composition of the water produced at Crossness, I am of opinion that such water was in a fit state to be admitted into any ordinary river without producing a dangerous degree of pollution. I must here again direct attention, however, to the extremely dilute state of the sewage during the experiment. The effect of this was to render the results somewhat inconclusive, as it is, of course, impossible to say, at least from this experiment, how far the A B C treatment would defecate sewage of a stronger character." So that, in fact, such a "very good" effluent was obtained from "extremely dilute" sewage at a dead loss of £5 6*s.* 4*d.* per ton of manure, or at such a price as effectually forbade the general adoption of such mode of treatment. The effect of the Crossness experiments was to afford a forcible illustration of the proposition, that purification can only be purchased at the sacrifice of solvency. It is true Mr. Rawson, the General Manager of the Native Guano Company, asserted in the discussion last year upon the reading of Mr. Shelford's Paper at the Institution,[1] that the Company, having proved the efficacy of the process as a purifier, would, if they had been given time, have also proved its value as a source of manurial profit. But, even assuming that the Company could produce a paying manure, which is more than doubtful, they could never do so concurrently with the production of a purified effluent. The two results of profit, or even solvency, and purification, are inconsistent and incompatible with each other. First, there is a bankrupt expenditure upon chemicals, and the sewage is purified, then money runs short, chemicals are stinted to save their cost, and the sewage returns to its native impurity. Or, it may be for a time, perhaps, that a sort of intermediate course is adopted, which, while aiming at economy of chemicals, at the same time attempts a partial purification; but this can only be a postponement of the inevitable result, for just as surely as the margin of indebtedness becomes reduced, so the margin of impurity is increased.

This proposition receives an apt illustration in the quasi-defence set up by Mr. Shelford, on behalf of the A B C system, in his

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlv., p. 167.

Paper already referred to. Starting with the statement that the effluent was extremely good, he attributed the financial failure of the process at Crossness to the extravagant use of chemicals there as compared with Leamington, namely, 31·8 lbs. per 1,000 gallons at the former, as compared with 1·86 lb. per 1,000 gallons at the latter place. That is to say, that when, as at Crossness, the admixture of chemicals was ruinously extravagant, the quality of an effluent derived from dilute sewage was very good; but when, as at Leamington, the chemicals were sparingly apportioned, the quality of the effluent was notoriously bad, although even under the latter state of things it does not appear that the Company were enabled to show any commercial profit.

The experience also at Hastings, Southampton, Bolton, and Leeds, all tends to point to the same conclusions. Great things were expected, and have been asserted, of the operation of the process at Leeds; but on account of the impossibility of obtaining a sale of the manure, the contract between the Corporation and the Native Guano Company has been annulled. After two or three years' intermittent experience of the A B C system, the Leeds Corporation have discovered that the process can purify, but has not paid, and it has therefore been abandoned by mutual consent.[1]

Before finally dismissing this process, the value of the manures produced by it remains to be considered. Some years ago Dr. Voelcker, in the Journal of the Royal Agricultural Society, thus stated the results of his analyses of five samples:—

		£.	s.	d.	
No. 1	sample was worth	0	18	6	per ton.
„ 2	„ „	1	13	6	„
„ 3	„ „	0	14	0	„
„ 4	„ „	0	18	6	„
„ 5	„ „	0	14	6	„

Basing the value on a comparison of the manure with phosphate of lime at £10 a ton, and ammonia at £60 a ton, Mr. Keates, the Chemist of the Metropolitan Board of Works, put the value, as has been already observed, at 20s., so that he and Dr. Voelcker are practically agreed in their valuations. These, then, may be taken to be the theoretical values of the manure per ton. But in speculating upon the probability of profit, it is not the theoretical

[1] *Vide* Report of the Society of Arts Conference on the Health and Sewage of Towns, May 9th, 10th, and 11th, 1876, p. 37.

but the market value which must be considered. This fact was well put by the Chairman of the Council of the Society of Arts in his inaugural address on the 15th of November, 1876, when alluding to the conference held in May last on the health and sewage of towns. He remarked that exaggerated notions had been dispelled by experience, and the public were beginning to learn that, in the disposal of sewage, profit must not be looked for; and that at Leeds, where perhaps more experience had been gained on an extended scale than at any other town, the difficulty had been to dispose of the solid precipitate, arrangements having recently been made with a contractor to purchase it and take it away at 12*s.* a ton, a sum wholly inadequate to defray the cost of treatment.

Enough has been said to illustrate the limits of the capacity of the A B C process, although the results which have been stated could be fortified by much additional evidence.

3. *Sulphate of Alumina and Milk of Lime* (as worked by the General Sewage Manure Company, Limited).—The following particulars of this process as practised at Coventry, obtained at a personal inspection of the works last year, will sufficiently indicate the limits of its ability to purify sewage and produce a profitable manure. The total quantity of sludge precipitated daily is 22 tons, of which 11 tons, or one-half only is dried by Milburn's apparatus, the remaining half being deposited in a semi-solid state upon the adjacent land, or occasionally disposed of in small quantities at 4*s.* a load, or given away to the farmers. The drying grounds were offensive in their character, and the effluent which passed from the tanks into the river Sherburne was insufficiently purified, on account of the sparing admixture of chemicals, the Company being compelled to keep them down in order to avoid the cost contingent on their use. It was stated indeed that the manurial product was in some cases worth as much as £15 a ton, but that, in order to obtain this extreme value, it had to be previously fortified. In other words, the money had first to be put into the sewage, and then taken out again minus the waste.

4. *Phosphate of Alumina* (as practised by the Phosphate Sewage Company, Limited).—This process, the subject of a patent by Messrs. David Forbes and Astley Paston Price, professes to accomplish the defecation and utilisation of sewage, either by precipitation and irrigation, or by means of precipitation only. With regard to its ability to produce a satisfactory effluent, the following analysis of the effluent discharged during certain trials at Tottenham, the results being stated in grains per imperial

gallon, shows that it does not attain the degree of purity considered necessary by the Rivers Pollution Commissioners:—

Organic matter:—		
In solution	5·74	
In suspension	none	
		5·74
Mineral matter:—		
In solution	57·71	
In suspension	none	
		57·71
Total organic and mineral matter		63·45
Organic nitrogen:—		
In solution	0·47	
In suspension	none	
Total organic nitrogen		0·47
Equal to ammonia	0·57	
Saline ammonia	3·32	
Total nitrogen calculated as ammonia	3·89	

It is difficult to ascertain to what extent this Company professes to deal with sewage apart from irrigation. After having been the subject of experiment at Tottenham in 1871, when the foregoing analysis was obtained, the phosphate process was subsequently, in 1873, applied to the treatment of a small portion of the metropolitan sewage, previously to its being passed upon the Lodge Farm at Barking. When the works were visited by the shareholders and others, after having been in operation for seven months, favourable opinions with regard to the process appeared in most of the leading metropolitan journals, which were afterwards collected and published in a pamphlet form by the Phosphate Sewage Company. The "Times," December 18th, 1873, thus interprets the aims of the Company: "What does this Company profess to accomplish? Certainly not to arrest all or even the chief portion of the valuable fertilising constituents held in solution in town sewage; indeed, according to Dr. Voelcker's analysis, the effluent water after the Company have done with it, is quite as rich in manurial matter as it was before. Hence this process does not claim to arrest and collect in a dry, portable form the wealth of organic matter which our cities are now wasting and the land is crying for; though, like some inventions, it does profess to facilitate the application of the liquid in irrigation

farming by removing the suspended solid matters which have been found a terrible and, in some cases, an unwholesome nuisance."

This only claims for the process, that it prepares the sewage so as to render the effluent suitable for subsequent distribution upon land; but the preface to the pamphlet goes much further, and asserts its ability to deal independently with sewage, to produce a purified effluent without need of subsequent treatment. An inconsistency of statement seemingly underlies not only the claims put forward by the advocates of these processes, but even the opinions recorded by the chemical experts, namely, that the effluent is equally fit to be passed directly to the stream or to the land.

For instance, Dr. Voelcker, speaking of the clarified sewage of this process, observes, "It is free from any perceptibly disagreeable odour and may be safely run into a watercourse; and having lost none of its mineral fertilising matters, and become slightly richer in saline ammonia, while it has been freed from suspended matters, which greatly interfere with sewage irrigation, the effluent sewage is more valuable, bulk for bulk, for irrigation purposes than the raw liquid."

But if it be true, from the chemical standpoint, that the most fertilising elements of sewage are at the same time the most putrescible in their character—always excepting the ready-formed ammonia retained in the effluent, which is unimportant as regards pollution—how can sewage consistently be described as equally fit for the land or the stream? These propositions appear to be incompatible, and certainly are not reconcilable with the chemical opinions which will shortly be referred to.

However, to recur to the practical history of the process. It was tried in combination with irrigation at the Lodge Farm, Barking, but had to be given up upon the ground of expense.

With regard to its experience at Hertford, where it superseded the lime process, Captain Flower, Engineer to the Lee Conservancy Board, referring to its introduction there, says in a Paper presented to the Conference at the Society of Arts last year (p. 42), "Since then I have received fewer complaints, but the same remark which I made just now as to the necessity of filtering the effluent produced by chemical process applies here. It is true that it may be said filtration is carried on at Hertford, inasmuch as small coke filters are used, but I think the area is too limited. Here again the sewage is much diluted by infiltration of subsoil water."

This testimony can hardly be considered favourable, so far as the

purifying power of the phosphate process is concerned, and no details of its financial results have come to the knowledge of the Author. Suffice it to say, that when the Corporation of Leeds abandoned the A B C process, the Committee advertised, inviting any one who had a better system to propose to test it at the trial tanks, and that amongst others the Phosphate Sewage Company responded to this request, but the process was not tested, the Company either not foreseeing a successful issue, or being unwilling to bear the cost of a trial.

The Report of Professor Tanner, the Chemist of the Phosphate Sewage Company, seems to dispose of any claims put forward as to its ability to deal independently with sewage apart from filtration or application to land. Referring to its purifying power, he says it can effect "the production of an effluent water which may be applied direct to the land, and is valuable for irrigation purposes; or the effluent, if passed through filter beds of limited area, can be so completely purified, as to be capable of being discharged into any river or stream without causing a nuisance." So while it is stated that the effect of precipitation *per se* is to produce an effluent fit for irrigation, it is also conceded that, if it is to be passed into a stream, a subsequent filtration is necessary for the purpose of preventing a nuisance.

5. *Goodall's Process* (The Clarifying and Utilisation of Sewage Company, Limited) failed at Leeds. It professed to deal with sewage at a cost of 7*s.* 6*d.* per 1,000,000 gallons, but incurred a cost of £4 6*s.* 6*d.* at the experimental tanks, reduced to £2 13*s.* 4*d.* at the larger works.

6. *Bird's Process* (Bird's Sewage Company), applied at Cheltenham and Stroud, was reported unfavourably of by the Rivers Pollution Commissioners with regard to its application at the latter place.

7. *Dugald Campbell's Patent*, 1872.—This process, as well as Whitthread's process, having been brought before the notice of the Institution in the course of last year by Mr. Shelford, M. Inst. C.E., and spoken of in favourable terms as dealing *per se* with sewage, requires to be briefly mentioned. The model works at Battersea were the scene of its practical operation, the agents employed being lime and superphosphate, and the sewage treated at all times of a weak description. First as regards the quality of the effluent. This must have been unsatisfactory, for Mr. Shelford observes that "it was more suitable for irrigation than raw sewage." If so it was plainly unfit to be admitted into running water. The process, even when operating upon sewage at all times weak, failed

to effect a proper degree of purification. Secondly, as regards the cost of producing so unsatisfactory an effluent, Mr. Shelford's estimate is as follows:—

	£.	s.	d.
Cost of superphosphate and lime per ton of manure	2	13	4
Cost of manufacture	1	8	10
Total cost per ton	4	2	2
Value per ton	4	7	2
Manurial profit	0	5	0

This shows a profit of 5*s.* a ton; but on some occasions the manure yielded a value of only £3 per ton, when of course this slight profit was converted into a loss. From these figures Mr. Shelford deduced the inference that Dugald Campbell's process may be made to pay its own expenses, leaving the public to bear the expense of labour and drying, or £1 8*s.* per ton of manure produced. In order to appreciate this view, it should be applied upon a working scale. Thus, at Leamington the manurial product was put down at 5 tons a day, which, at £1 8*s.* per ton, represents an expense to the public of £7 a day, or £2,555 a year; or, capitalising at slightly more than 5 per cent., a permanent charge upon a capital of £50,000. And this expense, it must be borne in mind, is for the working of a process which, after treatment of weak sewage, produces an effluent more suitable for irrigation than raw sewage.

8. *Whitthread's Process, patented* 1872, was tested at the Tottenham Sewage Works, the agents being dicalcic and monocalcic phosphate, and a little milk of lime. As regards the quality of the effluent, Mr. Shelford observed that it bore out the favourable opinion expressed by Mr. Hope. But Mr. Hope's opinion, as recorded at a meeting of the Social Science Congress of the same year, scarcely appears to be so unqualified in its praise, for he says (p. 342) "although of course it cannot extract the ammonia in solution, it does remove altogether the other forms of 'organic nitrogen' in solution"; and again, that it "to some extent purifies." It is unnecessary to consider the question of cost, for the Company working the patent failed, and though a report of Colonel Cox has been cited in its favour, it was finally abandoned at Tottenham for Hille's process.

There would be no advantage in multiplying evidence beyond the stage which has now been reached, for the practical experience of any of the many chemical processes—and their name is legion

—all tends to point the conclusion, namely, the incompetency of any method of chemical treatment to deal independently with sewage. In this respect, what is true of the processes specifically mentioned, is also true of many others which, on account of their number, cannot be referred to; as, for instance, Holden's, Hille's, Lenk's, Suvern's, and Scott's.

The dicta of three eminent authorities will fittingly close this section of the Paper.

Frankland (Rivers Pollution Commissioners, first report, p. 52). "The operations of the chemist have, therefore, been directed chiefly to the soluble constituents of sewage; and have had for their objeet, either the precipitation in a solid form of the valuable, but offensive, ingredients, so as to convert them into portable manure, or, secondly, the rendering them inoffensive by the action of disinfectants. Although these operations have not been altogether unsuccessful, they have hitherto entirely failed in purifying average sewage to such an extent as to render it admissible into running water. We have formed this opinion both from observations of the polluting effect of such chemically purified sewage upon the streams into which it was admitted, and from the amount of putrescible organic matter revealed by the chemical analysis of the sewage after treatment."

Krepp, on "The Sewage Question," 1867, p. 36. "These instances are enough to prove that solids extracted from fluid sewage cannot be manufactured into dry manure, so as to pay for the trouble. Apart from this, chemical analyses, most carefully conducted, of the results of various processes of deodorisation prove, that none of them have thus far succeeded in precipitating or retaining fertilising parts held in solution, the only substances precipitated being those which are held only in suspense, and which would just as well have been retained by the mere mechanical process of filtering."

Corfield, "The Treatment and Utilisation of Sewage," 2nd edition, p. 222. "All these precipitation processes do, then, to a certain extent, purify the sewage and prevent the pollution of rivers, chiefly by removing the suspended matters from the sewage; but they all leave a very large amount of putrescible matter in the effluent water, and at least all the ammonia contained in the sewage (sometimes they add to it); the greater part of the phosphoric acid is precipitated by some of them, while they increase the hardness of the river water, a matter of great importance if the stream be a small one.

"The manures that they produce are in every case very inferior,

as may be expected from the known value of the sewage constituents that can be precipitated. They have all failed in producing valuable manure, because the valuable constituent of sewage *par excellence* is the ammonia, which, of course, invariably totally escapes in the effluent water, and is lost to the manure: this shows the futility of all attempts to utilise sewage by precipitation alone."

Surely this concurrence of opinion, coupled with the results derived from practice, justifies the following limitations of the province of chemistry with regard to the Sewage Question.

1. That no chemical treatment can of its own independent ability deal permanently with sewage upon a practical scale, for these reasons—

(*a*) Because it either fails to effect purification, or

(*b*) Because purification is purchased at such a cost as to render the adoption of the process impracticable, or

(*c*) Because it is impossible to manipulate the enormous accumulations of sludge necessarily incident to treatment by chemicals.

2. That chemical treatment has therefore no province as an independent means of treating sewage, and its adoption must be ancillary to the adoption of some other process.

3. That the province of chemistry must be limited to the treatment of sewage in combination with subsequent natural or artificial filtration of the effluent.

4. That a chemical process may be employed with advantage in the case of irrigation or downward filtration, either, when contiguity to human habitation, or limited surface area, requires a more efficient screening of the raw sewage, before it is passed upon the land, than can be effected by mere subsidence or mechanical extraction. In these cases, however, as in every other where chemicals are introduced, the accumulation of sludge is an objection inseparable from their use.

The Author thinks these views must be recognised at last, as he cannot suppose that the state of things disclosed in the most modern American sanitary text-book, published in January of last year, by the State Board of Massachusetts, will continue to hold good in England. Referring to the numberless array of chemical processes from time to time paraded before the notice of the public, it says (p. 333), "This list might be extended almost indefinitely, and seems to be limited only by the bounds of human credulity. In France and Germany the precipitating processes have been given up as inefficient. In England a new 'successful'

patent process is hawked about every few months, to be soon found only an addition to the list of failures; and the public is perfectly bewildered by the maze of conflicting statements and propositions."

It is to be hoped that the example of France and Germany may be soon followed in this country.

II. The Application of Sewage to Land, including (1) Irrigation, and (2) Intermittent Downward Filtration.

Irrigation.—It will readily be acknowledged that, where land for the purpose can be obtained at a reasonable cost, the practice of broad irrigation presents at once the most efficient and the most satisfactory means of dealing with the sewage of towns. But though the merits and defects of broad irrigation are now generally understood, there are two points which have recently excited the greatest difference of opinion:

(1) Whether a profit can be derived from it; and

(2) What proportion population should bear to acreage.

With regard to the first point, there is abundant evidence, but of a conflicting character.

Thus, from the Parliamentary Return of 1873, it appears that out of twenty-five places practising irrigation, only two professed to show a profit. Swindon exhibited a profit of £12; but Warwick, the large profit of £1,310. With a view of ascertaining what exceptional circumstances were in operation to take Warwick out of the general category, the Author visited Warwick in the course of last year, when the following facts were obtained. The farm was worked up to Michaelmas 1875 by the Town Council, and was then abandoned because it had proved to be a dead loss. It has since been taken by a limited company, composed of members of the Town Council, and no statistics can be had as to its subsequent financial results. The population is 11,000; the area of the sewage farm, 133 acres; the rent paid, £3 10*s.* an acre; the sewage is very weak; the land is clay; rough surface irrigation is practised. Vegetables are grown, but there is no sale for them; and to improve the financial position, a dairy farm was just being started. The effluent goes to the Avon.

The Conference at the Society of Arts last May on the health and sewage of towns was supplied with numerous returns as to the various methods of treating sewage. It had the additional advantage of a Paper by Mr. W. Hope, V.C., as to the profit

derivable from sewage agriculture, and similar communications referring to the Beddington and Wrexham farms from Dr. Carpenter and Colonel Jones, V.C., Assoc. Inst. C.E. Consequently the judgment pronounced by the Conference upon this point may be taken as based upon a considerable accumulation of the most recent evidence. It is to the following effect (p. i): "It is essential, however, to bear in mind that a profit should not be looked for by the locality establishing the sewage farm and only a moderate one by the farmer." The Author adopts this view; but, before leaving the question of the agricultural value of sewage, he would wish to invite serious consideration to the question of the real value of sewage, as compared with water, for the purposes of irrigation. The use of water as an irrigant is well known, and its effect as a fructifying agent upon crops of a certain kind well established. Can it be shown that sewage produces any appreciable effect, beyond that which might be obtained by irrigation with an equal quantity of water? The kind of vegetable growth produced most successfully upon sewage farms is just that which might be expected to thrive upon water irrigation; succulent roots, grasses, the cabbage tribe, and plants absorbing into their system a large amount of water, are those which flourish best, and the effect upon plants requiring a higher form of nourishment is by many considered doubtful. The measure of nutriment in sewage is the nitrogen it contains, and this exists in the ammonia ready-formed by decomposition which has advanced more or less; and in the organic compounds containing nitrogen may appear as ammonia as the result of subsequent decomposition. These are the pabula of the plant, so far as that particular kind of nourishment is concerned; but is it certain that the nitrogen applied to the land in sewage is actually taken up by the growing plants? Does such nitrogen form indeed the active nourishing principle of the sewage, so far as the vegetation grown upon the sewaged area is concerned? Upon these points it appears that uncertainty exists, even if evidence be not forthcoming to show that the nitrogen does really not produce the effect ascribed to it, and that sewage, therefore, as an irrigant, possesses little or no real value beyond water for agricultural purposes.

In a report upon the results of the use of sewage at the Barking farm, by Mr. Morgan, dated September 1871, there appear two analyses by Dr. Frankland; one of the sewage employed on the farm, and the other of the effluent water draining away from the farm.

RESULTS of ANALYSES EXPRESSED in PARTS per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrate and Nitrites.	Total combined Nitrogen.	Chlorine.
Barking. Sewage from wooden carriers on E., 10.30 A.M. Sept. 5th, 1871 . . .	96·1	2·583	1·752	5·450	..	6·240	22·1
Effluent water from main outfall on F., 1.30 P.M. Sept. 5th, 1871 . . .	91·3	0·676	0·198	0·005	4·143	4·345	13·4

Description.	Hardness.			Remarks.
	Temporary.	Permanent.	Total.	
Barking. Sewage from wooden carriers on E., 10.30 A.M. Sept. 5th, 1871 . . .	..	..	..	Suspended matter: Mineral. 5·24 | Organic. 5·60 | Total. 10·84
Effluent water from main outfall on F., 1.30 P.M. Sept. 5th, 1871 . . .	7	39·3	40·0	Few suspended parts.

These analyses present this remarkable fact that, whereas the sewage contains 6·24 of combined nitrogen, the effluent water contains no less than 4·34 of the same ingredient, or more than 70 per cent. of the whole quantity. In considering what amount of the remaining 30 per cent. can be credited to the fructification of the crop, it must be remembered that by far the greater part of this nitrogen was in the form of ammonia—really carbonate of ammonia, a volatile salt—and it can hardly, therefore, be believed that some portion of this was not dispersed into the atmosphere; so that, in reality, much less nitrogen than is shown by these analyses would actually find its way to assimilation with the plant. Whether or not experience bears out this view, it practically raises the questions: Is sewage irrigation anything more than water irrigation; and does sewage, as applied to land, possess any special monetary value? If not, it goes far to explain the financial difficulty which has attached to the working of sewage farms, for it shows that the money paid for the use of sewage as a fertilising agent has been thrown away, and that water, if

employed in its stead for the cultivation of crops, would have proved nearly, if not quite, as efficacious.

The proportion of population to acreage is a question upon which, although it has formed the subject of much discussion, it is impossible to do more than found a very general conclusion. In fact the proportion is clearly governed by such a variety of circumstances, as character of soil, depth of natural drainage, contiguity to population, strength of sewage, &c., that it would be folly to attempt to set up any definite standard. All that can be done therefore, is to indicate what would be a safe proportion under ordinary conditions, by taking the proportions adopted in various cases, and finding a mean. For example, taking the eleven towns referred to in the Report of the Birmingham Sewage Committee, where the relative proportions of population and acreage are stated, and striking an average between them, a mean result is obtained of 103 persons to an acre. Perhaps, bearing in mind the two things required of broad irrigation, namely, sufficient purification and agricultural return, 100 persons to an acre, the soil being favourable, is a safe proportion for general practice. At the same time if the eleven instances referred to, and which have yielded the above standard, be analytically examined, it will appear how impossible it is to lay down a universal rule. At Bury, with a population of 15,000, the propertion runs as high as 577 persons to an acre, and there is absolutely no effluent; while at Banbury, population 11,500, it is 90 to the acre. At Warwick, population 11,000, 81 to the acre, and at Romford, population 7,000, only 58 to the acre. The explanation of the enormous difference in the proportion adopted in various localities depends no doubt to some extent on the porosity or retentiveness of the soil, but much more upon the depth of soil which remains clear above the level of the subsoil water. For even in broad irrigation it is not merely the surface contact of the sewage with the soil, assisted by the oxidising influence of vegetation, which conduces to the resolution of sewage into its innocuous elements, but above all, its passage through that aerated earth filter which intervenes between the surface and the subsoil water. This is the principle upon which Intermittent Downward Filtration claims to proceed, the capacity of which will now be considered.

2. *Intermittent Downward Filtration* is a new term coined to express a very old meaning, and which claims as a novelty a very old principle. There is nothing in Intermittent Downward Filtration, so far as principle is concerned, which did not exist

before the so-called invention came forth from the laboratory of the Rivers Pollution Commissioners. Intermittent Downward Filtration is merely the artificial production of what is frequently found in nature, and its only claim to novelty lies in the fact, that though found in some instances, it does not exist in all. There is nothing in Intermittent Downward Filtration which is not sometimes common to irrigation; in fact irrigation sometimes is Intermittent Downward Filtration, in the strongest sense in which the latter system is explained by its advocates. To illustrate this: The theory of those under whose patronage Intermittent Downward Filtration has been introduced as a new system is shortly this, that if deep drainage, say to the depth of 6 feet, be adopted, the proportion of population to acreage may be enormously increased, and, consequently, the surface area correspondingly diminished. But this is the same old principle which accounts for the varying proportions in the practice of irrigation. Take a professed example of Intermittent Downward Filtration, namely, Merthyr Tydvil, and one of irrigation, namely, the Eton Sewage Farm. Where is the difference which constitutes irrigation in one case, and Downward Filtration in the other, save that the conditions at Eton are those of nature and at Merthyr they are imitations of nature? At Merthyr there is artificial drainage to the depth of 6 feet, at Eton there is natural drainage to the depth of 8 feet, so that, as far as deep drainage goes, irrigation has the best of it, and draining therefore to a depth of 6 feet can scarcely be claimed as a startling innovation. At Merthyr Tydvil the filter is divided into plots, and the sewage is applied intermittently to each plot. At Eton the sewage is turned on to one portion of the farm for a while, and then diverted and poured upon another section. The Eton Sewage Farm fulfils all the conditions of Intermittent Downward Filtration, and yet it is called irrigation. But it is not the name that Intermittent Downward Filtration bears which calls for any serious comment; it is rather the careless and erroneous pretensions asserted with regard to its capacity which really demand serious criticism and investigation. Certain standards have been persistently put forward as indicating the capacity of the new system, never justified in the extent to which they go, either by the experiments out of which the new system was evolved, or by the subsequent experience of its practical operation.

To make the bearing of the argument plain, by which it is proposed to establish the fallacious character given to Intermittent Downward Filtration, it will be advisable to state the points to

which attention is sought to be particularly directed. First, it may be premised that when reference is made to the standards set up by the Rivers Pollution Commissioners, it is not to be inferred from the use of the word "standard" that the Commissioners have actually committed themselves to the publication of any absolute rule. What is intended to be conveyed is that they have stated certain authoritative opinions, as to the proportion population should bear to acreage, first of all with certain reservations, but afterwards in such dogmatic terms that the record of such opinions has become little removed in its character from the promulgation of a definite standard. In the first instance the proportion was variously stated at from 2,000 to 3,300 persons to an acre, with certain reservations as to its effects pending the application of the experiments on a practical scale. It was afterwards claimed that such a test had been afforded by the experience of the system at Merthyr Tydvil, and all reservations were consequently withdrawn. Accordingly, it is proposed to show first, that the proportions stated by the Commissioners in their reports were not justified by the experiments upon which they are based; secondly, to prove that the experience of Merthyr, instead of confirming, entirely refuted the accuracy of the suggested standards; and thirdly, to establish the fact, that in no case does experience warrant the permanent adoption of a larger proportion than 500 or 600 persons to the acre.

It appears from the First Report of the Rivers Pollution Commissioners, that a number of experiments were instituted in their laboratory by Dr. Frankland, extending over the years 1868–1869, for the purpose of determining the effect of the downward filtration of sewage through various soils, of which the following short summary will suffice:—Satisfactory purification of London sewage can be effected through 15 feet of sand and chalk, at the rate of 5·6 gallons of sewage per cubic yard in twenty-four hours; through Beddington soil, at the rate of 7·6 gallons; through Dursley soil, at the rate of 9·9 gallons; through Hambrook soil, barely at the rate of 4·4 gallons; while through Barking soil, purification was not effected at the rate of 3·8 gallons; and Leyland peat might be educated into effecting purification at the rate of 4 gallons.

Before examining these results with a view to found a logical conclusion upon them, it is submitted that whatever the mathematical mean may prove to be, it is still too high, looking to the fact that it is derived from laboratory experiments. A certain margin must be allowed for the well-known unreliability of

such experiments, as affording an absolute criterion of what will occur in practice. Such an element of unreliability must be a necessary incident of all laboratory experiments, for the experiment is freed from those disturbing influences which attach to a similar operation on a large scale, exposed to the ordinary conditions of nature. The chemist who conducts the experiment adjusts everything with a nicety of methodical arrangement which must conduce to the most favourable results. The earth is carefully packed layer upon layer in the glass cylinder, and that irregularity of composition is avoided which almost invariably occurs in the soil forming the natural filter bed. The chemicals are weighed out in scales, and allowed to mingle with the sewage in accurate proportion, and thus that rough-and-ready admixture which distinguishes the practical application is entirely excluded from the experiment. The sewage itself is probably collected by means of a bucket from the top waters of a sewer, and so those heavier particles are avoided, which, gravitating downwards, pass along the invert, and which distributed upon the land tend to clog the pores of the natural filter. Then again, there is no rainfall to impede filtration, no sunshine to develop noxious exhalations, and no wind to waft such odours in the direction of contiguous habitations. Freed from every disturbing influence, the experiment, proceeding in the uninterrupted quiet of the laboratory, necessarily yields the most favourable results. Laboratory experiments must therefore be discounted before they can be accepted as affording a standard of any real practical value.

But have the experiments referred to been so discounted? On the contrary, they have been strained, and the opinions based upon them exaggerated. To test this: It is clear that for the purpose of arriving at the true indication of the experiments, a process of selection must not be adopted. If a proportion is to be asserted or a standard set up, it must not proceed upon the best or the worst, but upon the mean results afforded by the experiments from which they are derived. But if the six experiments in the Commissioners' Report be grouped together for the purpose of striking an average, the mean result will be too favourable, as two out of the six experiments show negative results. Thus in the case of filtration through Barking soil, not only was no purification effected at the rate of 3·8 gallons per cubic yard in twenty-four hours, but deterioration was actually taking place; so that, for the purpose of obtaining a true mean, a lower figure than 3·8 gallons should be taken to represent the positive result of the experiment. And again, in the case of filtration through Leyland

peat, the Commissioners merely express a hope that it might be educated into purifying at the rate of 4 gallons per cubic yard in twenty-four hours; so that, for the purposes of a true mean, a lower figure than 4 gallons should be adopted. Nevertheless, both these negative results are for the present purpose treated as though they were positive. Striking an average, the mean obtained indicates that a satisfactory purification of London sewage may be effected at the rate of 5·9 gallons of sewage per cubic yard of soil in twenty-four hours. Now the first suggestion of a standard is to this effect (p. 69 of same Report): "These experiments upon the filtration of sewage through various materials leave no doubt that this liquid can be effectually purified by such processes. . . . . In this way the sewage of a water-closet town of 10,000 inhabitants, could at a very moderate estimate, be cleansed upon 5 acres of land if the latter were well drained to the depth of 6 feet." Setting on one side the discount due to a laboratory experiment, it is clear that, even then, this proportion of population to acreage is not justified in its extent by the mean of the experiments. A population of 10,000 persons to 5 acres is in the proportion of 2,000 persons to 1 acre. The sewage of these 2,000 persons must be taken at 30 gallons a head, the London water supply, for it was upon London sewage that the experiments were made; and as the water supply represents the amount of dilution, and, consequently, determines the strength of dry-weather sewage, it is important that, in applying the experiments, the same ratio of 30 gallons per head should be preserved. To say, therefore, that the sewage of 2,000 persons can be disposed of every twenty-four hours, upon an acre drained 6 feet deep, is equivalent to saying that 60,000 gallons of sewage can be purified every twenty-four hours upon 9,680 cubic yards of soil, or that purification can be effected at the rate of 6·2 gallons per cubic yard in twenty-four hours. But the mean of the experiments was only 5·9 gallons, so that the first standard suggested by the Commissioners is in excess of the mean.

The element of exaggeration becomes more manifest in subsequent utterances. For instance, at p. 128 of their First Report, a population of 3,300 is stated to represent the purifying capacity of an acre drained 6 feet deep, which at once raises the proportion to 10 gallons per cubic yard in twenty-four hours, as compared with 5·9 gallons, the mean of the experiments. In their third Report, p. 51, the Commissioners appear to have cast off the reserve with which they had expressed their conclusions in the first Report, and at the same time to have strained the experiments to their fullest extent. They say: "And whereas 100 acres or

more might be needed to cleanse, certainly to profitably utilise, the drainage of a town of 10,000 people by means of irrigation, it would need but 3 acres of a porous medium 6 feet deep, worked as an intermittent filter, to oxidise and therefore purify the drainage water of such a town, provided the mass of earth through which it percolated were frequently and effectually aerated, and the foul liquid were so added that every part of this aerated filter had its equal share and equal interval of aeration. The laboratory experiments, on which we build our confidence in filtration thus conducted for cleansing sewage, may be considered conclusive as to the satisfactory and permanent efficacy of the remedy thus provided; and although it is by no means certain that such an apparatus, on the scale needed for a large town, would not itself be a formidable nuisance, yet there is every reason to believe that the water running from it would be sweet and clean."

This extract contains an absolute expression of opinion on the part of the Commissioners, that though the filter might be a nuisance, the sewage of 3,333 persons may be permanently purified upon an acre of land drained 6 feet deep, or that permanent purification can be effected at the rate of 10 gallons per cubic yard in twenty-four hours. But the highest result afforded by the experiments was in the case of the Dursley soil, where purification was effected at the rate of 9·9 gallons per cubic yard in twenty-four hours, while the mean result, as already stated, only justified application at the rate of 5·9 gallons in the same period; and yet the Commissioners have laid down a standard for adoption in practice, which is actually in excess of the highest and most favourable experimental return, and nearly twice as high as the mean result of their experiments. How, then, can it be contended that the experiments have not been strained, and that the conclusions of the Commissioners, even as they stand upon their own experiments, are not fallacious and calculated to mislead?

A different tone distinguished the statements of the Commissioners in their second Report on the A B C process, dated the 4th of July, 1870, in which (p. 19) they say, "It is no doubt very desirable, in the interest of those towns where sewage cannot be dealt with by irrigation, that an experiment in intermittent downward filtration should be conducted on what may be considered a working scale, when all those difficulties would arise which do not show themselves in a laboratory experiment, and when it would be proved whether the process can be conducted on the

drainage water of, say, 20,000 people, with the efficiency to which our laboratory experiments pointed, and without creating a nuisance."

The contrast between this hesitation of 1870 and the confidence of 1871 is sufficiently striking. In 1870 there are difficulties to be considered which do not show themselves in a laboratory; but in 1871 "the laboratory experiments may be considered conclusive." In 1870 some doubt is expressed as to the possible efficiency of the process; but in 1871 it would require only 3 acres to permanently purify the sewage of a population of 10,000 inhabitants. An experiment upon a working scale was obtained at last at Merthyr Tydvil, under the auspices of Mr. Bailey Denton, M. Inst. C.E., and the Commissioners, in their fourth Report, 1872, were able to point to this practical proof of the accuracy of their theoretical conclusions. They say (p. 55), referring to the works at Merthyr, "They were designed by Mr. Denton expressly for the purpose of realising on a large scale the results of that process of intermittent filtration which had been devised and investigated in the laboratory of this Commission." And again (p. 56), referring to the dilution of the effluent by subsoil water, "Nevertheless, and even assuming a very high degree of purity for the subsoil water, the net result of the action of the soil of the intermittent filters upon the sewage was highly satisfactory, especially when it is considered that the sewage of a town of 50,000 inhabitants was thus purified on about 20 acres of land." And again (p. 102), "That intermittent filtration, conducted either on the extensive or intensive scale, is perfectly trustworthy for the abatement of the nuisance thus created, there is now ample testimony to prove." It thus stands upon record that at Merthyr the sewage of a population of 50,000 has been satisfactorily purified upon 20 acres of land, or in the proportion of 2,500 persons to an acre, and that the apprehension formerly expressed as to possible nuisance has been proved to be without foundation.

Never was there a more complete delusion. Never were exaggerated conclusions, based upon laboratory experiments, more completely confuted than by that very experience at Merthyr, which was quoted and relied upon as confirming their truth. Before proceeding to prove the facts incident to the first practical exposition of Downward Filtration at Merthyr, it is curious to observe how deeply the misapprehension concerning them had sunk into the minds of the Commissioners. In the Session of 1872 Dr. Frankland gave evidence before the House of Commons

in support of the Birmingham Sewage Bill, and, in speaking of Downward Filtration, had his attention called (*Q.* 3769) to the passage already referred to, in which the Commissioners declared their confidence in its permanent efficacy, but at the same time their apprehension that the apparatus on a large scale might give rise to a nuisance, and he then replied, "Yes, at the time that Report was written we had not seen the Merthyr works. They had only been established a few months." So also Mr. W. Hope, V.C., in answer to the late Mr. Horace Lloyd, in the course of his evidence upon the same Bill, gave this explanation of his not having visited the Merthyr works: "*Q.* 2101. I asked, if there were anything to be learned there, you would go there?—*A.* If I thought I could learn anything more than I am taught by Dr. Frankland's experiments, I should go there." And again, "*Q.* 2103. But you have never gone to see it?—*A.* Because it tallies exactly with Dr. Frankland's experiments. If the result had not been as good as Dr. Frankland predicted, I should have gone." And the same confidence in the Merthyr fallacy, which distinguished the evidence of Dr. Frankland and Mr. Hope, was equally characteristic of that which was given by the majority of the many eminent experts who supported that Bill, so that when the Bill left Committee the fact stood, founded upon a concurrence of the highest testimony in the kingdom, that the experience of the Merthyr filter beds was identical with the conclusions of the Rivers Pollution Commissioners, and that, the reliability of such experiments having been established, they might safely be accepted as a model for future practice. But the most remarkable incident in the whole history of the Merthyr filter beds is that Mr. Bailey Denton, at whose instance they were laid down, appears to have participated to some extent in the general misapprehension, and by his public utterances to have assisted in its dissemination, although it must be at once admitted that they exhibit a large amount of contradictory statement. For example, in a Paper by him in the Journal of the Society of Arts, December 8th, 1871, it is stated (p. 65), "Short as the interval has been since intermittent downward filtration was first suggested by the Rivers Pollution Commissioners, that process has, like irrigation, undergone a change. . . . . The change to which I have referred has arisen on the proof which I have had the satisfaction myself of affording, that vegetation may be grown upon the surface of filtering areas, even when receiving sewage equal to the discharged refuse of 3,000 persons to each acre, thus adding, in the most apposite manner, to the cleansing powers of the soil the scavengering properties of vegetation." And again

(p. 66), "Having dwelt upon the practice of irrigation, I ought now to explain the process of intermittent filtration as it may be carried into practice, but as I shall presently deal with it when considering 'Land as a purifier of sewage,' I will only state that by adopting the process as technically described, the liquid refuse of from 1,000 to 3,000 persons—and probably more—may be cleansed by the soil of a single acre of land." On what authority does Mr. Denton state that a proportion of 3,000 persons to an acre may be adopted? Is it on the faith of the Rivers Pollution laboratory experiments, or of the experience of Merthyr? Surely not the latter, for (p. 68) he puts the population contributing sewage to the filter beds at Merthyr at 30,000, which, it will be presently shown, is an excessive estimate, and the acreage at 20 acres, which would only justify a proportion of 1,500 persons to an acre, or less by one-half than the proportion previously suggested.

The only way in which this apparent inconsistency can be explained, is by supposing that when speaking of the proportion of 3,000 persons to an acre, Mr. Denton alludes merely to the temporary effect of such a proportion; but that when he has in view the permanent purification of the sewage, the proportion must be reduced to 1,000 persons to an acre. In a Report made by him in 1873, suggesting Intermittent Downward Filtration as the best means of disposing of the sewage of Kew, Mortlake, and Barnes, he says (p. 54), "The quantity of land, actually required for the purification of sewage of average foulness by intermittent filtration, may be calculated at 1 acre for every 1,000 persons if it be drained 2 yards deep, so as to secure 2 cubic yards of filtering material for every square yard of surface. The Rivers Pollution Commissioners deduced from their laboratory experiments that 1 acre of suitable land drained 2 yards deep might suffice for 3,300 people, and in increasing the quantity of land to 1 acre for 1,000 persons, as I propose to do, the object is to avoid any doubt as to permanency of effect."

When Mr. Bailey Denton gave evidence in support of this scheme before Major Tulloch, R.E., Assoc. Inst. C.E., the Local Government Inspector, who held the usual district inquiry preliminary to the grant of a provisional order, he at once admitted that his supervision of the Merthyr works had been limited to five or six occasional visits, and expressed himself unable to speak definitely as to the extent to which the practice of Downward Filtration had been carried there. Under these circumstances, and for the purpose of arriving at an accurate knowledge of the Merthyr facts, it was considered advisable to procure the attendance of Mr. Harpur, Assoc.

Inst. C.E., the Resident Surveyor, under whose immediate superintendence Downward Filtration had been adopted, and had continued in operation from the time of its introduction in January 1871 until the time of the inquiry in April 1874. His evidence is not a little remarkable, considering that it was actually given as an advocate of Intermittent Downward Filtration, objecting to a proposal which would have this effect, to use his own words, "that the valuable process of Downward Intermittent Filtration would be put off very seriously throughout the country."

The following evidence, extracted from the short-hand notes of the proceedings, shows the actual facts as to Merthyr, and the true conclusions to be drawn from them, as defining the capacity of Downward Filtration to deal with sewage:—

On p. 57 of the Notes Mr. Harpur is asked: "*Q.* Then we may take it that it was only for five months that the sewage of 25,000 people was put upon the 20 acres at Merthyr Tydvil?—*A.* That is the fact; the whole of the sewage. *Q.* And that is the whole of your experience in reference to the power of 20 acres to receive and deal with satisfactorily the whole of the sewage of the 25,000 people?—*A.* Just so. *Q.* Then in taking 50,000 the Rivers Pollution Commission was in error?—*A.* There was not the sewage of 50,000; nothing like it. *Q.* Then the deductions drawn by the Commissioners in their Report, based upon the sewage of 50,000, must therefore be erroneous?—*A.* Yes; they must be erroneous."

Again, p. 69: "*Q.* What do you consider is the population the sewage from which might be safely drained or turned upon the 20 acres at Merthyr Tydvil?—*A.* I have given that a great deal of consideration, and my opinion is that those 20 acres would take the sewage and cleanse the sewage of 12,000 in perpetuity. I do not think they would cleanse the sewage of more than 12,000. *Q.* That is the result of two years' experience and careful watching? —*A.* Yes, it is." So that so far these significant facts are distinctly proved by the Resident Surveyor at Merthyr: (1) That for a short period of five months only the filter beds were exposed to their greatest strain, sewage being applied in the proportion of 1,250 persons to an acre. (2) That the opinion based upon two years' experience is, that if permanent purification is sought, the proportion must not exceed 600 persons to the acre. Before directing attention to the marked contrast between this evidence and the statements of the Commissioners, it will be well to establish its conclusiveness by carrying it a stage further. After stating that he would only recommend Downward Filtration where suffi-

cient land cannot be obtained for irrigation, Mr. Harpur is asked (p. 60): "*Q.* Under such circumstances as those at Merthyr Tydvil, where the land is exceptionally favourable, you would not put more than the 12,000 to the 20 acres?—*A.* No; I do not think it would be safe generally to place more sewage than that of 500 on an acre. *Q.* Not more than 500 persons to an acre is the result of your experience?—*A.* Yes; it is so."

How far, then, are the experiments of the Rivers Pollution Commissioners substantiated, or their statements justified, by the experience of Merthyr? If Mr. Harpur is accurate in his facts and opinions, their statements are erroneous and their experiments fallacious. Instead of the capacity of the land to receive sewage being continuously tested by the application of the sewage of 2,500 to the acre, the greatest temporary strain to which it was ever exposed was in the proportion of 1,250 persons to the acre. Instead of their opinions that the sewage of from 2,000 to 3,300 persons might be cleansed on a single acre of land, Mr. Harpur states that 600 persons to the acre, in his opinion, represents the capacity of the filters. The issue between these opinions is important, and inasmuch as Downward Filtration is by way of marking a new era in the much-vexed question of the disposal of sewage upon land, it is essential that its capacity should be accurately defined by the experience obtained from its practical operation. The truth can only be ascertained and error refuted by a survey of the evidence which has been supplied by such experience. In order to place the Merthyr facts beyond the range of discussion, it is necessary to examine the evidence relating to them in somewhat tedious detail. Mr. Arnold Taylor, one of the Inspectors of the Local Government Board, having visited the works at Merthyr, presented a Report, dated November 8th, 1872, which may be taken as conclusive up to the time when that Report was made. The following are the most important extracts: "The population of the district draining into the river Taff is estimated at 40,000, of whom about 20,000 are living in houses directly connected with the existing sewers; the other 20,000, having cesspool or surface drainage only, or perhaps no drainage at all, contribute but little to the existing volume of sewage. This should be borne in mind, because I see it constantly stated in the newspapers and elsewhere, that the sewage of the population of Merthyr—*i.e.* 40,000 people—is being successfully purified upon 20 acres of land at Troed-y-rhiew. The fact is, that for some four or five months at most, viz. from January to May 1871, the sewage of 20,000 was run on to the 20 acres of

filtration area. But after that time, and to the present moment, one-half only of this sewage of 20,000 people has gone to the 20 acres, the other half having, since June 1871, been continuously applied to the 54 acres of adjoining land under ordinary irrigation.

"I do not wish to be misunderstood. The filtration process at Merthyr must be regarded by every one who visits the place as a very great success, and Mr. Denton is justly entitled to the credit of having first applied on a large scale a system which Dr. Frankland had previously worked out in a series of careful laboratory experiments.

"But just because it is so successful, does it seem to me of importance that the exact truth should be stated with respect to earth filtration as a means of sewage purification.

"The exact history of the Merthyr case will be this: That for some five months, say from January to June 1871, 20 acres of land, most exceptionally situated and very carefully prepared, were found sufficient to purify a volume of sewage from 20,000 persons, equal to a daily discharge of say 900,000 gallons, or at the rate of 45,000 gallons per acre per day. That for the next eighteen months, the same 20 acres are found capable of purifying half this quantity, the rest being distributed and purified over the 54 acres of irrigated area.

"When I saw the land at Troed-y-rhiew last August my impression was this: that the 20 acres of filtration area did show signs here and there of saturation, and that though the appearance of the surface and of the crops grown upon it was wonderful, regard being had to the quantity of sewage which had been poured upon so small an area, yet that the appearance of the crops and the surface of the 54 acres of the adjoining irrigated farm was in all respects the better of the two.

"It is stated by Mr. Harpur that he has dug trial holes at various parts of the filtration area, and that in none of them has he found any sign of earth saturation or of offensiveness. Hence it may be argued that by a continuance of the present intermittent system of filtration, one 5-acre area being in use at a time, whilst the other three are at rest, the land is capable of being used for an indefinite period of time.

"This may be so, but what I urge is, that the 20 acres of earth filters at Merthyr purified the sewage of 20,000 people for at most five or six months; that since then they have purified the sewage of 10,000 people, and that by the end of this year or the early part of next they may have ceased altogether to act as continuous earth filters.

"The Merthyr system may therefore be certainly quoted as an example of successful sewage purification, but the following exceptional favourable conditions and circumstances ought at the same time to be taken into account:—

"First, then, at Troed-y-rhiew, where the filtration areas are situated, there is no population which is likely to be at all sensitive on the subject of nuisance from any offensive smells or emanations.

"Second. The surface soil is light, and of a kind the best suited for active filtration.

"Third. The subsoil, a deep bed of open, porous, water-charged gravel, not only acts most favourably as an open filter, but also gives to the sewage liquid, after it has passed through 6 feet of earth, some three or four times its own bulk of pure water.

"These are favouring circumstances which cannot easily be found in combination. They are found at Troed-y-rhiew, and hence, in my opinion, the main cause of the success of the system of intermittent earth filtration as applied to the purification of the Merthyr sewage. But I believe that this success will be even more marked when the larger area for irrigation purposes is completed, for then, if earth filtration be practised at all, it will only be resorted to on an emergency or in wet or winter weather."

How do the statements of the Rivers Pollution Commissioners stand verified by this evidence? What becomes of the theoretical proportion of 3,300 persons to an acre? or of the illustration afforded by the experience of Merthyr, where, to quote their words, "the sewage of a town of 50,000 inhabitants was then pumped on about 20 acres of land," or in the proportion of 2,500 persons to an acre? Compare this statement with the facts, that, under circumstances so favourable as to be rarely expected in combination, a proportion of 1,000 persons to an acre, according to Mr. Arnold Taylor, was maintained for about five months, but was subsequently reduced to 500 persons to an acre, and so the filters were subjected to a strain somewhat less severe than the ordinary irrigation farm at Bury, where the permanent proportion observed is 577 persons to an acre, and a far less strain than is imposed upon the Eton sewage farm. This proves that irrigation can, upon the principle contended for by the Rivers Pollution Commissioners, namely, cubical capacity of aerated soil, or soil cleared of subsoil water, outdo Intermittent Downward Filtration in its purifying power; in other words, irrigation is, in some cases, naturally more intensive in its operation than a system of Down-

ward Filtration, for the simple reason that, in some irrigation farms, the subsoil water lies naturally at a lower depth than in a filter bed, where it has been artificially lowered to a depth of 6 feet. With a view of ascertaining the degree of purity of the effluent at Merthyr, various chemical tests were applied. If it be true that deterioration was actually taking place when the proportion of only 500 or 600 persons to the acre was observed, it would seem to be somewhat doubtful whether 1 acre of filter bed drained 6 feet deep could effectually purify even that limited population with permanency of effect; or, to put the case somewhat differently, it would be questionable whether a 6-feet depth of drainage gives a sufficient cubical capacity of oxygen-charged soil to effect permanent purification in the proportion of 500 persons to an acre. This would seem to be the fact, for the results of the experiments at Merthyr in 1871 and 1872, by the Rivers Pollution Commission and the Committee of the British Association, on the utilisation of sewage, clearly indicate that such a gradual deterioration was taking place in the quality of the effluent. The following table, based on the experiments of the Rivers Pollution Commission, exhibits the decrease in the percentage of impurity removed from the sewage by the action of the filters in the interval between the months of June and October 1871:—

	In June 1871.			In October 1871.		
	Quantity contained in Sewage.	Quantity contained in Effluent.	Per-centage removed.	Quantity contained in Sewage.	Quantity contained in Effluent.	Per-centage removed.
Total solid matter . .	54·000	34·600	35·97	49·200	33·480	31·95
Organic carbon . . .	2·788	0·249	91·07	1·282	0·323	74·81
Organic nitrogen . .	0·783	0·056	92·85	0·952	0·107	88·76
Ammonia	4·854	0·075	98·46	1·280	0·058	95·47
Total combined nitrogen	4·780	0·349	92·70	2·058	0·455	77·89

A comparison of the two series of experiments made by the Committee of the British Association gives a similar result:—

In January 1872 the quantity of organic nitrogen removed was 96·43 per cent.
In July 1872 „ „ „ „ 86·55 „

In the above comparisons the effect of the subsoil water in diluting the sewage is not taken into account.

The Committee of the British Association, in their Report of 1872, p. 151, thus summarise the results of their experiments: "The effluent water this summer was not quite so pure as last

winter, but still four-fifths of its nitrogen was in the form of nitrates and nitrites."

It will have been observed that the most recent evidence referred to, as to the operation of the Merthyr filters, has been that of Mr. Harpur in the spring of 1874. There had then been three years' experience of their action, which might have been considered sufficient to form a judgment as to their effect. And yet, in a Paper, submitted to the Conference at the Society of Arts in 1876, Mr. Denton gives colour and credence to what might have been justly looked upon as the somewhat faded pretensions of Downward Filtration. First of all, he makes the following statement (p. 23):—"We have now had sufficient trial of actual works to assure us, first, that the suggestion which Dr. Frankland based upon his laboratory experiments, to the effect that an acre of suitable soil drained 6 feet deep, and used intermittently, would cleanse the sewage of 3,300 people, can be realised." What is the "trial of actual works" alluded to as proving the practicability of cleansing sewage with such a proportion of population to soil? The specific experience is referred to in the following statement, but it must be observed that the difference between temporary and permanent effect is not always clearly expressed. It is this (p. 24):—"Although experience at Merthyr, Kendal, Walton Convalescent Hospital, and other places, has most conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people, a fact, the importance of which cannot be over-estimated in those cases where land is very difficult to get and very expensive when obtained, I may be pardoned for stating that I do not wish to be considered the advocate of dealing with the sewage in such a concentrated form under all circumstances." To these allegations the Author makes the following distinct and unqualified reply:—

1. That experience at Merthyr has never proved that the sewage of 3,300 persons could even be cleansed temporarily upon an acre of land, the greatest proportion which ever obtained there being from 1,000 to 1,250 persons to an acre (*vide* the evidence of Mr. Harpur and Mr. Arnold Taylor).

2. That experience at Merthyr has never conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people; but it has conclusively shown that if permanency of effect be required, the proportion, where the filter beds have a 6-feet depth of drainage, must not exceed 500 persons to the acre.

3. That the case of Walton Convalescent Hospital has never

conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people, for the simple reason that the proportion there has never exceeded 400 persons to an acre, as is proved by the following extract from the short-hand notes of the inquiry already referred to, when, in answer to questions, Mr. Denton stated as follows:—"*Q.* Have you ever carried the laboratory experiments of Dr. Frankland into anything like practical effect?—*A.* The Merthyr Tydvil works are nearly three years old, and the works at the Convalescent Hospital at Walton have been in operation four years; once in twenty-four hours the sewage is intermittently applied there. *Q.* What is the population per acre there?—*A.* It varies from 100 to 400. I am not instancing this as a proof that Dr. Frankland's statement is correct." The only further comment to be made upon this evidence of 1874 is this, if the Walton Convalescent Hospital was not cited as substantiating Dr. Frankland's statements, why is it quoted in support of them in the Paper of 1876?

4. That Downward Filtration as practised at Kendal has never conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people. The facts are given by Mr. Denton, in the Journal of the Society of Arts already referred to, thus (p. 25):—"At Kendal, where there is a population of 13,500, the intermittent downward filtration work has hitherto been confined to about 5 acres of land, contrary to the advice which I gave the Corporation when first consulted, to the effect that 15 acres should be prepared. The experience gained on these 5 acres surpasses all expectation. It confirms, nevertheless, the opinion already stated, that the proper proportion of sewage to land should be that of 1,000 persons to an acre. In this view it appears that the Corporation now concur, for the sewage is not always confined to the 5 acres, but is occasionally applied also to the remaining 10 acres which I had proposed should be prepared for filtration."

Does this mean that the sewage of 13,500 persons has been applied to 5 acres of filter beds, or at the rate of 2,700 persons to an acre? or has no distinction been drawn between population and population directly contributing sewage? To this vague generalisation of statement the origin of the Merthyr misapprehension may be traced. Referring to the return furnished from Kendal to the Society of Arts, it appears that, for this population of 13,500 persons, there are only 500 closets in use, so that it is erroneous to speak of the sewage of a population of 13,500 persons draining upon the 5 or $5\frac{1}{2}$ acres of filtration area. What the sewage-contributing

population proper is, it is difficult to estimate, but taking the above limited number of closets, coupled with the fact that middens are principally in use, the sewage probably is not derived from more than one-third of the population. Adopting this view, the sewage of a population of 4,500 would have been dealt with upon a surface area of filter bed of 5½ acres (for 5½ acres, and not 5 acres, as appears from a letter from the Borough Surveyor of Kendal to the Author, dated November 13th, 1876, are the accurate dimensions), which yields a proportion of rather more more than 800 persons to the acre. This is, of course, to some extent speculative, in the absence of positive information. But before proceeding to conclusions there are several important elements for consideration. First of all, the sewage is rendered extremely dilute by the enormous infiltration of subsoil water into the sewers; secondly, the depth at which the subsoil water in the filter beds stands below the surface-level is not stated, so that it is impossible to argue upon the capacity of Downward Filtration as practised at Kendal, inasmuch as the whole principle is based upon the cubical capacity which a 2-yards depth of drainage would afford; thirdly, according to Mr. Denton, and also from information supplied by the Borough Surveyor, the whole 15 acres will soon be required for the purposes of filtration, the present limited surface showing a tendency to become clogged. Then, if the Author is right in the assumption that one-third of the sewage proper passes to the filters there, the history of the operation of Downward Filtration at Kendal is this: that for a time the dilute sewage of the town has been applied to the filter beds in the proportion of about 800 persons to an acre; that such filters have shown symptoms of clogging; and it is, therefore, intended to reduce the proportion from 800 persons to an acre to 300 persons to an acre. If this statement of the Kendal experience be an accurate one (and the Author need hardly say that, as he proceeds upon assumption in this case, and is not dealing with facts proven, he is open to correction), there is nothing in any of the cases cited to establish either the soundness of Dr. Frankland's conclusions or the accuracy of Mr. Denton's statements. Merthyr clearly fails at the touchstone of inquiry, Walton fails on Mr. Denton's own evidence, Kendal it is submitted fails on account of the facts stated, and by obvious parity of reasoning from the circumstances at Merthyr.

Surely it is time that the Merthyr fallacy was stamped out, and yet the advocates of Downward Filtration seem unwilling that it should die. The following extracts from a recent correspondence will, however, it is hoped, supply it with a suitable

apotheosis. Mr. Denton commences his Paper by introducing (p. 25) a letter from himself, dated May 11th, 1875, addressed to Mr. Jones, the Chairman of the Merthyr Local Board, which, will "satisfy the most sceptical that the value of intermittent downward filtration is as great in combination with surface irrigation on a wide area as when adopted by itself on a small one." In this letter, after expressing apprehension lest the extension of the irrigation area should be interpreted as meaning the abandonment of Downward Filtration, he thus concludes: "Will you kindly say if your Board has changed its mind as to the retention of the filtration areas as part of its permanent works, and if so, what has led to such change?" And again, "I am glad to find that Mr. Dyke (the Medical Officer of the district) has the same confidence in the permanency of their action as I have. In his letter to me of the 6th of May last, he says: 'There is still no evidence of any clogging or over-saturation of the beds.'" In his reply (also set out in the same Paper) Mr. Jones states that the Board contemplates no abandonment of the filtration areas, but looks upon them as a "safety valve." Then the Paper concludes, so far as Merthyr is concerned, with the following observations (p. 25): "If anything more than this is needed to prove the thorough success of the intermittent downward filtration work at Merthyr, I cannot do better than point to the following passages of a letter from Mr. Dyke, the medical officer of the district, who wrote me as lately as July last in the following terms." The gist of Mr. Dyke's letter was to the effect that filtration was perfect, the effluent pure, and the vegetables grown on the filters had been eaten without producing diarrhœa; and then the important statement follows "that there has never been any sign of clogging or over-saturation." Can anything more be needed to prove the thorough success of the Intermittent Downward Filtration work at Merthyr? Only this letter from Mr. Harpur, which states how this success has been achieved. It is addressed to the Author, is dated 8th November, 1876, and runs thus:—

"The total area of land acquired by the Board for sewage purposes, including roads, rivers, unsuitable and at present unformed land, is 334 acres.

"The sewage is now being applied to 210 acres, including the 20 acres of filtration areas. Of the land acquired about 90 acres have yet to be formed for the reception of sewage.

"For the last four years no more sewage has been applied to each acre of the filtration areas than to an acre of the irrigated ground.

"The population draining to the sewage farms is 48,000. Each acre of both the irrigation land and the filtration areas receives the sewage of 229 persons.

"The filtration areas do not show any sign of deterioration.

"It is intended to use them permanently for irrigation."

Can anything more be needed "to prove the thorough success of the Intermittent Downward Filtration work at Merthyr" than the facts—

(1) That for the last four years the filter beds have never received the sewage of more than 229 persons to the acre, and yet up to the present time "there is no evidence of any clogging or over-saturation of the beds."

(2) That the filter beds are to be preserved—for what? to perform *en permanence* the functions of ordinary irrigation.

Conclusions.—1. Intermittent Downward Filtration is merely an artificial production of intensified irrigation, and is a useful process to adopt, where land for irrigation cannot reasonably be acquired, or where the necessary depth of soil free from subsoil water cannot be obtained without recourse to artificial drainage.

2. That there is no evidence to show that a larger proportion than the sewage of 500 persons can be permanently purified upon an acre drained 6 feet deep, though there is positive evidence to show that it must not be exceeded, and that this proportion therefore represents the capacity of downward filtration over and through such area and depth of soil.

3. That Dr. Frankland's experiments are strained in the conclusions drawn from them by the Rivers Pollution Commissioners, and that such conclusions, instead of having been confirmed, have been refuted by subsequent practice.

4. That the statements with regard to Merthyr are without foundation or justification; the true facts being that for five months the sewage was applied in the proportion of 1,000, or at most 1,250, persons to an acre, then of 500 persons to an acre, and afterwards permanently of 229 persons to an acre. That though the formation necessary for downward filtration has been preserved, to all intents and purposes the filters are performing the permanent functions of an ordinary sewage irrigation farm.

III. The Dry Earth System.

The first and most prominent objection to the introduction of this system into any town is, that instead of being substitutive for a water-carriage system, it is merely supplementary to it; for

there must still be a water-carriage system in every town where the dry earth system is adopted, independent of it, which in its capacity shall be equivalent to such a water-carriage system as would be laid down even if the dry earth system was not practised. Therefore the cost of the dry earth system must be superadded to the cost of the water-carriage system, and thus the expense to be incurred by the town in respect of its drainage must be increased without any additional benefit being conferred, but, on the contrary, enormous additional expenditure, disadvantage, and difficulty.

To make good these propositions, assume that it is proposed to introduce the dry earth system into the metropolis, which may be taken to contain a population of 4,200,000 souls, and a superficial area of 150 square miles, composed to a large extent of roof and paved surface. The rain falling upon this hard surface cannot be absorbed, and must flow somewhere. Can the dry earth system take it? No, for it only proposes to intercept the solid refuse of the town; therefore a system of sewers at once becomes a necessity. Then, again, what is to become of the dry-weather flow of sewage or the sewage proper, the dimensions of which are measured by the water supply of a town? The water supply of London is 30 gallons a head per day, which gives a daily volume of sewage to be disposed of amounting to 126,000,000 gallons in twenty-four hours. Can the dry earth system deal with this great bulk of liquid? It does not profess to. Therefore there must be a system of sewers to receive it, and a system, moreover, of equivalent magnitude to that which would be adopted if the dry earth system were not in the town; for the dry earth system does not reduce to any appreciable extent the volume of sewage produced, inasmuch as its proper province is to intercept the solid matters, with a small portion of the liquid, which would otherwise be carried away in the water supply. Nor does the dry earth system diminish to any great extent the foulness of the sewage, inasmuch as, according to the Rivers Pollution Commissioners, the foulness of the solid refuse is only one-seventh of the foulness of the liquid, and the extraction therefore of so subordinate a polluting element from the sewage could not much affect the degree of its general pollution. Of course some portion of the liquid refuse is disposed of by the dry earth system, and in the sense, therefore, that the volume of foul liquid in the sewers is diminished in quantity and more diluted in quality it may be said that its foulness is reduced.

Again, if the dry earth system is to be a substitutive system, supplanting all other systems, what is to become of the garbage

and washings of the streets, manure consequent on traffic, liquid refuse from breweries, slaughter-houses, cattle markets, urinals, factories where offensive trades are carried on, and to resolve the dry weather flow into some of its constituent parts, the household slops from kitchens and bedchambers? Either streets must fail to accumulate refuse, such trades and institutions cease to exist, slops and ablutions be banished, or some provision must be made for them. This provision can only be by means of a water-carriage system of sewers. Hence the first proposition becomes manifest, that given the dry earth system, the water-carriage system is still a necessity. If this be so, it follows as a natural consequence that the cost of the dry earth system must be superadded to the cost of the water-carriage system, and that as the dry earth system disposes of nothing which is not disposed of by the water-carriage system, it imposes, therefore, an additional expense without conferring any corresponding advantage.

To illustrate the statement that its operation would be attended with great cost and enormous difficulty the following figures, which proceed upon the assumption of its introduction into the metropolis, may prove instructive.

Moule's Earth Closet System as applied to London.—4½ lbs. of earth per head are equal to 14·66 cwt. per annum, or (on a population of 4,200,000) 3,078,600 tons, cubic yards, or cart loads; or 10,000 cart loads per day for six days in the week. The same quantity would have to be carried out, with the addition of 470 loads of fæcal matter. There are 450,000 houses in London; therefore each cart would deliver earth and remove soil from 45 houses per day. Suppose two pails to each house equal to 900,000 pails, then the figures will stand thus:—

(1) *Prime cost of introduction of system.*

	£.
450,000 houses in London; water-closets removed, earth closets substituted, and metallic wagons provided, say, 700,000 closets, at £10 each	7,000,000
10,000 carts and horses . . . . . (horses . £40 / carts . £20)	
£60 × 10,000	600,000
3,078,600 cubic yards of earth taken off land ½ yard deep = 1,272 acres, say two years' supply = 2,544 acres at £300	763,200
Drying sheds (say 600 acres) at £1,200	720,000
	9,083,200
10 per cent. for London depots, offices, &c.	908,320
	9,991,520

(2) *Annual expenditure.*

	£.
3,078,600 cubic yards carted in 10,000 carts per annum at 12s. = £6,000 (1 man 4s., 1 boy 2s., 1 horse 4s., wear and tear of cart 2s.)	1,878,000
Labour in digging, loading and unloading carts, railway to London and back at 2s. per yard	307,860
	2,185,860

	£.
Representing at 4 per cent..	43,717,200
	9,991,520
	53,708,720

These figures have not been strained; on the contrary, each item has been stated upon the most moderate estimate, and in some cases evidently at too low a figure. So that, after having constructed and paid for a water-carriage system, an additional preliminary expenditure of £9,991,520 would be needed to introduce the dry earth system, and an annual expenditure of £2,185,860 to maintain it, which, capitalised at 4 per cent. and added to the original outlay, represents the enormous sum of £53,708,720, and all this without effecting anything which the water-carriage system is not competent to perform. These figures also illustrate the cumbrous machinery which would be required to give practical existence to the system on a large scale. Where are thousands of acres to be obtained near London for the supply of mould? How is the constant manipulation of sewage refuse to be tolerated in an English town? And, lastly, how are the already overcrowded streets to accommodate the multitude of carts which would be let loose upon them, when the number of such carts would actually exceed the existing number of hansoms and four-wheeled cabs, omnibuses, and tram-cars?

Enough has been said to demonstrate the impracticability of introducing the dry earth system into a populous town. That it has a province cannot be denied, but it is essentially a limited one. It is well adapted for the wants of small rural villages like those of Halton and Aston Clinton in Buckinghamshire, with a joint total of 55 cottages, where it has been adopted, and of detached houses so situated that an abundance of suitable earth can be obtained. So also it may be appropriately applied in the case of detached public buildings under some general control, such as hospitals, workhouses, almshouses, and asylums, always premising, as a condition precedent to its adoption, that the soil in the neighbourhood should be of a porous character, so as to

be capable of absorbing the liquid house refuse undisposed of by the dry earth system, which is of so decomposing and putrescible a character that if allowed to stagnate in trenches or open ditches it would soon poison the atmosphere and generate malaria. But when it is proposed to introduce it into towns, the conditions are, as has been shown, entirely changed, and the sphere of its usefulness becomes narrowed in proportion as population increases. In fact it may be laid down as a universal proposition, that the applicability of the dry earth system becomes diminished in the inverse ratio to the increase of population to which it is proposed to apply it. The general conclusions, therefore, which must be laid down with regard to this system are—

1. That its adoption in the case of large towns would be costly, cumbrous, useless, and virtually impracticable.

2. That its use must be limited to rural places and detached buildings where a water-carriage system cannot easily be constructed.

IV. The Liernur or Pneumatic System.

This system is one of those which still persists in asserting a pertinacious and pernicious vitality in spite of the experience which ought long ago to have extinguished it, and would have done so, had it not been for the energy of those interested in its survivorship. There appear no less than seven notices of it in the Society of Arts Journal of May 1876, one by Captain Liernur, one by T. A. Van der Kloes, Director of Public Works at Dordrecht, and the other five by Mr. Adam Scott, Captain Liernur's agent in this country. But as the term "Liernur System" may not suggest to the minds of all persons the principle upon which it is based and the machinery by which it is applied, the following description extracted from a pamphlet by Mr. Adam Scott, and verified by the inventor's specification, may assist a proper comprehension of its defects.

"In a building, in any convenient part of the town, is placed a steam engine, which drives an air pump, so as to maintain about three-fourths vacuum in certain cast-iron hermetically-closed reservoirs sunk below the floor.

"From these reservoirs central pipes radiate in all directions, following the main streets. On these central pipes are laid, from distance to distance, street reservoirs sunk below the pavement.

"From the street reservoirs, up and down the street, are main pipes, communicating by short branch pipes with the closets of each house.

"All the junctions of pipes with reservoirs are furnished with cocks so that they can be shut off or turned on at pleasure, like water mains, and are got at by cock boxes, and turned by keys in the ordinary way.

"The vacuum created in the central building reservoirs can thus be communicated to any given street reservoir, so as to furnish the motive power by which, when the connections with the houses are opened, all the closets are simultaneously emptied.

"When their contents reach the central reservoir, they are in like manner forced through the central tubes to the reservoirs under the central building, and thence transferred by means of vacuum power to hermetically-closed tanks above the floor of the building. From these retorts the matter is decanted in a fluid form in barrels, for immediate transport to the country, by means of hermetically-closed apparatus."

As regards the inception of this system, it is said that Captain Liernur got his idea from the rude pneumatic system in use at Milan, where a vacuum is obtained by first filling the tanks with water and then exhausting them. The water is carted about in ox carts. The system was first introduced into Prague in 1863 for some military barracks; later, into an insane asylum at Hanau. In answer to the statement of the Berlin Commission, that in these places it had proved offensive, and so unsatisfactory as not to be extended, Captain Liernur stated that the first attempts had been improved upon, and that in Holland he had overcome the difficulties which had proved so troublesome at Prague and Hanau. A Commission at the Hague recommended Liernur's system for that city in 1867, but it has never been introduced there. It has had a similar fate lately in Rotterdam. In St. Petersburg, at the beginning of last year, Captain Liernur was making an experimental introduction of his method, with the understanding that the city was not to bear any of the expense, and that no extension was to be made unless the system proved satisfactory. About the same time he was also preparing plans, which he hoped might be accepted, for Gaeta and Naples. His system has been partially introduced at Leyden, Amsterdam, and Dordrecht in Holland, but none of the cities or towns in England have been persuaded to follow the example of their Dutch neighbours.

The objections to the system, which render its adoption impracticable, may be shortly stated. The most important is that which has already been mentioned with regard to the dry earth system, and which, apart from all other considerations, is absolutely fatal,

namely, (1) that the Liernur system only deals with the solid refuse and a limited quantity of liquid, and is therefore merely supplementary to a water-carriage system, thus entailing additional cost and conferring no corresponding advantage. (2) The machinery by which the pneumatic principle is applied, consisting principally of wrought-iron pipes and chambers, is enormously expensive, and of limited capacity as compared with brickwork sewers. (3) That it is complicated and liable to get out of order. (4) That the closet arrangements for the houses, as well as the operation of decanting sewage, are offensive, and such as could not be tolerated in an English town.

From the evidence afforded by the experience of the system in Holland, it may be premised, in the first place, that in the towns where the system has been introduced in that country, there was absolutely no previous sanitary provision, the whole sewage being either thrown by hand, or allowed to pass away into the tide-locked canals characteristic of the Netherlands towns, so that the introduction of any system was of necessity an improvement on the former unsatisfactory condition of things.

1. *Leyden.*—Plans were accepted for Leyden in 1870. The population is 40,000, and out of this population 1,200 people in the poorest quarter have had the Liernur system applied to their houses. The evidence as to the measure of success with which its operation has been attended has been matter of animated discussion. In a letter, addressed on April 1st, 1873, by the Master of Public Works, J. W. Schaap, to the Magistrate President of the Commission of Manufacturing Industry, he speaks in the following favourable terms of the system (Seventh Annual Report of the State Board of Health of Massachusetts, p. 319): "While it cannot be denied that the expenses of introducing the system and the necessary experiments were greatly in excess of what was anticipated, that the amount received for the fæcal material was less than was anticipated, and that the interest on the money and the instalment paid must be taken into account, yet a favourable judgment, as to the result, must remain." And again, "Therefore the great question concerning this matter is to be looked upon as entirely settled, and the system deserves recommendation to extension everywhere as well as in this city." So far the opinion was satisfactory, but it was soon to undergo a change. In one of his Papers to the Society of Arts, Mr. Scott states, that it was reported that a Government Commission from this country had visited Holland to inquire into the Liernur system. After expressing doubts as to the existence of such a Commission, he refers to their

reported conclusions (p. 60): "as these have thus, in an irregular way, become public, it is right I should, to prevent persons being misled, record the fact that most of the so-called conclusions are misleading, and some of them, in dealing with matters of fact, are simply untrue, as I can show by official letters in my possession. For instance, one of the statements made is that the system is not to be further extended at Amsterdam and Leyden. I have spoken above as to Leyden." On referring back Mr. Scott appears to have said: "I may add to this that the Commission for Public Works have reported in favour of extending the system to the whole town of 40,000 people. In that report they designate it as 'the system of the future for all large towns.' The Financial Commission have reported in similar terms, as have also the Mayor and Aldermen." Surely there is a strange discrepancy of statement somewhere. In his Paper to the Conference at the Society of Arts on the 9th and 10th of May, 1876, Mr. Scott asserts that the Government Commission, if it existed, has been guilty of untruth, and that the Mayor of Leyden had actually reported in favour of the extension of the Liernur system to the whole city. But how can this statement be reconciled with the following opinion expressed by the Mayor on the 21st of January preceding? Replying to the United States Consul at Rotterdam, he says (his letter being published in the Seventh Annual Report of the State Board of Health of Massachusetts, p. 318), "Meanwhile there exists for the present no intention to extend the system in other parts of the city, because of the considerable expense involved in so doing." And again, in conclusion, "Although the experiment with the Liernur system, taken in this city from a technical point of view, may be said to have entirely succeeded, the financial results, however, must become considerably more favourable before an extension of the system will be resolved upon." If, then, the Mayor, to whom Mr. Scott refers, be taken as the best interpreter of his own sentiments, and of the intentions of his fellow-townsmen, the Government Commission, if it existed, was right after all, and did not state what was "simply untrue"; but Mr. Scott must himself be in error with regard to the "matters of fact." The system, then, is not to be extended at Leyden, on account of its cost.

But perhaps the most suggestive and pertinent evidence which has been contributed, with reference to the operation of the system at Leyden, is that which is contained in a Report by a Committee of the Town Council of Southport, which was appointed, at the time when its adoption for Southport was under consideration, to

visit Leyden and report upon it. The Report is dated December 15th, 1874. As the statements and opinion expressed apply with equal force to its operation in other localities, and go far to prove the objections which have been raised against its use, it will be expedient to refer to them. The following are the more important passages:—"It should be stated that no slop, or waste water, passes into the Liernur closets. These liquids are disposed of in the quarter sewered on the Liernur system, in the same way as in other parts of the city. Neither does kitchen waste go into the closets, so that the system, as developed at Leyden, is one of collection of human excreta only, and no other duty is subserved by it." "In order to complete the statement of what we observed at Leyden, it is necessary to say that 'sewers,' as we understand the term, do not exist there. The canals which intersect the city in every direction are the sewers, and house drains enter the nearest canal at the most available point, taking apparently the most direct route without the slightest care or regard as to whether they go under houses or not. This primitive method appears to have prevailed from time immemorial." "A pneumatic system of collecting human excreta would, therefore, relieve the sewers of no appreciable amount of their contents under the present, or even a universal watercloset, system. The daily collection at Leyden from the Liernur closet is only at the rate of about a quarter of a gallon per head, so that even if this were much more augmented than would be compatible with any economical manufacture of 'poudrette' the relief afforded to the sewers, however valuable as regards the quality of their contents, could, as regards quantity passed in, be altogether insignificant. It is clear, then, that the pneumatic system will not, if adopted, relieve the borough of the cost of constructing new sewers, which must be of sufficient capacity to carry away, not only the daily flow of between 30 and 40 gallons per head of a rapidly increasing population, but the storm water, which constantly increases in volume as a larger area of the borough is built over and paved, and less of the rainfall sinks into the soil itself." "Captain Liernur himself put down £4 per head of population as the probable cost of applying the system here."

"The impression of your deputation is—

"1. That the system of sewerage already adopted by the Council would be absolutely necessary, even if the pneumatic system were in actual operation in the borough.

"2. That the pneumatic system is highly ingenious and efficient, and probably highly meritorious in a sanitary sense also, though

no statistics appear to have been collected which would give us a measure of its excellence.

"3. That in a town of so large an area as Southport, relatively to population, the pneumatic sewerage works would be enormously costly to put down and maintain.

"4. That the amount of revenue derivable is very difficult to estimate.

"5. That, from a financial point of view, it would, therefore, be a great experiment; and,

"6. That if experience in England should at any future time demonstrate in a fuller and more complete manner than has been done at Leyden, that the pneumatic system is, as has been claimed for it, 'an engineering, a sanitary, and a financial success,' it will be as open to Southport as to any other place to lay it down and profit by the practical experience of places having larger means to undertake costly experiments."

The above Report proves that the Liernur system is merely supplementary, both in its operation and its cost; that it disposes of nothing that the water-carriage system cannot dispose of without its assistance; and that there is no sanitary advantage to be gained by its adoption. On the question of cost, it is to be observed that Captain Liernur put the cost of introducing the system at £4 per head of population at Southport, as against £2 5*s*. at Leyden. Making allowance for the difference in the price of labour between the two countries, it is probable that £4 per head in England is considerably below the mark; but adopting it for the purpose of argument, and taking the population of London at 4,200,000, the cost of the introduction of this system into the metropolis would reach the enormous total of £16,800,000; and to this expenditure the cost of the main-drainage system, which would be in no sense superseded by the new system, would have to be superadded. It is difficult to estimate what the annual expenditure for the maintenance and working of the system would be; though one thing is sufficiently clear, that no profitable return from the manufacture of 'poudrette' could be looked for in England.

Assuming the cost of maintenance and working at 2*s*. a head, this would represent for London an annual outlay of £420,000, which, capitalised at £4 per cent., would require £10,500,000 to be raised; and adding this sum to the prime cost, it would appear that the introduction of the system into the metropolis would involve an expenditure of £27,300,000. It is worthy of remark that it is customary in continental towns to remove the solid refuse by manual labour, at a cost largely in excess of anything

in operation in England, and the annual cost, therefore, of the pneumatic system would not commend itself so strongly as an objection abroad as it would in this country.

2. *Amsterdam.*—Mr. Scott, in his Paper of May 1876, on the operation of the system at Amsterdam, quotes passages from a Decree of the Common Council, issued on the 10th of April, 1873—an account of the system by Dr. Egeling, of the Hague, which appeared in "Public Health," November 2nd, 1874—and a letter from Mr. Bergsma, of Amsterdam, dated August, 1874, in proof of the success with which its adoption has been attended there. Without going so far back in point of time, the following extracts from the Seventh Annual Report of the State Board of Health of Massachusetts, United States, published in January 1876, which treats of this system from personal observation, sufficiently indicate the measure of success with which its practical operation has been attended. The writer says (p. 312): "In Amsterdam, the odours from the canals have been for years extremely offensive. They are all open sewers, with no current, and foul gases are constantly bubbling up during the summer. During winter the offence is less, and arises chiefly from the distribution of so much filth upon the ice. Naturally, the authorities were willing to try any system which promised any solution of their difficulty. They adopted the Liernur system in one of the poorest quarters of the city in 1870. On the 10th of April, 1872, Mayor den Tex and the aldermen decided upon its compulsory adoption in seven other small districts. At the present time, it has been introduced for a population of 6,000, or one-fiftieth of the whole city. Mayor den Tex, and the present Master of Public Works, state that it has given entire satisfaction in the poorer parts of the city, where there was absolutely no accommodation before, and where the closets connected with it are out of doors. They state, also, that its first cost renders it doubtful whether it will be extended even there; and that among the better classes the system is considered inferior to waterclosets and cesspools." This extract contrasts strangely with Mr. Scott's Report, as to the extension of the system at Amsterdam. Again: "Captain Liernur's calculations of cost, although very high, provide for the removal of excrement alone. With his system, there must be also sewers for rain-water, street drainage, slops, &c. He would have separate pipes, too, for the drainage of the soil." Again: "By the politeness of Mr. Bergsma, Secretary of the Board of Works of Amsterdam, a friend of the system, I was able to see it in actual operation.

"The emptying of the tanks was complete, rapid, and, as far as I could see, successful. There was no trace of odour. In the central building, where the matter was transferred to barrels, and in its immediate vicinity, the stench was very great. In the houses of the poorest class, where one house is used by several families, they become soiled, and in some cases filled to overflowing, before any one takes care of them. They become clogged occasionally by coffee-grounds, ashes, &c., which will find their way into them. They are not as offensive as the midden, or privy, still to be found in many large cities. They are in all cases out of doors, and the people who use them prefer them to the arrangements which existed before their introduction.

"In a few houses of the middle class, where they are in the yards, a few rods from the houses, they were scrupulously clean, received frequent washing, and were not offensive. In a primary school-house, where the closets were separated by only a narrow passage-way from the class-rooms, they were frequently washed, and although there was a slight disagreeable odour, there was nothing really offensive at the time of my visit. It is undoubtedly true, as the teacher said, that the closets are much more satisfactory than anything which they had ever had before.

"In the houses of the better class, there is so much complaint of the bad odour from the closets, that they get rid of it as best they can by flushing, with a sudden dash of a large quantity of water, after each use of the seat. Occasionally they become entirely clogged, when the odours are simply insupportable. Mr. Dyck, a resident of Amsterdam, who has also a farm in the country, states that twice in one year this intolerable stench drove him and his family entirely out of his house, until the obstructions could be removed.

"Captain Liernur proposes to meet this difficulty by automatic waterclosets, using only 1 litre of water at each time of use; but they have not been put to the test of practice, and so small a quantity can be of no more service there than in our ordinary hopper closets.

"A part of the original plan was to sell the excrement at a remunerative price; but people of the neater class cannot be prevented from flushing their closets liberally, and the contents of the reservoirs contain so large a proportion of water as to have the general appearance of ordinary sewage, except in colour. Dr. Amersfordt made a contract with the city to take the whole of it, to be delivered on his farm at 11½ cents (U. S. currency) for each 100 litres. The contract expired January 1, 1875, and

has not been renewed, for two reasons. Dr. Amersfordt states that the distribution of largely-diluted manure from barrels is costly and difficult; also that, when delivered to him in the winter, it is often frozen in the barrels. It is now sold for $16\frac{3}{4}$ cents (U. S. currency), delivered by boats on the farms, during the summer only. In winter it is carted down below the city and thrown into the harbour, as it cannot be sold."

Thus the example of Amsterdam proves the substantial character of some of the objections which have been urged against the system. For instance, it is abundantly clear that the central building, where the process of decanting the liquid into barrels goes on, is an institution which could never be tolerated in an English town; that the closets are of such a character that, though they might be appreciated by the poorer classes in the open air, would be insufferable as applied to the wants of a high-class population; that the manufacture of manure can never be attended with profit, first, because the closets can only be preserved in a sanitary state by a copious use of water, which water is fatal to the efficient manufacture of "poudrette," and, secondly, because it cannot command a sale.

3. *Dordrecht.*—At Dordrecht, the Liernur system was applied in 1875, upon an area of 17,300 mètres, containing a population of 800 inhabitants, distributed over 128 houses fitted with 117 privies. The great feature of its operation there appears to be the manufacture of poudrette on a large scale, and a provisional project for the extension of the system to other parts of the city is contingent upon the success of this manufacture. In his account of the system at Dordrecht, published on the 7th of October, 1875, which appears in the Journal of the Society of Arts of the following May, Mr. T. A. Van der Kloes, Director of Public Works there, states that it would be several months before the "poudrette scheme" would be in regular operation, and he is not therefore in a position to supply statistics with regard to its manufacture. In a letter addressed, on the 20th of January, 1876, by D. W. Hoop, the Mayor of Dordrecht, to the Honourable Frederick Schütz, United States Consul at Rotterdam, the Mayor states that "the extension of the above-mentioned provisional project is delayed, awaiting the results of the poudrette preparations, with regard to which it is thought that sufficient information will be obtained within a few months;" and again, in conclusion, "with regard to the profit on the capital invested in the system, nothing can be stated as yet with certainty, as this community finds itself still too undecided to do so

definitely. While the experiment is being carried on, we await more definite regulations from the person who has the contract for cleansing the city."

So that so far poudrette has not proved a financial success at Dordrecht. At Leyden, the Mayor's letter proves that it has been a financial failure, and the same result has followed the manufacture of manure by Dr. Amersfordt at Amsterdam. In addition to this practical experience, the Report of the State Board of Health for Massachusetts (p. 317) concludes by saying, "It should be remembered that a similar experiment failed in Amsterdam twenty years ago; that the Paris poudrette sold for one-twentieth of the value placed upon it by the chemists; and that an English company has become bankrupt in attempting to pay 2 francs a cubic mètre for the contents of the cesspools in Paris, leaving several hundred thousand cubic mètres at Bondy, of which the authorities would be glad to rid themselves."

Surely nothing more is wanted in the way of practical proof to point the irresistible conclusion: that though the Liernur system may be used with partial and costly advantage in the tide-locked cities of the Hague, where a system of sewerage is said to be impracticable, the population is not fastidious in its notions, and anything in the nature of a system must be an improvement on the previous unsanitary condition, it can never for one moment have a place in the operations of the English engineer.

V. Seaboard and Tidal Outfalls.

Having regard to the unsuitability and costliness of chemical processes, and of the dry earth and Liernur systems, and the many difficulties, financial and otherwise, which attach to the disposition of sewage upon land, there can be but little doubt that, given a seaboard town, the proper destination of the sewage is the sea. By some, who insist strongly on the value of sewage, it has been objected that such means of disposal are, in fact, an absolute waste of most precious material—material which, if properly handled, must constitute in itself an almost inexhaustible mine of wealth. But day by day the belief that sewage possesses any recuperative value is becoming rudely dispelled, and the doctrine is gaining ground that, instead of keeping sewage at the door as though it were a friend, the right view is to treat it as an enemy, to get rid of which by any means or at any cost should be the primary consideration.

But though such an outfall certainly suggests, in the case of a

seaboard town, a natural, economical, and feasible method of dealing with its refuse, there are a few points affecting its construction and position, such as the propriety of tide-locked outfalls, the course of currents, and silting-up, which are more or less matters of controversy. Into the first of these points, a tide-locked outfall, it is not proposed to enter in this Paper, as it comes more properly within the province of a discussion upon the principles of sewer construction than the disposition of sewage at the outfall. As to the second point, namely, course of currents, it may be laid down as a general rule that, assuming any doubt to exist with regard to the force or set of the currents to which the sewage is to be committed, careful float observations should be taken with a view to preclude the possibility of its being returned upon the beach. If such precautions are taken, there ought to be no special difficulty in guarding against the occurrence of such a return. The last point, or the question of silting-up at the outfall, is one which affects tidal rivers rather than marine outfalls. But if the site for such outfall be judiciously selected, and proper means be taken, in the town which drains to the outfall, for the exclusion of silt and heavy matters by catchpits and an efficient system of scavenging, there can be little reasonable apprehension of silting-up taking place. At the metropolitan outfalls, no less a quantity than 120,000,000 gallons of sewage, taking the dry-weather flow alone, is passed daily into the river—a volume of sewage equivalent to a fair-sized stream—and yet no silting-up has occurred. In fact, it would seem to be a logical inference, in the absence of disturbing causes, that where the velocity of the current into which the sewage is discharged is greater than the velocity of the current which carries it down through the sewers to the outfall, there cannot be much danger of silting-up or interference with the navigable channel. Of course it is difficult to frame a rule to meet all cases. Much must depend upon the means taken to exclude heavy matters from the sewers, and much upon the character of the locality sewered, some localities producing far more detritus than others. Then, again, the amount of sewage discharged, the sectional area of the river, the volume of water in its channel, and the velocity of the current, are all items in the consideration of the propriety of the outfall, so far as silting-up is concerned. But still it may be accepted as a generally sound proposition, that where efficient means are adopted for the exclusion of heavy matters, such as road detritus, from the sewers, sewage may be discharged into tidal rivers without any material amount of silting-up taking place at the outfall.

This completes the classification which the Author adopted for the purpose of reviewing the various processes or systems in practical use for the disposal or utilisation of town sewage. He now ventures, referring once more to such classification, to submit the following definite conclusions for the consideration of The Institution of Civil Engineers, in the hope that they will induce such a discussion as may tend to promote a more unanimous opinion, than at present appears to exist, upon the various questions which attach to their consideration :—

1. Treatment with Chemicals.

Conclusions :—No chemical process can efficiently deal single-handed with sewage, but must be assisted by subsequent natural or artificial filtration of the treated sewage, and therefore no chemical process *per se* should be adopted for the purification of town sewage.

2. Application of Sewage to Land.

(*a*) *Irrigation.*

Conclusions :—That where land can be reasonably acquired, irrigation is the best and most satisfactory known system for the disposal of sewage. That no profit must be expected from the cultivation of crops by the sanitary authority, and only a moderate one by the farmer. That no definite standard can be laid down as to the proportion population should bear to acreage.

(*b*) *Intermittent Downward Filtration.*

Conclusions :—That Intermittent Downward Filtration may be practised, where irrigation cannot be reasonably adopted. That experience shows that the permanent proportion of population to acreage, where land is drained 6 feet deep, should in no case exceed 500 or 600 persons to an acre. That the term Intermittent Downward Filtration means no more than the production by deep drainage of a state of things frequently found in irrigation, and that irrigation can in some cases accommodate a larger proportion of population to acreage than Intermittent Downward Filtration. That Intermittent Downward Filtration, as expounded and explained by the Rivers Pollution Commissioners, has never had and never can have any practical existence.

3. The Dry Earth System.

Conclusion :—That the dry earth system can never be adopted for the purpose of dealing with town sewage,

but may be occasionally used with advantage in small hamlets or detached buildings and institutions.

4. THE LIERNUR OR PNEUMATIC SYSTEM.

Conclusion :—That the Liernur system is of such a character that it should never be imported into an English town.

5. SEABOARD OR TIDAL OUTFALLS.

Conclusion :—That towns situated upon the sea-coast, or within the tidal range of rivers, should avail themselves of the means of outfall thus presented, as affording the most economical and efficient means of dealing with their sewage, careful regard being always had to the position of the outfall. That proper precautions being observed for the purpose of excluding silt from the sewers, and care being taken in the selection of outfalls upon the banks of tidal rivers, there is no reasonable danger of the silting-up of the navigable channel.
