

"A STUDY OF SEWAGE DISPOSAL
IN CERTAIN MINING VILLAGES."

THESIS FOR THE DEGREE OF M.D.

by

JOHN CRAWFORD,

M.B., B.Sc.

April 1907.



The question of sewage disposal has become within the last decade especially, one of great and increasing importance. More particularly is this the case for rural communities, where the smallest addition to the rates is felt severely by small proprietors and yet where the adoption of a system of drainage and sewage disposal is of the greatest importance to the comfort and health of the inhabitants and the amenity of the district. In many such communities there is great reluctance to embark on any sewage scheme, just as there used to be reluctance, and occasionally is still, to embark upon a proper scheme of water supply. But while in the most of such cases the eventual carrying out of a water scheme has been followed by general satisfaction, this has not been so with the sewage schemes. For this there are two main reasons: both because the whole question of sewage disposal is an extremely difficult and changing one and also because local authorities have been prone to tie the hands of their advisers by limiting the expenditure in such a way as to make the problem almost hopeless of solution. Certainly, it is well to be cautious but in Scotland at least the rash expenditure of public money is not a very pressing danger. And in this particular direction local authorities appear to/

to have erred upon the other side. The local authorities that have the guidance of this matter have also considerable control over education in their districts and while money has been freely spent upon technical education and 'County Council lectures' in many varying directions, they have failed to grasp the influence for good of proper scavenging and a proper system of disposal of sewage and refuse: for surely a district in which there are no foul streams and no filthy ditches will tend to rear children not only healthier in body but cleaner in mind. There is therefore an aspect of the question wider than that of the Public Health.

The whole question of the disposal of sewage is, as has been said, a most difficult one and perhaps in such districts as I am about to consider it is more so than in others. For in inland rural communities effluents have to be eventually allowed to run into streams which lower in their course are used for certain manufacturing processes, if not for drinking, so that from an economic aspect alone these effluents have to reach a higher standard of purity than those that can be run direct into the sea or an estuary.

The study of sewage disposal is a science of comparatively/

comparatively recent growth and opinions are as yet in a state of flux. Authorities are by no means agreed even upon what seem to be quite broad principles, and it is by no means unusual to find at the annual sanitary congresses that discussions take place in which new ideas are demolished and those that seemed dead revived in the most unexpected manner.

For the study of this great and continually varying question there is a large quantity of recent material available of rather a diffuse kind, the most valuable consisting of papers read at sanitary meetings and the discussions following such papers in which the views of practical authorities are ventilated.

But it will be found that, as a general rule such material is derived from the experience of those in charge of sewage installations in the larger towns, where the problem and the conditions vary considerably from those with which I am here concerned. It seemed therefore that it might be of interest to describe the results of a study of certain small installations with which I am personally acquainted: perhaps the more so as in each case the problem is the same and one very commonly presented to local authorities, namely the disposal of sewage of detached mining villages: and in each case the same system/

system approximately has been used, and the same sort of sewage dealt with, though of varying concentration. But the purification effected has varied to some extent and it may be of interest to consider what factors have led to this variation and what improvements might be effected.

The same methods were adopted in each instance for the collection and analysis of the samples of sewage and effluent. Bottles containing about 400 cc. were used. One of these was half-filled with sewage at the grit chamber where the sewage enters, at 10 a.m. and the other half-filled with effluent from the effluent channel at the same hour. The bottles were then put aside and the filling with sewage and effluent respectively completed at 4 p.m.

These were the times when (under the circumstances) it was considered that the sewage would be at its strongest and its weakest.

It was found impossible to have samples taken every hour, as is desirable, since the works were situated usually in a place remote from the house of the attendant and he had various other work to occupy his attention. But it was thought that by the means adopted an average sample of the sewage or effluent of the 24 hours would be obtained.

At/

At least four of such samples were analysed for each sewage and each effluent and as from the pressure of other work the analysis was spread over some weeks in each case it is thought that a fairly representative average of the sewage and effluent in varying weathers has thus been obtained. The samples could never be analysed on the day of collection as they had always to be sent some distance by train, but this was always done on the succeeding day and where this was found impossible the sample rejected and a fresh one obtained.

In view of the rapid change taking place in sewage it is most desirable, as Rideal has pointed out and as indeed is well-known, that samples should be analysed as early as possible after collection.

Exactly the same methods of analysis and the same apparatus were used throughout and admitting the likelihood of a certain margin of error in the result, they are at least comparable. The ordinary laboratory methods were used and the results obtained are returned in terms of Free and albumnoid Ammonia (Wanklyn), Chlorides (as Sodium Chloride by Titration with silver solution), Nitrates (as Potassium Nitrites by Griess' method), Nitrates (as Potassium Nitrite by phenolsulphuric acid method), Total/

Total Solids, and Oxygen absorbed in four hours at 60^o C. (Tidy's method). All results being returned in parts per 100000. It is admitted that there are other particulars which would have been interesting and desirable such as the amount of fats present and other points but it was thought better to admit the limitations of a small laboratory and rather to spend the time available by obtaining results as accurate as possible on the lines described than to strain at further results which might be unreliable.

Before going on to the discussion of these analytical results it might be best to describe first of all what would seem from the opinions of authorities to be an ideal installation for treating the sewage of a detached mining village whose effluent has to be run into a stream and taking this as a model to discuss separately and in detail each installation that has been studied. This comparison will enable one to discover wherein each installation differs from the ideal and whether such difference has been prejudicial to the treatment of the sewage concerned.

It is only because the problems offered by these detached mining villages in the same part of Fifeshire are similar that it is possible to lay down the principles on which an ideal system of sewage disposal might/

might be installed. For as Mr. Watson remarks -

"The sewage disposal problem varies with every town and every district and the overlooking of this fact has led not only Local Authorities but their advisers to make mistakes and engineers cannot be too careful in obtaining reliable data upon which to base their design before they finally determine what that design should be. Each case should unfold its own conditions and the more exhaustively the circumstances are considered the more likely is the scheme to give permanent satisfaction, unless indeed the drainage authority places money restrictions on the execution of the scheme and so hampers the execution. It is always unfortunate when the engineer is compelled to choose between declining to go on with a work which he knows cannot be well done for the money available and trying to do the best he can with the money at his disposal."

It is only therefore because of the great resemblance in the requirements of the districts, and in the data that I shall venture to describe an ideal system.

At the outset we are confronted with a choice between some form of bacterial system and the 'land treatment'

Now/

Now as Dibdin has pointed out "The bacterial process really is land treatment, concentrated controlled and accelerated and therefore effective and economical whilst 'land treatment' as generally practised is haphazard, uncertain and ineffective." Land treatment is only suited to certain definite conditions and certain kind of soil. Says Mr. Watson "Diverse opinions may be held but it may be assumed that where there is one acre of suitable land available for irrigation and not more sewage than is represented by a population of 100 - 150 to be treated upon it, the efficiently worked sewage farm is still in the foremost rank."

Now in the districts in question these requirements were not fulfilled. The land was not available and it was of the wrong kind, being mostly a stiff clay. Even where land treatment is used it is well to filter the sewage before running it upon the soil. (Bailey Denton) The Manchester Committee reported that the bacterial method was the only satisfactory one. Dr. Rideal says:- "The strongest argument for sewage farms and irrigation must be the restoration to the land of the matter taken away from it but I point out how under graduated bacterial purification an effluent containing practically all the /

all the nitrogen, phosphates and other constituents can be obtained in a condition suitable to be returned to the soil without loss."

It is therefore generally agreed that except under certain favourable conditions, which do not here exist, bacterial treatment is to be preferred. The question remains - what form of bacterial treatment?

Not very much is yet accurately known about the conversion of sewage into a good effluent by micro-organisms, but as the result of experiments of engineers, such as Scott Moncrieff and Cameron and chemists and bacteriologists such as Dr. Dupre, Dr. Sims Woodhead, Dr. Dibdin, Dr. Houston and Dr. Rideal, it has been determined that the complete transformation desirable can only be brought about by the operation of both anaerobic and aerobic bacteria. An aerobic filter alone if it can be worked unchoked produces an effluent liable to secondary putrefaction and an anaerobic arrangement alone such as a septic tank or a Scott Moncrieff tank produces a bad-smelling dirty liquid needing oxidation to make it suitable for an effluent. Chemists and biologists now seem to be agreed that the two classes of organisms are necessary and all successful and satisfactory schemes have/

have been founded upon this principle. The occasional success of 'contact beds' may be due to the way in which they combine the two essential processes, but it ^{is} surely logical to provide first for the one then for the other since two so opposed processes cannot take place satisfactorily within the same apparatus.

This process of decomposition of the suspended solids into roughly CO_2 , CH_4 , H_2 , N_2 , and NH_3 and the further oxidation of the ammoniated bodies into nitrites and nitrates is thus shown to be the natural and only logical process: and it is in addition the simplest and the cheapest requiring least attention and requiring the least head. No chemicals need to be added to the sewage and ^{the} effluent can be sent into a stream or used for purposes of irrigation.

Taking it for granted then that this is when efficiently carried out the best method for the purpose concerned, can any broad principles be laid down to guide the construction of an installation with a view to economy and success?

Firstly it is maintained by most authorities with the exception of Mr. Cameron that a preliminary screening of the sewage is desirable in order to remove the hundred and one floating matters that occur in/

in sewage. Mr. Cameron maintains that most of this floating material is organic and will in time be decomposed and that if the effluent from the tank is taken from below the surface there is no risk of it clogging the filter. Probably a screen would be an advantage at not very great expense. But it is undoubtedly desirable that all road grit and heavy material should be removed by a properly constructed grit chamber in order to prevent the necessity of frequently cleaning out the tank. Thus a good grit tank is really an economy. Secondly the main tank or tanks should be of a capacity to hold about 24 hours flow of the sewage to be treated. In Exeter they hold 18 - 20 hours flow and at Barrhead the four tanks hold 312,500 gallons the flow being 400000. Dr. Barwise is of opinion that a day's flow is the proper quantity. Dr. Rideal remarks - "The L. G. B. have recently asked for a tank capacity equal to $1\frac{1}{2}$ times the dry weather flow. I believe that this is largely in excess of what is necessary." With regard to shape the principle to be kept in mind is that the sewage should run through with as little disturbance and as slowly as possible. The tanks must not be too large or they they will be over exposed to the wind. They should tend to be long, narrow and deep and/

and where the total flow cannot be accommodated in a certain number, the number should be increased rather than the size. That size must vary with the site of the tanks since in an exposed place they cannot be so large. At Exeter they are 181 X 35 X 7 feet and at Barrhead 100 X 18 X 7 feet.

All authorities are now agreed that the covering of such tanks is quite unnecessary expense and that where proper grit chambers have been provided, sludge pipes will be also needless. It is probably an advantage that the tanks should be provided with sunk walls and scum-boards in order to ensure that each drop of the liquid takes a slow and sinuous course and has ample time to be exposed to the bacterial action: this being at any rate a possible advantage at little expense.

The changes induced in the liquid by anaerobic organisms having now taken place the sewage now passes, usually over an aerating weir, into some form of measuring chamber provided with automatic apparatus for directing it to different filters in turn if it is to be treated by intermittent filtration: or if it is to be treated by a continuous filter it now passes to that direct.

It is not considered necessary to discuss the action/

action of contact beds. Though there are many of these acting efficiently in different localities their interest is now mainly historical dating from the Sutton experiments of 1896 - 1898. More is known now about sewage changes than was then and probably there are few authorities who would maintain that the contact system can be compared to the aerating filter for efficiency and economy. There may be special circumstances but speaking generally most authorities will agree with Dr. Barwise when he remarked at Glasgow in 1904 that he thought the contact system was dead. Dr. Reid has recently (1906) remarked the same.

The filters are the point round which the greatest discussion has centred. Here again certain principles clearly emerge and if these are observed and provided for as economically as possible the best result will be secured. What is required is (1) the greatest surface of material in the smallest bulk, (2) the completest penetration of air to every part of that material and (3) absolute homogeneity of that material in every part.

Materials used for filters have been very various such as gravel, coal, slate, clinker, cinder, slag, burned ballast, "saggers" or broken crockery (at Hanley), and coke. There seems a consensus of opinion/

opinion that for nitrifying purposes the last is the best presenting as it does a large and durable surface. But it is sometimes dear and if a desirable and efficient substitute can be obtained more cheaply that should be used. In Fifeshire slag from the numerous furnaces is cheap and at hand. The shape and size of the beds and their depth and the size of the material must so depend upon the method of distribution of the sewage that it is impossible to keep the two subjects apart in discussion.

Is, then, the percolation of the sewage through the filter to be continuous or intermittent? Continuous percolation after all is merely intermittent percolation with very small doses separated by very small intervals. Intermittent percolation has been insisted on because it was considered necessary that air should penetrate to every part of the filter between the heavy doses of sewage that were given. But if the sewage travels slowly and in a thin film over the material, as Dr. Reid has shown it will carry its own air supply down with it and the oxidation becoming a continuous process the dosage may be also continuous.

The fact is that as regards depth and size of grain and dosage, no hard and fast rules can be laid down/

down: nor are they needful if the principles are kept in mind and experiments made with the particular sewage and the particular material to be used.

Economy will be observed by reducing the size of the material to the smallest limit compatible with free aeration: and if this be done Dr. Reid whose experiments at Hanley are probably the latest on the subject, maintains that greater depth than 2'6" is unnecessary and indeed may set up a new anaerobic action.

Wallis Stoddart again advocates the use of large grain 3 inch filters and a depth of seven or eight feet: indeed he thinks the depth can be increased indefinitely. He says:- 'more than twice the amount of sewage can be dealt with per yard by doubling the depth of the filter.'

The shape and size of the filters and whether they to be built within a retaining wall or not will depend largely upon the distribution employed. And this is perhaps the most unsatisfactory point (practically) in the whole process especially where continuous percolation is employed, as it is then necessary to ensure more complete comminution of the liquid. Stoddart thus describes the requirements of a distributing apparatus.

- (1) The comminution of the liquid must be as complete as/

as possible, but

- (2) must not depend on passage through fine orifices.
- (3) There must be no disturbance likely to diffuse the odour of the sewage.
- (4) No artificial force must be required.
- (5) No appreciable loss of head must be involved.
- (6) Automatic action must be perfect.
- (7) The distributor must be cheap and applicable on any scale.

He then describes a patent of his own. But on practice it is found to lack strength, it offers a great surface of metal to the action of heat and cold, and the V shaped channels of which it is built up are found to sag in the centre with the result that while the sewage pours on to one part of the filter the rest gets none. The commonest distributor is probably the revolving arm or Barker's mill type and its modifications. These do well for intermittent filters at least where the beds are small and there is head of sewage to drive them or power at hand: but where they are large they are apt to get off the straight and where there is little head they stick: wind also affects them too easily and they need constant attention. The Fiddian type is efficient but expensive and requires considerable head. Mr Watson/

Watson of Birmingham advocates a system of fixed spray jets but does not go into particulars as to their construction. Mr. Frew, Sanitary Inspector of Linlithgow County has at Torphichen a simple arrangement of V shaped rails of heavy section having lateral notches at close intervals. The level can be adjusted at either end so that a continuous drip occurs from each of the lateral notches. The arrangement was probably suggested by Stoddart's but seemed simple, stronger, and less liable to give.

Whichever system is adopted will be sure to require careful watching and adjustment and if it does not act well it will be liable to ruin the action of a filter otherwise perfect.

The rate of filtration is a point which depends upon so many factors that to give any definite figure is difficult: into consideration must be taken the area, depth, consistence, of the filter and the quality of the tank effluent supplied: so that it may reach any figure from 50 to 500 or more gallons per square yard per day.

As however the number and size of the filters to be provided will depend upon some estimate of this rate, it will be well to mention an average figure: and one would be safe in concluding that for a continuous /

continuous filter dealing with an average tank effluent an area should be provided which will allow of the dosage being reduced at least to 150 gallons per square yard per day, the depth of the filter being four feet. At Barrhead the figure is 142, at Horfield 400. Dr. Reid says 200 and Dr. Barwise suggests 120. These it must be remembered are only approximate figures.

If our hypothetical system has been properly constructed and worked the effluent should now be capable of discharge into any stream. But when the filter has been worked for some time, in many cases solids will begin to pass through, and in nearly all effluents of the kind described there will be found a bulky, soot-like deposit in the effluent channels. This consists of partly mineral matter such as sulphides and partly of the residue of decomposition, such as bits of fibre, hard parts of seed coverings, portions of insects and many other varied materials. And if it is desired to eliminate this entirely and render the effluent clear, it is desirable to provide either a small coarse sand filter, the upper inch of which can be frequently washed, or a settling tank. In many cases, for reasons not well understood this will be found unnecessary, but as a rule it will be desirable. If it is not provided the upper foot or so of the aerating/

aerating filter should be of fine material and changed fairly frequently. But the elimination of this black sediment with the minimum of filter area is one of the most difficult parts of the sewage problem.

(1) The Kelty sewage works were constructed for the Dunfermline District Committee by Mr. Baird Laing: they are situated on a piece of low lying ground beside the Ore stream and very little fall could be utilised. Surface water from a considerable length of macadamised roadway is admitted to the sewers so that there is much grit to be removed. The situation is open and windy. The works consist of -
Two grit chambers having a capacity of 1850 gallons.
Two septic tanks together holding 210,000 gallons, a collecting chamber of 40,000 and two circular filters of clinker seven feet in depth with a combined area of 628 square yards. The method of distribution is by revolving sprinklers and the filters are circular built with open brick retaining walls.

After observation the average dry weather flow was found to be 220,000 gallons and on this basis the septic tanks do not quite provide for a twenty-four hours flow while the rate of filtration (intermittent) is about 220 gallons per square yard.
The/

The engineer in this case had several difficulties to face: he had very little fall to utilise, he had to provide for a sewage containing much road grit and liable to sudden great increase, and his estimates were repeatedly cut down. And above all the works are situated on ground which is undermined by coal-mining, so that cracks have appeared in the tanks, his circular filters have tilted and deranged his distribution and the ground is so sinking under the weight of the tanks and filters that the little fall he had to come and go on, is being annulled and the least increase of storm water causes an accumulation in the effluent channels and renders the filters waterlogged. The wind has prevented scum remaining on the tanks and several times when a scum has formed quantities of have been washed by waves over the scum boards and have choked the upper layers of his filters. With such a chapter of accidents one does not expect good results: they are as follows:-

	Average of five analysés.		Purification %
	Sewage.	Effluent.	
Free ammonia	3.76	1.78	52.6
Albuminoid ammonia	.77	.31	59.74
Chlorides	17.44	14.34	
Nitrites	0	.082	
Nitrates	1.02	2.53	increase.

Average of five analyses continued.			
	Sewage.	Effluent	Purification %
Oxygen absorbed.	2.5	1.3	48
Total Solids.	74	31	58.1

The effluent contained a black sediment and was occasionally putrescible.

Professor Hunter Stewart reported on the works in May and July 1905, soon after their completion. At that time there was probably a spell of dry weather, since his results show the sewage to have been stronger. More purification was taking place, though the eventual effluent was not so good. He pointed out that the sewage contained a quantity of fatty matter. His results for May 11, 1905 are as follows, taking the same particulars:-

	Sewage.	Effluent	Purification%
Free ammonia	5.76	2.98	68
Albuminoid ammonia	1.12	.415	63
Oxygen consumed	9.21	2.15	76
Total Solids.	78	48	39

In his opinion the rate of filtration was at that time too fast and the effluent unfit to be discharged into a stream. The rate of filtration remains the same and other defects have since then developed/

developed for which remedies are proposed. But it is doubtful whether, with the ground continually subsiding, anything will be of much service at present.

The engineer has proposed a number of alterations such as preliminary screening measures to prevent scum being carried over, additional filter area, and a settling tank for the effluent, but the committee are not willing to spend anything further. The result is that the whole of the sewage is discharged half-treated into the River Ore and it is only because that stream flows through a dirty mining district and others are rather glad to have it dirty already as a sort of excuse for discharging into it themselves all kinds of additional filth, that no notice is taken of the matter. It is this unfortunate kind of result that makes Local Authorities chary of embarking on sewage schemes.

(2) The Hill of Beath sewage works were erected some years ago by Buchanan and Bennett, Edinburgh for the mining village of that name, which has a population of 1400. Sewage and slop water only are treated the road drains being ^{kept} separate. The tank here is divided into four compartments, the first being used as a grit chamber and the sewage is/

is unscreened. The middle part of the tank is covered in and the fourth part just before the sewage escapes over a weir, is again open. The capacity of the tank is 34,350 gallons and the flow is about 35,000 gallons per day. The filter used is about six feet deep and built of large clinker with no retaining wall. It is 60 square yards in area and distribution is effected by a Stoddart apparatus, the distribution figure being 583 gallons per square yard.

On examination it is found that the system is in good working order with the exception of the Stoddart apparatus which is practically useless. So that the sewage streams through one part of the filter, leaving the rest practically dry.

The results were as follows:-

Average of five analyses.

	Sewage	Effluent	Purification.
Free ammonia	5.02	2.6	48.3
Albuminoid ammonia	1.24	.58	52.4
Chlorides	18.02	13.32	26.1
Nitrites	.05	.23	increase
Nitrates	.90	1.27	
Oxygen absorbed	5.74	2.18	62
Total Solid	168	82	52

This effluent also contains much black sediment and is sometimes putrescible.

This apparatus has never been reported on and the effluent is simply discharged into a small burn whose course it fouls for a mile or so gradually improving until it is joined by some more sewage, and further improvement becoming impossible the burn becomes an open sewer. Yet it seems probable that for comparatively little expense the works could be made fairly efficient: the tank is of ample capacity and in good order. All that is needed is increase in the filter area, which might be doubled with advantage, and the provision of some real method of distribution. But no further expenditure is contemplated.

(3) At the village of Thornton, the drainage system is divided into two sections, North and South, the natural fall of the ground from the centre of the place being in opposite directions. The operations at both works are similar except that the South works are about 12 feet below the level of the river and the effluent has to be pumped from the works. The total population is 1380 and the flow calculated at 34,500 gallons. The sewage is first led into a small detritus tank, after a rough screening, thence it enters the uncovered septic tanks of which there are two, the combined capacity being 24 hours flow: the overflow/

overflow is taken to a measuring chamber, by a sunk outlet and distributed over three clinker beds in turn by revolving spreaders. The filters are three feet deep, built in all round with the exception of two or three small openings, and the rate of distribution is 125 to 140 gallons per square yard, per day.

On examination of the North or larger works every part is to all appearance in good working order. The tanks are well sheltered from wind and covered with a thick leathery scum as much as nine inches to a foot thick in places, the distributors work regularly and well. But it is probable that little aeration can be going in the filters. These are of small broken clinker, of about inch size, closely pressed down and in some places with moss growing on the surface: there are a few openings of about four inches square in the walls at irregular distances.

In the case of the South works, which are in a deep hollow, and thus sheltered, the tanks seem in equally good order. The same remarks as before apply to the filters, but in addition the distributors are practically useless: they move feebly a yard or two sometimes at the first gush of the sewage but with that exception the sewage streams through the filter all in the same spot and there is no real distribution/

distribution. The effluent thus unaerated is collected in a large tank at the end and at intervals pumped into the stream. It evidently undergoes some slight further anaerobic change, for it can be seen to bubble slightly, though the tank contents are fairly clear and there is no scum. A considerable black deposit falls and the only way to get rid of this is for the attendant to stir it up among the effluent with a long scoop and pump it also into the stream. This seems unsatisfactory but has been going on for some years without complaint. The analyses are appended and these from the North works will be seen to show the better effluent.

North Works. Average of four analyses.

	Sewage	Effluent	Purification %
Free ammonia	2.25	.796	65
Albuminoid ammonia	1.06	.69	35
Chlorides	11.2	9.7	
Nitrites	.052	.106	Increase
Nitrates	.18	3.27	
Oxygen absorbed	1.56	.86	45
Total Solid	81	77	5

This effluent was never found putrescible.

South Works. Average of four analyses.

	Sewage	Effluent	Purification %
Free Ammonia	1.92	1.13	42
Albuminoid ammonia	.57	.29	50
Chlorides	8.5	7.5	
Nitrites	0	.101	increase
Nitrates	.02	.465	
Oxygen absorbed	2.64	1.81	32
Total Solids	66	47	22

The effluent seems to undergo change in the tank but samples are not found putrescible.

The percentage purification in these cases appears to be small, but it will be borne in mind that the sewage is a very weak domestic one and that the effluent as compared with others is by no means very bad.

Probably improvement might be effected in both cases by securing proper aeration in the filters and in the case of the South Works by arranging some method whereby the black deposit could be separated from the effluent and kept from the river. It is, however, a considerable handicap that the level of that effluent is here twelve feet below the stream.

(4) The last installation to be dealt with is the small one at Methilhill.

There/

There are here following on a small grit chamber two tanks with a combined capacity of 7087 gallons the daily flow being 6675 gallons.

From a measuring chamber the sewage passes to a circular filter six feet in depth and having an area of 17 square yards giving a distribution by a revolving sprinkler of 392 gallons per square yard per day. On examination the works are found to be in a sheltered position and all parts working well. The filter is walled round, with only few small openings. There is a considerable depth of sludge in the tanks, due possibly to the unusually small grit chamber. The analyses are as follows:-

Average of four analyses.

	Sewage	Effluent	Purification %
Free ammonia	3.62	1.007	72
Albuminoid ammonia	1.057	.392	63
Chlorides	18.85	14.75	
Nitrites	0	.0125	increase
Nitrates	0	4.2	
Oxygen absorbed	5.2	1.137	79
Total Solids	237	91	63

Considering the character of the sewage this cannot be considered a very unsatisfactory result and the/

the effluent is clear and non-putrescible, though it has a good deal of deposit. But the purification is comparatively good and the increase in nitrates show that this bed is working better than the others.

Probably the provision of a better grit chamber, the cleaning out of the tanks and arrangement for a more complete aeration of the filter would make a considerable difference and produce a really good effluent. It is of interest to note that this is the only instance described in which the distribution to the filter is almost continuous. There being only one bed and a small measuring chamber, the doses are so small and follow so rapidly upon one another as to be almost continuous in flow. Yet the result is notably the best.

On comparing these different sewage installations and the manner in which they are worked with our ideal installation and the principles on which it would be worked the weak points of the former stand out pretty clearly. And one fact seems particularly striking, namely that, with some small exceptions, it is in the aerobic or latter part of the preparation of the effluent that failure occurs. It is the filters and the distributing apparatus that are to blame: the organisms faithfully do their work in the anaerobic/

anaerobic tank and that work is well done because the supply of their food is simply and easily carried out: they would do it equally well in the aerobic filter were the food supplied with equal regularity. But it is the human side of the apparatus that is to blame and if filters are arranged in such a way or of such a kind that air cannot penetrate them and if distributors of such a kind are supplied that part of the filter is starved while the rest is overworked, success will be impossible.

Also another fact strikes one clearly, upon reading over the story of these different installations. It is a fact only too often brought out by the history of public undertakings, and it is this. In the laudable desire to spend the public money with economy, local authorities are apt to forget that a certain amount of expense is necessary to success. And not only is this apparent in the actual outlay upon the works, when the engineer is too often called upon to reduce his estimates and to cut down this and that item, in spite of his protests. But when the works are finished and in working order, they are expected to cost no more; they are given over to the charge of a man who is almost unskilled, usually a scavenger, and all or nearly all idea of upkeep is dismissed/

dismissed from the public mind. This is especially the case in rural districts.

It cannot be too clearly brought out that if sewage works are to produce satisfactory effluents they must be well looked after. Especially at first, many experiments will be necessary to ascertain the best depth for the filters and the best method of dosage to them. The filters will always require attention to keep them in a condition suitable for their work, and the distributor of whatever variety must be kept in perfect working order if success is to be attained.

But too often, once the works are under way, the local authority loses all interest. If the effluent is not what was expected, they blame their advisers, the very advisers whose estimates they curtailed: they shrug their shoulders, considering that they have spent so many hundred pounds and so done their duty. And they firmly refuse to spend any more.

With regard to the state of these effluents as brought out by analysis, it is difficult to say much. As Dr. Dunbar, of Hamburgh, pointed out some time ago in a most masterly paper, the subject of standards for sewage effluents is a most difficult and thorny one./

one. Judged by most of the arbitrary standards that have been used in this country most of these effluents would be fit to pass into a stream. He gives examples of sewages and effluents containing as much as 3.55 and 2.19 grains of organic nitrogen per gallon which have been clear and non putrescible while others having only 2.1 and even .63 of the same have been the reverse.

The effluents I have described with the exception of those of North Thornton and Methilhill have all been sometimes putrescible. They are all disagreeable in appearance and throw down some sediment on standing.

The remarks made by Dr. Dunbar are so interesting and important that they may well be quoted in extenso, on this point. He says:-

"How are we to understand these singular facts? According to my view, it would be a mistake to think that by biological sewage purification only about three quarters of the soluble organic matters present are entirely removed from the sewage, the remainder staying unaltered in the effluent. We have good reasons to believe that by biological treatment the entire organic matter present in the crude sewage is retained and decomposed. If therefore a crude sewage/

sewage contains, say about 3 grains per gallon of organic nitrogen, the effluent 1 grain, we must not believe that about one third of the organic substances had passed the plant unaltered: but we may suppose that with the exception of those substances unusually resistant to decomposition and therefore not liable to putrefaction, all of the organic matter has been decomposed and that those substances giving the reaction of one grain of organic nitrogen are entirely different substances, not liable to undergo putrefaction. Therefore it ought to be of little consequence whether the effluent contains .1 or .2 grains per gallon or several times as much of these substances, (as indicated by the albuminoid ammonia test), or whether we find 1 or 2 grains per gallon of oxygen absorbed or even much larger amounts, so long as these substances are non-putrescible and not harmful to fish even if they are placed into the concentrated effluents. Such effluents should be considered as harmless and we ought not therefore to object to their being discharged into our rivers."

This theory is of great interest and seems to fit well to facts: it explains the reason why certain effluents, though by analysis conforming to standards which/

which have as a rule been trust-worthy, should be found putrescible and unsatisfactory.

This evidence given by the analyses which have been presented seems also to confirm what has been said by Dr. Dunbar. For if "by biological treatment the entire organic matter present is decomposed" when everything is in working order, then if it can be shown that there are gross faults in the working of the purifying apparatus, it ought to follow that whatever results are given by analyses, the 'entire organic matter' has not been decomposed and a putrescible effluent will result: and this seems to be clear from the analyses and the remarks made upon them. To judge from the analyses alone, by most of the rough standards that have been laid down, these effluents would be fit for discharge into a stream; but their appearance and after history proves that they are not: and examination of the purification works from which they come supplies the reason why.

While the discussion of these effluents is under consideration, there is another question in this relation which might be here introduced. Is it more difficult to purify a 'strong' domestic sewage than a 'weak' one? It will be noted that all the sewages which have been analysed have been 'weak' domestic/

domestic sewages and it is unfortunate that there are no results of the purification of a strong one upon the same basis of comparison. There have been published however many analyses giving admirable results from the strong domestic sewage of towns, where as even in the two cases I have described (Thornton North and Methilhill) where little fault is to be found with the state of the apparatus, yet the effluent is by no means perfect. It seems that within reasonable limits, the richer and more nitrogenous the pabulum presented to the organisms, the healthier and more numerous they are and the more thoroughly they are able to dispose of it. So that possibly the very fact of the sewages with which we have had to deal being in most instances of the weak domestic category has told rather as a hindrance to the healthy growth of the organisms than as an alleviation of the work to be done by them.

There are possibly other points for consideration which might be raised by a study of the description of these sewage works as I have hastily described them and of the analyses of the sewages and effluents which I have presented: But I have thought it unwise to make these a text for a disquisition upon sewage purification in general. Also I might have gone/

gone fully into the arrangement of each installation, with detailed description and criticism. But knowing that the general is more interesting and valuable than the particular, I have rather confined myself to a rough description in each case, criticising the most obvious faults and suggesting possible remedies broadly: and in the remarks I have ventured to make I have tried to bring out anything of general interest which could be deduced from the work I have done.

LIST OF AUTHORITIES CONSULTED.

- George Thudichum, F.C.S. 'Bacterial Treatment of Sewage.'
London, N.D.
- Wallis Stoddart, F.C.S. 'Continuous sewage Filters' Bristol
1901. 'The Tanking of Sewage'
London. 1905. 'Best Method of Sewage
Disposal.' Bristol 1905.
- Donald Cameron. 'Recent Experiments on Septic Tank at Exeter.'
Repr. San. Record. 1896.
'Purification of Sewage.' Engineering June 1898.
- Dr. Vacher. Paper Read at Ashley Hall, Liverpool. Sept. 1902.
- Dr. Barwise. As quoted in various places. Letter to Dr.
Nasmyth. June 1901.
- Prof. Hunter Stewart. Report on Kely Sewage. July 1905.
- Mr. Baird Laing. Report on Kelly Sewage. July 1905.
- J. D. Watson. 'Treatment and Disposal of Sewage.' Trans.
Incorp. San. Assoc. Scot. 1906.
- G. J. Fowler. 'Recent Experiments in treatment of Manchester
Sewage.' Jour. Roy. Sans. Inst. 1904.
- Prof. Dunbar. 'Standards of Purification of Sewage Effluents.'
Jour. Roy. Sans. Inst. 1904.
- Wilcox and Reid. 'Importance of Uniform Distribution of
Sewage etc.' Jour. Roy. San. Inst. 1904.
- Scott Moncrieff. 'Bacterial Treatment of Sewage.' Jour. Roy.
San. Inst. 1907.
- Dr. Reid. 'Nitrification of Sewage.' Jour. Roy. San. Inst. 1907.
- Prof. H. Beare./

Prof. H. Beare. Notes of lectures on Sanitary Engineering.
1904.

Dr. Dibdin. 'Purification of Sewage and Water.', London 1903.

Dr. Rideal. 'Sewage and Sewage Purification.' London. 1901.

Dr. Reid. 'Practical Sanitation. London. 1904.

Various Reports of Medical Officers of Health, and
the pamphlets of the Septic Tank Co. and Mather &
Platt.