Thesis

The Bacterial treatment of Sewage

with

references to Intermittent Downward Filtration & Broad Irrigation

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All who are engaged in Public Health work, either as M.O.H.: S.I: or Surveyor or even as members of Sanitary Committees, will admit that today we have to consider subjects of the highest importance from a sanitary point of view.

The faulty disposal of excretory matter and house refuse being the most prolific source of nuisance, and therefore one of the greatest dangers to health.

Experience has taught us that to maintain vigorous health, to prevent the attacks of various fevers, and to diminish the virulence of others, all excremental filth, slops and house refuse must be removed as speedily as possible from the immediate neighbourhood of inhabited dwellings.

All these matters more or less offensive from the first become more offensive and injurious by keeping, especially in a warm damp atmosphere;

for these conditions of warmth and moisture are those which facilitate putrefaction decomposition of all kinds. When these refuse matters are improperly disposed of or are allowed to accumulate in middens or cesspits; the air, the earth, and water are polluted and poisonous matters enter our systems through both the respiratory and digestive organs.

All are therefore agreed as to the importance of the removal of these waste and effete materials; and the question resolves into how can this best be done?

In rural districts and very small scattered villages some form of conservancy system must be adopted, but for larger districts and towns the question is a much more difficult one to solve.

Schemes fairly successful at certain places and under certain conditions are apt to prove failures,

when the conditions are altered;
and we must know authoritatively
what these conditions are and
that we can only expect to do,
as the result of many enquiries
and experiments conducted in a
painstaking and scientific
manner.

"Whenever and wherever there is
a decomposition of organic matter,
whether it be the case of a herb or
of an oak, of a worm or of a whale,
the work is exclusively done by
infinitely small organisms.
They are the important, almost the
only agents of universal hygiene"
(Duclaux).

This is the means by which Nature
rids herself of the effete matter
of the animal and vegetable
kingdoms.

The bacterial purification of Sewage
is essentially an attempt to imitate
the natural method of refuse disposal,
and with our growing knowledge

of Bacteriology we are able to encourage the life processes of living organisms "under control," with saftey and advantage.

<u>The Composition of Sewage</u> -
As a typical case, take the sewage of a town having a water supply and combined sewers.
The sewage is the total water supply, after use, except that employed in gardening, together with a large amount of rain water, plus matters taken up & washed down.
These matters may be divided into:-
1 <u>Inorganic matter in suspension</u> - Chiefly road grit & sand. This would separate out by simple subsidence if allowed to rest.
2 <u>Inorganic matter in Solution</u> - In addition to that already in water a small amount of phosphates are derived from sewage, which is one of the chief causes of the growth of sewage fungus.

But by far the most important factor is the Organic matter, which may be-

3. Organic matter in solution.-

None of the chemical processes have much effect on the removal of this, while some of them, which employ much lime, actually increase it.

It is this organic matter in solution that is the cause of many effluents, although bright & clear and comparatively free from odour, subsequently becoming putrid.

4 Organic matter in suspension -

These can be divided again into -

1. Dead organic matter both animal and vegetable.

Such as faeces & urine, soap & discharges from sinks, vegetable debris, paper etc

2 Living Organisms.

If in addition there are manufactories, which discharge their waste into the sewers, by the time it has received all its component parts the sewage will indeed be complex in character.

The sewage is usually alkaline in reaction, but at times local factories may discharge a great amount of acid waste & render it slightly acid for the time being. The reaction is important from the bacteriological standpoint.

Practically all sewage, apart from manufacturers' refuse, is made up of various compounds of Carbon, Hydrogen, Oxygen & Nitrogen. Other elements are present such as Sulphur & Phosphorus, but only in slight amount. The different combinations of three or four of these elements are very numerous and often ~~extremely~~ complicated.

But however complex the structure of these compounds may be, they are disintegrated and dissolved into simpler and elementary forms; the Carbon becoming CO_2, the hydrogen H_2O and the nitrogen N_2O_3, & N_2O_5.

Such a resolution, although apparently simple, is probably a complex one in its intermediary products.

Referring to the way in which the Sulphur is got rid of; Dr Rideal says, "In the septic tank I have found, that a mercaptan, (methyl hydro-sulphide), and other ethereal compounds are undoubtedly present in small quantities. They are very soluble and fairly easily oxidised. Most of the Sulphur however enters into combination with the iron present in the sewage forming insoluble Ferrous Sulphide and giving a black color to the suspended matters."

Living organisms —

The organic matters found in Sewage, as we have seen are partly in solution and partly in suspension and sewage contains in itself naturally, the necessary organisms for the destruction of this organic matter.

Our object therefore in the bacterial treatment of sewage, is to make use of and control this innate force, so that the organisms may live out their natural life history and execute their allotted task, of breaking up the organic solids, rendering them soluable and further resolving them into their simpler elements.

In the final process of purification an effluent should be produced, which is free from putrescible matter and practically contains only inorganic or mineral substances.

As has been pointed out by Dr Houston, in the 1st report, on "the Bacteriological Examination of London Crude Sewage;" by Dr Clowes to the London County Council, (May 1898), the importance of obtaining an knowledge of the number and variety of bacteria in crude sewage, preparatory to an examination of the effluents from any system, is very essential.

With a view to this end, he spent several months, while the Crossness and Barking contact beds were in course of construction, in collecting samples of crude sewage and after making suitable dilutions, in cultivating on gelatine and other media and counting the colonies.

He also estimated the number of Spores of bacteria present, the number of liquefying forms, and he describes the methods he adopted to isolate special forms of Specific varieties. viz - B. Coli, B. Typhosus, B. Diphtheria and the Spores of B. Enteritidis Sporogenes, Staphylococcus and Streptococcus.

He gives as a summary of his results, the following:-

1 "The total number of bacteria, in 1.C.C. of Barking crude sewage, averaged 3.899.259, (19 cultures of 9 samples). And in 1.cc. of Crossness crude sewage 3.526.667, (11 cultures of 6 samples).

2 The number of Spores of bacteria, in 1.c.c. of Barking Crude sewage, averaged 332, and in 1.cc. Crossness crude sewage 365, which gives a ratio of Spores to total number of bacteria of

of 1 — 11.744; and 1 — 9.662; respectively.

3 The number of <u>Liquefying bacteria</u>, in 1.c.c. of Barking crude sewage, averaged 430.750; and in 1.c.c. of Crossness crude sewage, 400.000; which gives a ratio of liquefying bacteria to total number of bacteria of 1 — 9; and 1 — 8·8 respectively.

As regards the <u>species of micro-organisms</u>, it was shown, that in Barking and Crossness crude sewage, the Spores of B. Enteritidis Sporogenes were present in numbers varying from atleast 10 to about 1000, per c.c. And B. Coli was present in numbers usually exceeding 100.000, per c.c.

Notes are also given of the occurrence of other bacteria, such as Proteus-like forms, B. fluorescens liquefaciens and B. non liquefaciens, B. mycoides, B mesentericus, B. subtilis. etc.

But it must be remembered, that these figures give only an approximate idea of the actual number of bacteria present in any sample of crude sewage.

It is not difficult to obtain gelatine plates cultures, with colonies sufficiently advanced to be counted; even although many rapid liquefying forms may be present. But can we rely upon our enumeration?

1 There is no doubt the large number of liquefying forms, obtained in crude sewage, obscure the growth of many other forms.

2 The only forms, which do show growth, are the aerobic; and only such of them that grow rapidly in Gelatine. We cannot tell what percentage these forms bear to the actual total number in crude sewage.

3 The Anaerobic forms are not in evidence at all, on account of the method for their growth employed.

4 The percentage of liquefying forms

again is unreliable, on account of many being embedded in the gelatine, and not being allowed time, on account of the overcrowding of the plates and the liquefaction of the gelatine, by forms which were not so handicapped, to prove their presence.

It is true much of this can be avoided by suitable dilutions of the sewage sample and by surface plate cultivations; but still the difficulty is a very practical one.

5 The number of colonies, which we are able to count, often vary very greatly even when the samples are taken within a few hours of each other, on the same day.

There does not seem to be any relationship, between the number of Spores and the total number of bacteria day by day.

For example, on March 2, 1898.

1.c.c. Crossness sewage gave

3.190.000 bacteria and 2.800 Spores;

4 5.290.000 Do and 500 Do;

on the same day, only an hour or two later.

6 It is comparatively easy to demonstrate the presence of B. Coli Communis and B. Enteritidis Sporogenes, on account of their marked growth characteristics; but to estimate their total number is again difficult, on account of the overcrowding of the plate culture and the rapid liquefaction brought about by other forms.

To search for Typhoid Bacillus, & other pathogenic organisms, in routine work, presents very great difficulty indeed.

We possess no method of encouraging the growth of Eberths' bacillus, without at the same time favoring the more energetic saprophytic organisms of the Coli group.

NB. Levy and Bruns consider, that the best prospect of success is offered by Kruse's modification of the Carbol-Gelatine plate culture method, first suggested by Chantemesse and Widal.

Method:- ·1 cc of a 5% soln. phenol is added to 10 c.c. sterile gelatine & allowed to solidify in a Petri's dish. From ·1 - ·5 c.c. of dilute sewage, (1: 10.000), is spread over the surface of the Gelatine.
Suspicious colonies are stabbed off into 2% glucose agar; and those which produce no gas and the growth of which is not exclusively superficial, are further worked out and not passed as genuine Typhoid untill they have responded to the Pfeiffer-Grüber-Widal reactions.
But in several recent epidemics we have not been able to demonstrate the presence of B. Typhosus at all, in water: Eg. Worthing.
Cholera again presents like difficulty, as exemplyfied by the epidemics in Hamburg & Altona, where the bacillus could not be found in the water supply & yet it is unquestion-ably a waterborne disease.

A very large number of bacteria have been met with in sewage, which have never as yet been isolated or described; for example a cultivation of Crossness Sewage, containing only ·00001 c.c. sewage, showed at least 5 distinct species of microorganisms, out of a total of 34 colonies.

The relative importance of these constituents of sewage, in reference to its purification, is a subject which admits of considerable diversity of opinion. It will however be admitted by all, that when the effluent must pass into a stream furnishing the water supply to communities lower down along its course, that no system of treatment will be satisfactory, which does not remove entirely any specific organisms, which may be present and all suspended impurities.

It is only by a thorough study of the growth requirements of bacteria, that we can hope to arrive at a

Knowledge of how to construct their environment; so as to allow the fullest scope possible for their action.

A brief reference to some important points with reference to bacteria, will not, I think, be out of place.—

Given an adequate food supply + ideal conditions, a single bacterium can multiply into millions in a few days, the possibility in this direction is infinite.

As before mentioned, the great function of bacteria in Nature is the breaking up of complex organic matter into simpler forms.

Many varieties of bacteria grow side by side, and the food supply of any particular variety is relatively bit altered by the growth of the other varieties present. Sometimes the growth of others around favors, sometimes it retards, or even kills out, another species.

Again most bacteria seem to produce excretions, which are unfavorable to their own vitality, and so arrest their growth, long before the medium in which they started to grow is exhausted. But this fact is mainly with reference to laboratory substrata; in nature this may not occur to the same extent.

Moisture is absolutely essential for the continued growth of all forms. For every species there is a temperature at which it grows best, — the Optimum temperature. — There are also maximum and minimum temperatures, beyond which range it will not grow. As a general rule the Optimum temperature is about the temperature of the living organism's habitat.

Direct sunlight is powerfully inimical.

The deportment of bacteria in the presence of air is important. Some will only live and grow in the presence of Oxygen. —

– Obligatory Aerobes. – Others when none is present – Obligatory Anaerobes. – In still other cases the presence or absence of oxygen seems to be a matter of no great moment. – Facultative Anaerobes – i.e. preferably aerobic, but capable of existing without oxygen. To this latter class of organisms we are possibly indebted for a large amount of the nitrification which goes on in the contact beds.

Further we can classify bacteria according to their habitat.

1 Parasitic – (needing a living host) to which belong most of the pathogenic forms.

2 Saprophytic – (needing dead organic matter for their nidus.)

3 And a third class may be distinguished, which is of essential importance to our subject; that of Facultative Saprophytes – or those which can adapt themselves to circumstances and exist indifferently

as parasites or saprophytes.
It means that pathogenic organisms of class I, can continue to live or it may be even to multiply on dead organic matter. This fact is of vital importance to the health of the community.

An effluent very rich in bacteria may not of necessity be condemned as not fit to be admitted into a water way, when the latter is not to be used as a source of drinking water. On the other hand an effluent quantitatively very much purer, from a biological standpoint, may be most dangerous; as it may contain Specific organisms which may be pathogenic.

The fact of encouraging the life processes of micro-organisms in our very midst is not dangerous; considering that we do so under control. The eating up of the pabulum leading to the death of the organisms.
Again, even although Specific

pathogenic organisms should happen to be present in the sewage, instead of their multiplying and spreading disease, it has been noticed, that these forms to a great extent tend to become crowded out by the enzymes of the surrounding innumerable saprophytic species.

Method of bacterial action.—
In the year 1839, Schwann & Schultze made a most important discovery, that microorganisms are the true agents of decomposition.

This was followed by many additional statements by various observers, which have paved the way towards a scientific knowledge of the true nature of putrefactive processes.

In 1877 the essential discovery to a true knowledge of bacterial action, was made by Schlosing and Muntz; that there was a class of organisms which nitrify organic matter, or by their vital activity cause Ammonia to be oxidised to Nitric Acid.

Since then it has been demonstrated that this is brought about by the action of two classes of bacteria; one of which converts the Ammonia into N_2O_3; and the other, the N_2O_3 into N_2O_5. These acids, by their reaction on the bases always present, form Nitrites & nitrates & these go to nourish the living plant.

Nitrites & nitrates are in themselves innocuous, but their presence shows what stage has been reached in the process of nitrification of the putrescible organic matter.

To a certain extent some of the Nitrogen and hydrogen are liberated in the nascent state.

Winogradsky and others have succeeded in making agar cultures & isolating many of these forms.

<u>The power of liquefying gelatine</u> is characteristic of many bacteria,

and although we cannot assume that these organisms have for that reason a similar power over the many complex forms of organic matter in sewage; yet the supposition is, that by their conjoint action, they do possess that power; as evidenced by the fact that these complex bodies are really liquefied and rendered soluable by microbial means.

~~From our knowledge of bacterial~~ action, however limited, we know that it is by the combined action of many varieties of different species of micro-organisms, that their great achievements in the ultimate resolution of organic matter is brought about. ~~For~~ By example some bacteria liquefy gelatine, others do not; some coagulate the casein in milk and then dissolve it, others coagulate it, but do not further peptonize it; others peptonize it directly. Some forms which liquefy gelatine, coagulate milk, and others coagulate milk, without being able to liquefy gelatine. Some can liquefy fibrin and may at the same time be able to liquefy gelatine, or not; the same applies to blood serum, egg albumin, etc.

In the light of these facts it is safe to assert, that the number of liquefying organisms in proportion to the total number of bacteria is a factor evidencing the probable power of self purification of the sewage.

The nature of the Putrefactive process –

Although the study of fermentation and the proper understanding of the true nature of putrefaction are attended with great difficulties, the process is ~~probably~~ one analogous to peptonisation; or to what takes place in gastric ~~and~~ intestinal digestion.

As a proof of this, the production of albumoses, peptones, etc. similar to those of ordinary digestion can be demonstrated in putrefying solutions.

Experiment:- If a solution containing fibrin be allowed to undergo putrefaction, the fibrin dissolves & gaseous evolution of CO_2 + NH_3 occurs; but should the bacteria be killed or paralysed by chloroform at this stage, then only a peptonisation of the fibrin occurs, without the splitting up and gaseous production being observed.

The splitting up of complex organic material depends on the chemical nature of the bodies involved and on the varieties of the bacteria which are acting.

The decomposition of albuminous bodies, which is mostly involved in the wide and varied process of putrefaction in Nature, can be undertaken by whole groups of different varieties of bacteria. Each one of these germs may

may produce intermediary products of widely different character, but all of them, perhaps, tend in the direction of finally resolving highly complex organic substances into their simpler component parts.

It is probable therefore, that a peptic ferment is produced by these micro-organisms, similar, if not identical to that produced in the living Stomach.

Ferments have in fact been isolated from different bacteria, which split up sugars into alcohols and acids, coagulate caseins, and split up urea into ammonium carbonate. Such ferments may be diffused into the surrounding fluid or be retained in the cells, where they are formed or at any rate in their immediate proximity.

The organic matter is broken up and rendered soluable by this probably intracellular disintegration.

With these facts before us, let me

now give a brief description of one or two of the chief methods of bacterial treatment in use.

The aim of the earlier method was to subject the sewage immediately to Aerobic action, but it is now held by Authorities that a much better effluent is obtainable by a preliminary Anaerobic treatment; as this latter is of special value in breaking up and rendering soluable the coarse suspended matter, which it is otherwise necessary to screen off, to prevent clogging up of the interstices of the contact beds.

The methods available can be described as two; but although they may be called two distinct processes, yet in nature there is no hard & fast line between their spheres of action.

1 Aerobic.

(Dibdin's Sutton process, Barking & Crossness etc)

2 Anaerobic.

(The Septic tank.)

As before mentioned, these two processes ought to be combined to produce the highest degree of purification as yet obtained. There is no doubt a good deal of anaerobic action takes place in the sewers, but not sufficient.

The septic tank alone is insufficient for the complete purification of the sewage of a community and there is no doubt, that the final treatment ought to be aerobic.

Mr Cameron of Exeter, who was the pioneer in the use of the septic tank, claimed at first, that the tank alone was a sufficient treatment; but he selected a sewage so dilute, that indeed many of the older processes of sewage purification might have looked upon it as a satisfactory effluent. He has since adopted an ultimate aerobic treatment.

The Dibdin Method -

The sewage to be purified is first screened and then passed on to beds of coke. The sewage is distributed by one or more channels over the top of the bed, which is filled untill the coke is just outmerged. It is collected on the floor of the bed by rows of agricultural drain pipes, joining one main collector.

After a contact of some definitely arranged duration, the discharge-valve is raised and the effluent is received by a second filter. This one is made up of the same material as the first bed, but the particles are much finer. Dust however is ridigly excluded –

Series of coarse and of fine beds are provided, so that each may have a rest after dis-charging, in order that the interstices may be well aerated.

In the case of Crossness, the filling of the 4th bed usually takes about 4 minutes, and the sewage is allowed to remain in contact for about 3 hours and then discharged. Eight hours being given for aeration. In the case of the 6th bed the period of aeration is only 4 hours.

The beds have continued to work satisfactorily being filled twice daily, after having been "matured" in the first instance, while the coke was becoming stocked with organisms. It is very important not to overwork the beds therefore, before they are sufficiently matured to enable them to deal with the sewage.

The second filter will be filling up whilst the first is standing full.

It is an advantage to have a spare bed of each kind, so that a complete rest of some days may be given to all in turn. This prevents the beds from becoming "Sewage sick."

The beds require raking over from time to time, (twice weekly), to remove the slime which forms on the surface, as well as the growth of sewage weed, which is so very rapid in warm weather.

Much depends on the amount of fall in the land available, which would fix the depth to which the beds might be laid, but the effluents from a 4 ft bed, 6 ft bed, + 13 ft bed, seem to be much on a par + the use of secondary beds promises a much better result, than that of increasing the depth of the single bed.

These contact beds are very generally called aerobic beds, but, as for many of the impurities in sewage, an anaerobic process must be gone through before the aerobic bacteria can be of use; it is not unreasonable to assume, that some anaerobic action takes place in at least the first or coarse bed. The fine bed is mainly if not entirely aerobic.

At the screen there is a most objectionable smell and the sewage is not free therefrom, when being distributed over the coarse bed. On leaving them the taint is slight, and the liquid is cloudy in appearance. The discharge from the fine beds is clear + has but little, if any, odor.

The amount of sewage which can be treated by a superficial unit of the coke bed has been estimated by Dr Clowes, as 370.000 gallons per acre, for one single filling daily, of the 4 ft coke-bed; and 673.400 galls. for the 6 ft bed. And he says, that, if the 13 ft bed is found to work satisfactorily, it should be able to treat a volume of raw sewage, (previously screened), equal to at least 3.500.000 galls. per day.

As each bed is generally filled three times during the 24 hours, the data given suffice for calculating the dimensions of the necessary beds.

When filtration through the beds is continuous, 250 — 400 galls. may be passed through each square yard. (These estimates are however open to criticism as shall be seen later).

The Septic Tank —

It has been known for a long time, that if the suspended impurities were removed from sewage, it was comparatively easy to get a good effluent by filtration through suitable material.

But it was not till Mr Cameron of Exeter introduced his septic tank, that these matters could be satisfactorily dealt with.

The installations on this system, which have been introduced since, have been many and differ widely in extent; but are tolerably uniform in character.

The process, as it now works, is to pass the crude sewage into the tank and then on to the contact beds; so that it is really the combined systems of Cameron & Dibdin.

The tank may be made of any impermeable material and closed in with an arched roof, a man-hole is usually built to allow for inspection.

A grit chamber retains the road detritus, and a storm overflow pipe from this chamber comes into operation when there is more than three times the dry weather flow.

The sewage is delivered into the tank direct from the sewers and at a level, 18 inches or so below the level of fluid in the tank.

All the solids, other than road grit, enter into the tank and are there liquefied or turned into gases by anaerobic action. There is no smell from untreated sewage —

As the sewage flows very slowly through the tank a great improvement might be expected from sedimentation alone, but if that were all the resulting sludge would fill up the tank in a very few weeks.

I inspected the Septic tank near Romford, in Oct. 1899, and the idea presented itself, that the probability was, that the tank would fill up with deposit; as by passing a stick down to the bottom there seemed to be a good thickness present. But after a few weeks no further increase took place and today, March 17th 1900, it seems less than ever, instead of being greater.

A thick unwholesome scum forms on the surface and bubbles of ascending gas carry to the surface solid particles, only to let them sink again, when the bubbles burst.

This fermentation vat is teeming with organisms and the process of putrefaction will continue as long as putrefyable matter is present.

The effluent from the tank is very ammoniacal and very little purer than the sewage entering. Some of these ammoniacal gases escape, but they soon diffuse and are imperceptible at a few yards distance. Certainly no nuisance is created. These gases give off a great amount of heat when burnt, which might be utilised in providing power for pumping.

The exit aperture is at the lowest level of the tank floor, which is sloping, and by removing a valve the contents of the tank are forced out into a slump hole and are carried by a distributor & passed on to the beds by means of automatic gear, till the coke is all submerged. The process is then very similar to Dibdin's in the contact beds.

A scheme has recently been submitted to deal with a flow of 4,000,000 galls. per day; the chief details of which are 6 tanks, each some 375 ft. long by 29 ft. wide, and 8 ft. deep below the springing of the roof arches. And 20 contact beds, each 100 ft. long by 95 ft. wide, filled to a depth of 3½ ft. with furnace clinker.

20 beds, that is 5 sets only, are worked at one time.

On the other hand, the sewage from a country policeman's cottage is being treated by this method.

The capacity of the tank should be such that it can contain a little over 24 hours flow of the sewage of the district in dry weather.

Many ~~other~~ patents have been taken out for installations on similar principles to both Dibdin's & Cameron's methods; but it is unnecessary to even enumerate them in this instance.

Sludge –

There does not appear in any of these bacterial processes to be that large accumulation of sludge, which is so evident in the chemical precipitation method and which presents so great a difficulty in its removal.

A small amount of this blackish deposit forms at the bottom of the tank, but it is so slight that a year's accumulation is hardly worth removing.

Where screens are used in

in Dibdin's system, there is a certain amount of matter which must be removed; but this is not to be compared with that left by chemical processes.

The septic tank at Belle Isle, Exeter, has taken the sewage without screening from 1500 people for over 4 years; no mineral residue has yet been removed and the small quantity of matter in the tank in no way interferes with its efficiency.

Depth of Contact beds and material used for filling them:—

The depth of the beds is still under experiment, but, from the results so far obtained, a 4 ft bed is as efficient as a 6 ft bed.

Treatment through secondary beds points to a much greater purity of the effluent than by increasing the depth of the single beds, as might be expected. The effluent from the primary bed being usually clear and free from suspended matters, the secondary bed can exert all its power in further nitrification.

The use of material to fill the beds is very varied, but it has been found, that probably fragments of ordinary gas works coke, about the size of a walnut, are most suitable. This comparatively large size increases the capacity of the beds and enables them to be filled and emptied more rapidly, as well as aiding aeration.

The secondary beds would be filled with a smaller size of coke breeze, crushed clinker, ballast, sand, gravel or other material.

The material and the size of the individual fragments of that material used have a great deal to do with the depth to which a bed can be laid, as, in the case of using too fine fragments, the beds are apt to become clogged, if deepened below a certain distance

According to Dr Clowes, the following advantages over chemical precipitation processes are claimed by the Dibdin system.

"1 It requires no chemicals.

2 It produces no offensive sludge, but only a slight deposit of sand & vegetable tissue which is free from odor." It is reasonable to hope, that by the additional use of the septic tank previous to the sewage being admitted to the contact beds, even these impurities might be largely reduced.

"3 It removes the whole of the suspended matter, instead of only about 80 % thereof.

4 It affects the removal of 51.3 % of the dissolved oxidisable & putrescible matter, as compared with only 17 % removed by chemical ~~treatment~~." By the use of secondary beds an additional purification of about 19.3 % is secured.

5 "The resultant liquid is entirely free from objectionable smell and does not become foul when it is kept.
It further maintains the life of fish."

History of the bacterial Contact bed —

It is well to briefly consider the history of the bacterial treatment, because very little reading will prove to us, that in principle this method of Sewage disposal is not new —
For years chemists & engineers have been engaged upon the problem, and although they did not recognise the labors of the benignant microbe, or give us a true explanation of the action which takes place in a Contact bed, yet they had a very practical acquaintance, not only with the difficulties of the sewage question, but with the lines upon which we are still attempting

its solution.

Time alone will show whether our present ideas really constitute the best and most economical means of purifying sewage.

With our present knowledge we must regard the passing of sewage through land for its purification, whether it be by Intermittent Downward Filtration, or by Broad Irrigation, as dependent on bacterial agency. Not only so, but it is evident that the present contact beds are the out-come of the old land filter of 1834.

As far back as 1880 a brochure appeared from the pen of Wm Bailey Denton, entitled "Ten Years Experience in Works of Intermittent Downward Filtration."

The author selected porous plots of land, which he levelled and suitably underdrained at the depth of 6 ft, and surface channels distributed the sewage on to the plots.

Each plot was allowed an interval of rest necessary for its aeration.

He writes as follows "In speaking of intermittent filtration, I refer to the concentration of sewage, at regular intervals, on as few acres of land as will absorb and cleanse it, without preventing the production of vegetation."

Dr Frankland at a very early date, 1870, reported that "an acre of suitably constituted soil well & deeply underdrained, with its surface levelled and divided into 4 equal plots, each of which in succession would receive the sewage of 6 hours, would cleanse the sewage of 3,300 persons."

This has been to a great extent borne out by the experiences of others, but it has also been found that the land very soon becomes "sewage sick", if used frequently & for a long period; which would entail a very large amount of land necessary for the disposal of the sewage of a large community.

Sewage, unless previously treated by some chemical or other process, filters very slowly & rapidly clogs up the pores of the soil; at the same time little of the dissolved organic matter is removed.

It is now generally conceded, that it is far preferable to filter the sewage mechanically or remove suspended matter by precipitation or by anaerobic fermentation before passing it through the soil.

Broad Irrigation —

A knowledge of the geology of a district is essential in determining the most suitable site for sewage farming. A fair amount of porosity is necessary. It would be little use to establish one on a stiff boulder clay, as an artificial surface would have to be prepared at a great cost. On the other hand, if the clay had a good lapping of some porous substance, as sand or gravel or loam, such a site would be suitable.

In determining the site again it is highly desirable ~~to~~ consider any surrounding water supply, lest pollution should occur.

The following experiments seem to show that there is a possible danger, in the case of heavy and continuous rain, of it may be specific and injurious organisms finding their way into the subsoil water from the surface of the soil.

Experiments made on the filtrating power of the soil and the convection of bacteria by the ground water, by Abba, Orlandi and Rondelli of Turin and published in a recent number of the "Zeitschrift für Hygiene und Infektions Krankheiten" vol. XXXI, 1889. p. 66. Whose object was to find out whether bacteria were to any extent carried down into the ground water from the gathering grounds.

They used two tests.

1 By staining the water intensely with Methyleosin + uranin, and
2 by adding a strong solution of containing the B. Prodigiosus. This organism was selected as being harmless, growing well on ordinary substrata, easily recognisable from its chromogenesis and not generally present in Turin water.

The object of the investigations was "to test the filtering power of the ground above and on each side of the subsoil drains, and to discover how far the bacteria, which percolate, are carried along by the ground water, with a view to determining what effect, if any, is exercised upon the water entering the drains by contamination of the soil."

The drains mentioned were the subsoil drains laid underneath the natural plots of soil selected for the experiment.

Their results:—
The coloring matters were a less delicate test than the Bacillus, as they took nearly twice as long to appear in the drains.
The B. prodigiosus they think does not pass into the ground water, unless heavy and persistent rains force it to do so.
The B. prodigiosus was also found able to live and maintain its vitality in the soil for about 2 years, and could travel long distances, if the water carriage was sufficient; turning up in the city taps 19 Kilometres off & reappearing for successive years. (1897. 1898.)

The large Breton farm (Sewage) at Hornchurch near Romford, Essex, is an example of a paying concern and well exemplifies the advantages and disadvantages of sewage farming.
This farm is a very large one

1 acre to every 100 inhabitants. No pumping is necessary till the sewage reaches the farm. The manager is an experienced hand, for 13 years he has conducted the farm.

There are no offensive and injurious emanations from the land, and as far as is known no pollution of the subsoil water.

There have been no cases of infectious disease or other trouble, which might be attributable to the farm, for a number of years in its neighbourhood.

Still broad irrigation, as at present conducted, does not seem to offer a final solution to the sewage disposal difficulty, on account of its inapplicability in by far the majority of instances.

The Local Government Board has laid down certain requirements with regard to sewage farms.

If the strong sewage, that is all sewage not exceeding three times the dry weather flow, is disposed of entirely by broad irrigation, there should be one acre for every 200 persons.

If the sewage is previously treated chemically, then 1 acre will suffice for from 1000 - 2000 persons. Tanks must however be provided to hold the dry weather flow for 24 hours.

But in a few instances only has sewage farming proved a success.

With exceptionally favorable soil & situation and good management, such a farm may continue to be remunerative for many years, but it seems very probable that there is a limit to this period.

But such a farm even although it does not pay expenses may still, in the instances where land is cheap & easily procurable, prove much more economical than a process of sewage treatment requiring costly plant and machinery and a large annual expenditure in labor and chemicals and producing nothing but an invaluable manure.

Yet the difficulty of securing land suitable and sufficient in acreage to deal with the sewage of a large city, especially when manufacturies' refuse is added to the sewage, puts the process out of court in these instances. Apart altogether from the fact that in a very few instances only is a satisfactory effluent obtained.

Bacterial contact beds are capable of dealing, if properly conducted, with a far larger volume of sewage than land filters and very much less space is required.

There is not the same fear of the beds becoming "sewage-sick" and getting out of order, requiring relaying. The purification effected is probably greater and unquestionably more uniform.

The labor is slight if the beds are automatically filled & discharged.

And the cost, although the initial outlay may in some instances be greater, is probably on the whole less considering ~~that few farms pay~~ expenses which means an annual outlay.

With regard to the Cost, Mr Bailey Denton estimated the cost of preparing and running a sewage farm sufficiently large to deal with 1,000,000 gallons a day, at £624.10.6; as against Mr Dibdins' £1000 per acre of artificial contact bed at Sutton; or £2000 according to Mr Santo Crimp's estimate for Barking; or £9,166 according to Mr de Courcy Meade's estimate for Manchester.

An acre of artificial contact bed Mr Dibdin holds can successfully treat 1,000,000 galls per day.

These figures could be elaborated, but ~~I do not intend~~ entering upon the Question of cost more fully.

the Local Government Board of England, it is very important to remember, insists upon effluents from bacterial beds being finally treated by passing through land. The area of land required depending on its character. But it is suggested that land ought to be obtained at the rate of 1 acre per 1000 population.

Much invective has been levelled at the Board on this account, and there is much to say for and against this apparently stringent + needless provision of "final land treatment".

It applies to all schemes where loans are necessary to carry out the work + where it is practically impossible to pay for the construction out of revenue.

Many local Authorities are therefore waiting for the Report of the Sewage Disposal Commission.

It certainly very greatly enhances the cost of disposal, entailing additional expense for the purchase of land and increasing the difficulty of securing suitable sites for installations; as it is only after the sewage has passed through the contact beds and therefore fallen some 4-8 ft., that the land comes into use.

A sufficient fall is not always obtainable and pumping machinery may even be required.

As an instance of the apparent inutility of this "final land treatment", a reference to Hampton may be of interest –

The Urban District Council of Hampton, in order to satisfy the Thames Conservancy, decided to pass the sewage through three sets of contact beds & an unusually pure effluent is obtained.

But in order still further to satisfy the L. G. B., who had granted a loan, they have to pass the effluent over land, to which they have to pump it. The result is that not only is the cost very much enhanced, but the resulting effluent on leaving the land contains more than twice the amount of impurities that were present in it when discharged from the contact beds.

Still any disinterested person who has seen the Septic tank and also the contact beds, which are being so widely adopted, must admit that such provision is not so wholly unnecessary as might be supposed.

Whether the fault be in the construction or in the management, it is certain that the results produced are in many cases not satisfactory. And yet in the near future, let us hope that land will become quite unnecessary as the result of the further perfecting of ~~existing~~ methods.

The water capacity of any contact bed at starting is assumed to be 47 % of its total capacity.

But this is quickly reduced to 33 % after the first few applications of the crude sewage. So that only

1/3 the gross capacity of the bed can be relied upon. Still further, when the sewage is not "settled" in any way before entering the beds, only 1/4 of the capacity is available.

Each set of beds, that is both coarse and fine, must be of sufficient capacity to contain the normal dry weather flow for 24 hours; and if the capacity of the bed available is only 33 %, it means, that taking an 8 hours cycle, the beds must be large enough to deal with 3 times the dry weather flow.

Storm water beds of some coarse material, such as clinker, burnt ballast, or gravel, must be provided in addition to the above, to treat a further quantity of storm water, equal to 3 times the dry weather flow, or a special area of land may be set apart to receive the storm water.

The experts appointed by the Manchester Corporation issued their report last November, with reference to the suitability of the bacterial method to deal with the special sewage of Manchester. The following may briefly [be] the result of their enquiry:—

That the manufacturers' refuse & sewage was able to be satisfactorily disposed of, if the sewage was first subjected to treatment in the Septic tank and then in the contact beds.

The recommendations are to the effect that the sewage be screened and then passed through the present open tanks, that those tanks should be provided with submerged walls & floating scum boards, so as to retard the flow of the mineral & organic matters in suspension; and that the effluent from the tanks should be passed through the double contact beds.

The experiments show that the bacterial system of treatment is efficacious at all seasons of the year.

"Finally, we may state our confident opinion that, with the system of bacteriological treatment of the sewage of Manchester set forth above, an effluent will be produced, which, will not only conform with the Mersey and Irwell Standard, but which will also materially improve the condition of the Ship canal.

Furthermore, as this system does away entirely with the use of chemicals, and at the same time, to a very large extent, reduces the volume of sludge to be dealt with, it is obvious, that much of the present expense will be saved by its adoption, and this saving may be taken as a material set-off against the cost of the construction of the proposed works."

The manufacturing refuse will vary in character with the staple industry. In almost every little town a certain class of manufacture is carried on, in several of which an acid waste is produced. The question naturally arises, will this acid have a restraining effect on the action of the living organisms in the tank and contact beds?

Dr Clowes, in his 2nd Report to the London County Council, says:-

" The occasional diminution in the per centage purification does not appear to be due to an acid reaction of the sewage, hindering the bacterial action; since the sewage is always either alkaline or neutral in reaction. Neither is this diminished purification apparently to be referred to the presence in the sewage of undue proportions of chemical refuse, derived from gas works & chemical works.

No evidence has been obtained of interference with the normal action of the coke bed from such causes."

The results of the Manchester experiments have supplemented this statement with still further proof, that the waste from manufactories which is of a special kind in the case of Manchester, and large quantities of which are admitted to the sewers, does not tend to decrease the total number of the bacteria found in crude sewage.

Nor has it been found to do so in the case of the waste of London, which is of the most varied description and forms a large component part of the total sewage –

Again with reference to the purification of brewery refuse, which is very troublesome to cope with on account of its impurity. Mr. R. F. Grantham remarks that 33 % of the sewage dealt with, at the particular works he is connected with, is brewery refuse & although its disposal has been a difficulty for upwards of 30 years, yet a most satisfactory result was got from the use of the Septic tank

The fact that the multi-complex waste compounds from manufactories have no marked deterrent effect on the life and vital activity of the living organisms in sewage is of very great importance from a commercial point of view, making the task of sewage disposal less difficult & costly, and proving in a very marked manner the efficiency of the bacterial process, as certainly no other process has approached success in this respect before.

Dibdin's system depends for its efficacy on the fact, that the distribution of the sewage to the beds is <u>intermittent</u>.

Unless the beds are allowed to rest for several hours previous to another filling, as well as having a longer rest, say a day out of every ten, their aeration is rendered impossible.

This intermittency is a sine quâ non, and has been agreed to as such by the Royal Commission on Metropolitan Sewage Disposal in their report, p. 46, and also by all subsequent investigators including the advisers to the Manchester Corporation.

Now it has been recognised from the first and indeed is beyond question, that the chemical change on which purification depends is oxidisation, and whether this is effected by purely chemical or biological agency (hydrolosis), is a matter which does not seriously affect the principle, which should underlie the construction & manipulation of a Contact bed, that is to bring the sewage & air into the most intimate contact possible.

In order to ascertain whether the surfaces of the coke particles were fully aerated between the intervals of discharging & refilling, Dr Clowes inserted pipes of different lengths into the beds and drew off air at stated intervals, which he examined for the proportional amount of oxygen and CO_2.

The results indicated that, even after the air had been in contact with the lower strata of the coke (13 ft.) for 70 hours, it still contained an average of about 75% of its original oxygen and the average amount of CO_2 did not exceed 3%.

The depths from which the air was abstracted & the intervals of time allowed to elapse after aeration was allowed to commence were varied, but all gave similar proof of the very satisfactory condition of aeration.

But it is quite possible, that the conditions to which we subject the sewage in the beds, are not so favorable to the oxidising organisms, that they ever can attain their maximum efficiency.

Even although the crude sewage has been strained or even rendered soluble in the septic tank previous to its being passed on to the contact-beds, the bulk of liquid displaces the air to a very great extent from the beds & sewage being practically oxygen free, we have hardly the ideal conditions for oxidization.

It is quite true that, on draining off the sewage from a bed the majority of the nitrifying organisms may remain in the interstices of the coke, but to enable them to nitrify, when the sewage is again admitted, there must be a good supply of oxygen present at the same time.

Is it not possible to admit the sewage plus a sufficiency of air simultaneously to the coke bed?

Probably we are much indebted to the Facultative anaerobes in the beds and the sphere of action of the aerobes may be to a great extent confined to the surface of the bed and to the neighbourhood of such air as has been entangled in the in the meshes of the coke.

Another point which is of interest in this regard, is that direct sunlight has a most powerfully inimical effect on all organisms, a very few minutes exposure being all that is necessary for their destruction.

Is it not therefore very probable that the open contact bed being exposed to the sun's rays, especially during summer, has its surface organisms destroyed or at any rate rendered functionless by those direct rays and so depriving the bed of much of its possible efficacy?

A fermentation process, such as the oxidisation of sewage, should not require any intermittency.
It ought to be a continuous process, if the necessary mechanical conditions for the sustenance of the nitrifying organisms are attended to.

These conditions may be said to be –

1. A continuous supply of suitable food. i.e. food in a suitable form, as well as suitable in quality.
2. An abundant supply of fresh air for the aerobes.
3. A suitable temperature.
4. The uniform removal of the fermentation products.

These conditions might be fulfilled by the use of some form of properly constructed contact beds, well aerated and drained, as well as a proper distribution of the sewage over the surface of the bed, after it has been acted upon by the anaerobes in the Septic tank.

There is no doubt that when the organisms are immersed in a large body of liquid and more especially so when this is of an organic nature, such as sewage, their activity is to a more or less extent inhibited.

Mr Wallis Stoddart in the Public Health Engineer 1900 (Feb.)

in describing his process of sewage purification by means of the "Stoddart Improved Sewage Filter", brings this point out very strongly.

He holds that the "filter" should be composed of a coarse medium, the limit of depth depending on this coarseness.

His results show, that the greater the depth, the higher the per centage amount of oxidisation, but the essential point to be observed was that the sewage should never be admitted so rapidly to the "filter" as to "coalesce into a continuous layer".

The sewage and air are admitted simultaneously and in Mr. Stoddart's own words "the sewage must be applied over the whole upper surface of the "filter" in fine streams of drops, at such a rate that the maximum amount shall be passed without charging any part of the "filter" with visible liquid." "In other words if the interior of this filter be inspected there must be no body of liquid anywhere visible, but the particles of medium must merely appear moist. This state of things, too, must be maintainable for years together, without, if possible, any human interference"

With particles half an inch in diameter the amount of nitrogen oxidised would appear to be about 3000 galls. per square yard per day.

And then he goes on to describe in detail the mechanical appliances he has patented to fulfill the above conditions; an installation of which has been erected at Horfield nr. Bristol and another in a suburb of Bristol.

He points out that the previous removal of suspended matters is imperative to the application of sewage to any "filter" and does not therefore claim for his patent, that it constitutes a complete system of sewage disposal, but only that if is an improved "filter", in which the errors of conditions to which sewage ~~has~~ hitherto been subjected are corrected.

The Septic tank is therefore requisite as a preliminary measure.

The chief advantages of this "filter" over the intermittent method seem to be

~~Intermittent Filter~~	~~Stoddart's Filter~~
1 Flow interrupted	1 Flow continuous
2 Capacity 200-250 galls. per square yard.	2 Cap. 1000-2000 galls per sq. yard.
3 Costly construction of foundations + walls.	3 No retaining walls or foundations required.

If the above improvements are authentic and can be carried out on a large scale, they seem to me to present features of admirable promise.

Dibdin forces his beds to ~~work~~, which is both anaerobic and aerobic, and if these organisms demand different conditions for their sphere of action,

if again both these means are necessary for the complete purification of sewage, then any one system which is properly constructed to favor the action of one group of organisms, cannot be ideal for ~~the other group~~. Consequently Dr Clowes has been obliged to try and solve the problem of the contact beds filling up with deposit, which accumulates on the fragments of coke. This deposit consists of mineral and vegetable organic matter. The mineral matter might be removed by subsidence in a detritus chamber, before the sewage reached the beds. While the vegetable organic matter is of that nature that microorganisms find unsuitable as a pabulum.
It is composed mainly of humic acids, which are the terminal products of a long series of changes that began in cellulose and consequently are not putrescible. to an

appreciable extent, such as animal organic matter would be.

This vegetable debris finds itself detained in the septic tank and never reaches the beds, at the same time, that does not prove that it is resolved by the anaerobes, probably it forms much of the deposit in the tank. Peaty matter contains very few organisms.

Dr Clowes has issued a supplement to his 2nd Report on the Barking and Crossness treatment in which he says - "The deposit consists of coke and sand particles, cotton and woollen fibres, diatoms, chaff, straw and woody fibre."

This latest difficulty of Dr Clowes is one of the strongest arguments in favor of the preliminary use of the Septic tank. As this deposit amongst the coke increases, the sewage capacity of the beds decreases, at the rate of about 1 %. of the original capacity per week. Obviously with such a decrease, the life of a contact bed cannot be of long duration.

After working for a comparatively short time it becomes necessary to wash the "filtering" material, if constructed in the usual manner, a procedure involving much arduous & expensive labor, because the original capacity is not restored in any degree by prolonged aeration, which proves that the deposit is not organic matter of animal origin and also the powerlessness of the aerobic ~~org~~anisms to deal with it.

Dr Clowes by adopting a system of rapid precipitation, before allowing the sewage to pass through the contact beds, finds that the process of choking can be reduced to nearly one half.

The index of the efficiency of a system is to be found by estimating the per centage purification of the effluent, as compared with the raw clarified sewage, both from a chemical & bacteriological point of view, and whether the effluent uniformly falls within a chosen standard of purity.

The great variation in the strength and character of the Sewage in different localities renders it impossible to devise a standard, which might be universally applicable. (Nor in fact any one system of treatment, which would meet with all requirements in all localities)

Moreover the degree of purification required is not constant.

When the sewage can with safety be cast into the sea or into the estuary of a tidal river, purification need not be nearly so complete, as when its only outlet is into a stream, which a little lower down furnishes the water supply to the towns and villages on its banks.

As the sewage varies in character so the effluent varies to a great extent. The least satisfactory results being obtained during the very hot weather, when the rainfall is practically nil.

But even then in the cases of the Barking & Crossness effluents they were not offensive in character, and did not become so when kept. They differ from the better effluents only by containing a larger amount of dissolved oxidisable matter.

In judging the purity of an effluent, we must have regard to the amount of combined nitrogen and organic matter it contains; as estimated by the number of grains per gallon of the oxygen absorbed in a stated time and at a stated temperature from an acidulated solution of Potassium Permanganate; and

and comparing this with a similar estimation of the clarified raw Sewage.

From that we can estimate the percentage purification calculated on the raw sewage.

It is important to remember that the sewage is deprived of all its suspended organic matter in the contact bed.

Dr Clowes gives in his 2nd Report to the London County Council many results of the examinations of Effluents, both from the single 4 Ft. coke bed and from the primary & secondary 6 Ft beds, at Barking & Crossness: as follows:–

"Relative purity of clear Sewage Chemical Effluent. Coke bed effluents. and lower river water." (Thames.)

The relative amounts of dissolved putrescible matter in the sewage, chemical effluent and coke bed effluents, as measured by the oxygen which they absorb from Permanganate, are as follows:–

	Oxygen absorbed in 4 hours @ 80° F.	Percentage purification calculated on raw sewage
Raw Sewage	3·696	
Chemical Eff.	3·070	16·9
Coke bed Eff (single)	1·799	51·3
Coke bed Effs. (double)	1·137	69·2
River water (high tide)	0·350	
Do (low tide)	0·429	

A comparison of these numbers with one another shows that by substituting a single coke bed treatment, the effluent sewage discharged into the river would be completely free from suspended impurity and would possess a purity as regards dissolved putrescible matter of 51·3, as compared with 16·9 in the present effluent; representing an improvement of 67·1 per cent. If discharged after double treatment in the coke beds, the percentage improvement, on the chemical effluent, would be 75·6. The bacterial action continuing in the river would rapidly bring the

the purity of such a liquid into a condition equalling that of the river water itself."

With regard to the ~~filtrate~~ from the Septic tank and resulting coke bed effluent, the following may be regarded as representative of the normal efficiency of this installation at Belle Isle, Exeter.

On an average of 6 ~~examinations~~ of the crude sewage, the tank filtrate and coke bed effluent, we get these figures, by T. H. Pearmain and C.G. Moor. M.A.

Oxygen absorbed
in 4 hours @ 80°F.

Raw Sewage	4·3.
Tank Effluent	1·4.
Coke bed Effluent.	0·33

This final effluent chemically is as pure as the Thames water at high tide (·35). and if the process continues to give uniform results and is capable of treating sewage of varied quality on a large scale, as I think it has been proved to do, the prospect for this method is the best.

The process has been examined by several well known observers, whose figures are as follows:—

Percentage purification produced as calculated on raw sewage—

Authority.	Albuminoid ammonia.	Oxidisable matter.
Dibdin & Thudichum.	63·2	80·9
Dupré.	84·9 (1)	88·3
Pearmain & Moor.	80·0	90·0
Perkins.	64·4	78·7
Rideal.	77·0	82·0

(1) Organic nitrogen.

The results of chemical analysis of Crude sewage, tank filtrate, & Stoddarts Filter effluent, respectively, are given by him, expressed in grains per gall. as above;

Oxygen absorbed in 4 hrs @ 80°F.

Sewage	5·39	Dry weather flow
Tank Filtrate.	1·218	Oct 3rd. 1899.
Filter Effluent.	0·490	

The bacteriological state of the Effluent.—

A critical study of the comparative results of bacteriological examinations of the crude sewage and effluents from the contact beds, leads one to the conclusion that there is only a slight reduction in the total number of aerobic bacteria, the number of spores of aerobic bacteria, and the number of liquifying aerobic bacteria, in the effluent, as compared with the crude sewage.

Moreover there is apparently no reduction in the number of the pathogenic aerobic B. Coli, and its allied organisms, as well as the anaerobic B. Enteritidis. Sporogenes: which are so characteristic of sewage origin.

Further, although the experiments with reference to the other Species of bacteria have not been sufficient, to allow us to form a just estimate, as to the effect on them in the contact beds, yet it is not unreasonable to assume, that they also have not been materially decreased in numbers or species. Still further research is necessary before any definite statistics on this score are able to be formed.

In the light of these facts it must be admitted that the results are not satisfactory, if an effluent must be judged by its bacterial purity.

As we have seen, the chemical purification is most satisfactory, as compared with the results obtained by other and older methods, and it is to be considered, whether an effluent rich in bacteria, but low in organic impurity, is an insuperable objection to its being admitted either to a water supply, which is used for drinking purposes or to one which is not so used, and which is itself in an impure condition from the amount of oxidisable organic matter it contains, as well as its component bacterial impurity; such as the lower reaches of the River Thames below the lowest level of "intake" purposes for water works.

Before doing so I will give a digest of the results obtained, at the Crossness and Barking outfalls, May 9 – Aug 9. 1898, by Dr Houston, as tabulated by him in his report to the London County Council, p 20.

"

1.	Total number of bacteria, per c.c.	Crude sewage	6.140.000. (average of 10 experiments)
		4 ft. coke bed.	4.437.500 (av. of 8 experiments.)

Showing a per centage reduction of 27.7.

2.	Number of Spores of bacteria, per c.c.	Crude sewage	407.	(10)
		4 ft. coke bed.	252.	(8)

Showing a per centage reduction of 38.

Crude sewage 860.000.
(av. of 10 experiments.)

3 Number of liquefying bacteria, per c.c. — 4 Ft. coke bed. 762.500.
(av. of 8 experiments.)

Showing a per centage reduction of 11·3.

4. Spores of B. Enteritidis Sporogenes, per c.c.
Crude sewage. 10–1000, but usually more than 100.
4 Ft. coke bed. 10–1000.
Per centage reduction practically nil.

5 Number of B. Coli, per c.c.
Crude sewage – more than 100.000.
4 Ft. bed – the same, showing practically no reduction.

6 Microorganisms Other than the above
no difference observed. //

Although these results give a per-centage reduction in the total number of bacteria of 27·7, yet the resulting effluent is still exceedingly rich in organisms, and an effluent ought to be judged, not only by the percentage purification, but by the actual state it is in.

The results from the 6 ft bed show only a slight increase in this percentage reduction over that of the 4 ft bed.

2 With regard to the number of <u>Spores of bacteria</u>, the comparative experiments show that the crude sewage usually contains more than those in the effluents, but not even uniformly so. The per centage reduction is found to be, in the case of the 4 ft bed, on an average 38 and in that of the 6 ft bed, only 4. the latter however being the result of only 2 experiments.

In the case of the 4 ft bed, the per centage reduction is slightly greater than the per centage reduction in the total number of bacteria.

Spore formation is now usually accepted to be a resting stage in the life of an organism resorted to when its surroundings are unfavorable to its growth.

They are peculiarly resistant to inimical influences and their presence in large numbers in the effluent is not satisfactory, because the inference is that, although nearly all of them are spores of perfectly harmless species, there is no reason why those of virulent pathogenic organisms may not be among them.

III With regard to the liquefying bacteria the averages are 860.000 : 762.300 : 250.000 in the crude sewage : 4 ft bed : and 6 ft. bed respectively, giving a percentage reduction of 11.3 in the case of the 4 ft bed, and 70.9 in that of the 6 ft bed, but the latter again is the result of only 2 experiments.

The reduction is very small

indeed in the case of the 4 ft. bed, and as compared with the reductions in the total number of microbes and in spores is still greater.

Taking the figures —

6.140.000 : 4.437.500 : 4.150.000,

as representing the total number of bacteria,

407 : 252 : 390,

the number of spores of bacteria,

860.000 : 762.500 : 250.000,

the number of liquefying bacteria in 1 c.c. of an average sample of Crossness crude sewage, the effluent from the 4 ft bed and that from the 6 ft bed respectively; the ratio between these figures is as follows:—

Spores of bacteria.		Total number of Bacteria.	
1	in	15,086	Crude sewage
1	"	17,609	4 ft bed
1	"	10,641	6 ft bed.

Liquefying bacteria		
1	7·1	Crude sewage
1	5·8	4 ft bed
1	16·6	6 ft bed

It would seem that there is an increase in the number of spores in the 6 Ft. bed, in relation to the total number of bacteria, but this may be disregarded, as the experiments were insufficient.

Again in the case of the liquefying bacteria there is evidently an increase in their number in the 4 Ft. bed on an average of 8 experiments.

There is also an evident relationship between the rise & fall in the total number of bacteria and the number of liquefying forms in the crude sewage, as would probably be expected, but this relationship is not marked, and does not hold good between the number of spores and the number of liquefying organisms.

Turning again to the effluents from the coke beds, we have a much more decided relationship evident between the total number of bacteria, the number of spores, & the number of liquefying organisms. Yet the percentage deviation from the mean in each rise & fall shows no parallel.

Still further, there is no relationship whatever between the total number of bacteria, the number of spores, & liquefying organisms in the crude sewage & in the effluent from the 4 ft bed.

(4.5.6.) <u>With regard to the species of microorganisms</u> present in crude sewage & effluents, we have information only of a few and even that is inconclusive and small in amount.

We have seen, that in Crossness and Barking crude sewage, the spores of B. Enteritidis Sporogenes were present in numbers varying from at least 10 to about 1000, the average being over 100 per c.c.

and B. Coli and its gas forming species were present in numbers usually exceeding 100.000 per cc, which is a large proportion to the total number of bacteria estimated.

But in that regard it is probable, that our estimate of the total number of bacteria is much below what it ought to be, on account of the difficulty in enumeration; while our corresponding estimate of the number of gas forming Coli & Spores of Enteritidis may be much nearer the truth, on account of their very varied growth characteristics.

The Spores of B. Enteritidis being detected in some instances in ·001 c.c. crude sewage (Barking). while the B. Coli was found in ·000025 c.c. crude sewage (Barking) (Experiments 14. 1st Report p 5. and exp. 2nd respectively)

While as many as 200,000 germs of Coli have been counted in 1 c.c. Crossness sewage (Exps 11 and 15 1st Report p 6.)

Turning to the effluents from the Contact-beds in the examination of the sewage from Barking & Crossness, we find that, as regards the Spores of Enteritidis and the B. Coli group, there was practically the same percentage estimated as in the crude sewage; anyway showing no appreciable reduction in either organism.

In comparing the various results, we find that, with regard to the Spores of Enteritidis, as estimated in the crude sewage and 4 Ft bed, in 3 out of 10 experiments the number of spores was actually increased in the coke bed; in only 2 cases were they diminished and in the other 5 cases the numbers were approximately equal.

With regard to the B. Coli, on 3 occasions the organisms were found in the 4 Ft bed in excess of those in the crude sewage: in 3 the reverse holds good, and in 2 only they were equal.

The question naturally presents itself. If the effluents contain practically all the organisms present in the crude sewage, how can it be said to be efficiently purified? Is it permissible to pass such an effluent into any river or into an estuary in which shell fish are laid & from which they are removed for the purpose of sale?

We must acknowledge that these results are not satisfactory from the bacteriological stand point.

These organisms and spores evidently survive the processes at work in the contact beds, and it is not unreasonable to assume, that other and more virulently pathogenic organisms do so also. Which means that, unless the effluent is admitted to a water course never to be used as a water supply for domestic use, it becomes a source of danger to the community.

the argument that the pathogenic aerobic bacteria tend to become crowded out by the many forms of rapidly growing saprophytic species, must have support by further & fuller evidence before it can be relied upon; suffice it to say that this is not always so as exemplified by the above results.

It is probably true, that pathogenic species, especially Cholera & Typhoid, do not find our dead substrata much to their taste and are apt to be crowded out by the enormous numbers of non pathogenic species and thus fail to obtain recognition on our plate cultures, but by careful ad-justment of the method of culture we may to a certain extent avoid this.

Dr Klein, who discovered and described the B. Enteritidis Sporogenes gives it as his opinion, that this organism is causally related to diarrhoea. I take it that he means one or other forms of epidemic & undoubtedly infectious diarrhoeae, which are so frequent in Summer time.

Now, as we have seen, the smallest quantity of sewage containing the spores of Enteritidis, can be detected in an effluent or for that matter in a water. So much so, that it has been put forward as feasible, that this circumstance, coupled with the same fact with regard to B. Coli, might be used as a test for the bacterial purity of a potable water, more delicate than any chemical analysis we possess.

The inference is apparent, an effluent containing a trace of the Spores of Enteritidis or for that matter of many other virulent pathogenic species, if admitted to a water supply, which is used for domestic purposes, becomes a source of danger.

These Spores of B. Enteritidis are exceedingly virulent. 1 C.C. of the whey of an anaerobic milk culture has repeatedly caused the death of a guinea-pig, within 24 hours of its injection.

The B. Coli is probably ubiquitous, and may be found in a water, which could not have been contaminated by sewage; such as deep wells carefully protected. Probably the only explanation is, it is through the agency of dust, that it reaches the water.

It is an aerobic organism, capable of multiplying outside the body, and probably takes its part with other aerobic organisms in breaking up or resolving dead organic matter, but still an organism characteristic of faecal discharges.

The mere demonstration of B. Coli in a water is not therefore unimportant, especially as it is in itself non-pathogenic, but it becomes of great importance when it is present in considerable numbers,

as direct pollution with objectionable organic matter is the only known source. The same remarks apply with even greater truth to the spores of Enteritidis, except that it is in itself pathogenic.
These spores appear to be present in every sample of sewage, though not nearly in such large numbers as the B. Coli, and possibly from being anaerobic they are rarely found except in sewage or excrement-al matter. They show great resistance, as Dr Houston has found them in samples of soil, which had not been manured for a long period, when even the B. Coli was absent.
The mere presence of either of these organisms alone, would hardly serve to utterly condemn a water, without a careful examination of the source of the water, but should they be present together and espec-ially in large numbers, it would indicate excremental pollution.

It is of very great importance therefore, that a record should be kept of the average percentages of B. coli & spores of enteritidis, at sewage disposal works, so that a knowledge of their number in the sewage may be arrived at.

Dr Houston, in a recent supplementary report on the examination of the deposit, which has been choking the beds at Crossness & Barking, informs us, that the deposit contained — 1.800.000 bacteria in each gramme the spores of Enteritidis being particularly abundant.

He also found organisms closely resembling the Tubercle Bacillus, acid fast and staining like Tubercle & Leprosy.

Some of these appeared to be true Tubercle, since in one instance, a guinea-pig, inoculated with the deposit, died and presented on examination, the appearance of death from Tubercle infection, and sections of its organs, when appropriately stained, showed the presence of the Tubercle B. in numbers.

Speaking generally and leaving out of account, those mysterious sudden rises in the total number of of organisms, we may say that the more bacteria any effluent contains, the greater must be the amount of fermentable matter present.

When the number of bacteria is very great and the oxygen absorbed very small, nearly all the organic matter must be in a suitable state for bacterial consumption.

On the other hand when the number of bacteria is low and the oxygen absorbed is high, then the organic matter has already undergone complete oxidation; as evidenced by the highly oxidised products of vegetable organic compounds and is therefore unsuitable for bacterial support.

For example the addition of a little vegetable infusion, such as 1 % of a 1 % infusion of tea, to distilled water, gives a very high percentage of oxygen absorbed and yet is quite unfit for bacterial support and is not putrescible.

One would have surmised that as the oxidisable organic matter decreased in the contact beds, due to nitrification, the total number of organisms would have shown a corresponding decrease.

This was found to be so in the Massachusetts experiments.

We can only infer from the fact that we have not so found it in the experiments at Crossness & Barking, either, that the experiments were insufficient to show the actual decrease, which is not likely, or that sufficient time had not been allowed for the complete oxidisation of all the dissolved putrescible matters.

As long as the pabulum is present multiplication of the bacteria will take place and the effluent be rich in them. When there is a lack of nutrient material they on the other hand will certainly die out and decrease.

were it not for the fact that the contact beds are evidently no protection against virulent forms of pathogenic organisms surviving and passing through in the effluent, the fact of an effluent rich in bacteria would not be looked upon so questionably, because it may be argued, that the large number of bacteria present would certainly complete their work of nitrification in any water-course into which the effluent was admitted.

Still further, if the water course was already grossly polluted, this effluent rich in organisms, but low in organic matter, would tend to improve rather than pollute such a course.

Whether the ultimate passage of the effluent through land, as insisted on by the L. G. B., serves to further improve it bacteriologically, I do not know. It certainly does not always improve the effluent chemically, as evidenced in the case of Hampton before cited.

The treatment of the effluent from the primary coke beds by further contact in the secondary beds would, as far as our evidence goes, tend to a further chemical purification of about 20 %. and we might assume a corresponding bacterial purification, although reliable statistics are wanting.

~~Further~~ the preliminary ~~treatment~~ of the sewage, by passage through the septic tank, would relieve the contact beds from having to deal with the gross suspended matters of crude sewage.

On p. 26 of the Rpt on the experiments by the Manchester Commission, it is stated. "For the economical and efficient employment of bacteria beds for the purification of sewage, the suspended matters must be removed as far as possible by sedimentation"

Again in the final conclusions and recommendations of the Rpt p 54. we have these words - " In order that a bacterial bed may exercise its full powers of purification, it is necessary" amongst other things "that the sewage applied to it should, as far as possible, be free from suspended matters".

Care must be taken to avoid advocating any particular combination of plant or apparatus, or even of any individual system under all circumstances.

The local requirements of the district must be studied, the position of the town or district, the geological formation of the land & many other considerations, such as cost, have a very direct influence upon ~~the~~ choice of any system.

But the results of analyses show that, even although perfect purity is not obtained by bacteria agency, yet the complete resolution of the suspended matters, the comparative high percentage of Chemical purification, much greater than has been arrived at by any other known process, afford sufficient ground for a favorable opinion to be formed of the system; at any rate as a preliminary measure. Notwithstanding the fact that, from a bacterial point of view, the same comparatively high state of purity cannot be claimed.