The Bacterial treatment of Sore Eye

with

Downward references to Intermittent Fibrination & Broad-Irrigation

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All who are engaged in Public Health work, either as M.O.H., S.O., 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 sanitary matters 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 violence of office, 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
inertia, action, decomposition of all
kinds. Where 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 failure,
when the conditions are altered; and we cannot, therefore, authoritatively state what those 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" (Delaunay). This is the means by which Nature sheds 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 safety and advantage.

The Composition of Sewage -
As a typical case, take the sewage of a town having a water supply and combined sewers. The sewage is the total waste supply, after use, except that employed in gardening, together with a large amount of rain water, plus matter taken up or washed down. This matter may be divided into:

1. Inorganic matter in suspension
   Chiefly road grit and sand. This would separate out by simple subsidence if allowed to rest.

2. Inorganic matter in solution
   In addition to that already in water, a small amount of phosphates are derived from sewage, which is one of the chief sources of the growth of sewage fungus.
But by far the most important factor is the organic matter, which may be

Most 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 but clear and comparatively free from odours, subsequently becoming
putrid.

4. Organic matter in suspension—

These can be divided again into:

1. Dead organic matter both animal

and vegetable.

Such as feces, urine, swarf, drainage,
sfrom sinks, vegetable debris, paper, etc.

2. Living organisms.

If in addition there are manufacture
wastes, which discharge their works
into the sewer, 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 factors may discharge a great amount of acid waste and render it slightly acid for the time being. The reaction is important from the bacteriological standpoint.

Practically all sewage, apart from manufacturing refuse, is made up of various compounds of carbon, hydrogen, oxygen and nitrogen. Other elements are present such as sulphur and phosphorus, but only in slight amounts. The different combinations of these 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 CO₂, the hydrogen H₂O and the nitrogen N₂. Such a resolution, although apparently simple, is probably a complex one in its intermediaries.
Referring to the way in which the sulphur is got rid of, Dr. Ridgeway says, "In the peptic tank I have found, that a mercaptan, (methyl hydro-sulphide), and other ethereal compounds are undoubtedly present in small quantities. They are very volatile and fairly easily oxidized! Most of the sulphur however enters into combination with the iron present in the sewage forming insoluble ferric-sulphides and giving a black color to the undigested matter."

Living organisms

The organic matter 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 minute force, so that the organisms may live out
Their natural life history and activities
also allotted task of breaking up
the organic solids, rendering them
sensible 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 substance.

As has been pointed out by
Dr. Houston, in the 1st report on "The
Pathological Examination of
London Crude Sewage," by Dr. Close,
for 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 systems, is very essential.

With a view to this end, the
spent several months, while the
Croosee and Parking contact beds
were in course of construction, in
collecting samples of crude sewage.
and after making suitable dilutions, in cultivating on gelatinic 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: - P. Coli, P. Typhosus, P. Diphtheria and the Spores of P. Enteritidis, Streptococcus, Staphylococcus and Staphylococci.

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

1. The total number of bacteria, in 1 c.c. of Barkings crude sewage, averaged 13,899,259 (19 cultures of 9 samples). And in 1 c.c. of Crossness crude sewage 3,526,667 (11 cultures of 6 samples).

2. The number of Spores of bacteria, in 1 c.c. of Barkings Crude sewage, averaged 332, and in 1 c.c. 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 liquefying bacteria in 1 cc. of Rathloug crude sewage, averaged 430.750; and in 1 cc. 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 species of micro-organisms, it was shown, that in Rathloug and Crossness crude sewage, the forms of B. subtilis, B. sporogenes were present in numbers varying from at least 10 to about 1000 per cc. and B. coli was present in numbers usually exceeding 100,000 per cc.

Notes are also given of the occurrence of other bacteria, such as Proteus-like forms, B. fluorescens, liquefaciens and B. non liquefaciens, B. pyocyanus, 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 gelatinous plaque 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 liquefication of the gelatine, by forms which were not so hard and thick, and from 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 can 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,

1.5 c.c. Crossmen sewage face
3. 190,000 bacteria and 2,800 Spores
5. 290,000 do. and 500 do.
on the same day, only an hour or two late.

It is comparatively easy to demonstrate the presence of B. coli communis and B. enteritidis floropens, 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 begot by other forms.

To search for typhoid Bacillus, other pathogenic organisms, in routine work, presents very great difficulties indeed.

We foresee no method of encouraging the growth of libert's bacillus, without at the same time favoring the more enigmatic saprophytic organisms of the coli group.

Levy and Bernard consider that the best prospect of success is offered by Knoeiss modification of the Carbol-Gelatine plate culture method, first suggested by Chantemesse and Widal.
Method: 0.1 cc of a 5% voln. phenol is added to 10 cc sterile gelatin and allowed to solidify in a Petri dish. From 1-0.5 cc of dilute sewage, (1:10,000), is spread on the surface of the gelatin.
Suspicious colonies are stabbed off into 2% glucose agar, and those which produce no gas and the growth which is not exclusively superficial, are further worked out and not Passed as genuine typhoid until they have responded to the Pfeiffer-Grüber-tubidal reactions.
But in several recent epidemics, we have not been able to demonstrate the presence of B. Typhosus at all, in water, e.g. Worthing. Cholera again presents like difficulty as exemplified by the epidemics in Hamburg, where the bacillus could not be found in the water supply yet it is unquestionably a waterborne disease.

Very large numbers of bacteria have been unattainable in sewage.
which have never as yet been isolated or described, for example a cultivation of Crowner Sewage, containing only 0.0001 c.c. sewage, showed at least 3 distinct species of microorganisms, out of a total of 94 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, as to allow the fullest
possible for their action.

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
simple forms.

Many varieties of bacteria grow
side by side, and the food supply
of any particular variety is relatively
not altered by the growth of the other
varieties present. Sometimes the
growth of one around favors,
sometimes it retards, or even
kills out another species.

Again, most bacteria seem
to produce secretions, 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 detrimental.

The development 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 letter class of organisms we are forcibly indebted for a large amount of the nitrification which goes on in the coal beds.

Further, we can classify bacteria according to their habitat.

1. Parasites - (needing a living host) to which belong most of the pathogenic forms.
2. Saprophyties - (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 Saprophyties - 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 necessarily 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 poorer, 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 any midst is not dangerous, considering that we do so under control. The eating up of the food, leading to the death of the organisms.
Again, even although specific
Pathogenic organisms should happen to be present in the sewage, instead of the 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 enumerable saprophytic species.

Method of Bacterial Action

In the year 1839, Schwann and Schultze made an 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 saprophytic processes.

In 1877 the essential discovery, for a true knowledge of bacterial action, was made by Schlegel and Munthe; that there was a class of organisms which utilized 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 \( \text{N}_2\text{O}_3 \); and the other, into \( \text{N}_2\text{O}_5 \). These acids, by their reaction on the bases always present, form nitrites; nitrites and then go on to nourish the living plant.

Nitrites, nitrites are in themselves innocuous, but their formation shows what state has been reached in the process of nitification of the putrescible organic matter.

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

Winogradsky and other have succeeded in culturing agar culture isolating many of these forms.

The forms of liquefying gelatin, characteristic of many bacteria,
and although we cannot assume
that their 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 their
complex bodies are really liquefied
and rendered soluble 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 microorganisms, that their great
achievements in the ultimate resolution
of organic matter is brought about.
For 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 often 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 former 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 peptization; as 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 gut-tapping solutions.

Experiment: If a solution containing fibrin be allowed to undergo putrefaction, the fibrin dissolves, gasous evolution of CO$_2$ and NH$_3$ occurs, but should the bacteria be killed or paralyzed by chloroform at this stage, then only a decomposition of the fibrin occurs, without the splitting up and gasous production being observed.

The splitting up of complex organic material depends on the chemical nature of the body 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 understood 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 specific ferment is produced by these microorganisms, 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 to their immediate proximities.

The organic matter is broken up and rendered soluble by this probably intra-cellular disintegration.

With these facts before us, let me
how give a brief description of one or two of the chief methods of bacterial treatment in use.

The aim of the earlier methods 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 soluble the coarse suspended matters, which it is otherwise necessary to screen off, to prevent clogging up of the inlet pipes of the contact beds.

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

1. **Aerobic**
   - (Biological Suton process, Barking Crossness)

2. **Anaerobic**
   - (The Septic tanks.)

As before mentioned, these two processes might 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 sewage, 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.

H. 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 decided—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 Biolitic 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 until the coke is just submerged. It is connected 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 value 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 rigidly excluded.

Sewer overflow and of course waste provision, so that each may have a rest after discharging, in order that the intestines may be well aerated.

In the case of Crosseners, the filling of the bed usually lasts about 4 minutes, and the sewer is allowed to remain in contact for about 3 hours and then discharged. Eight hours being given for aeration. In the case of the beds 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 choked 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 fill will be filling up whilst the first is standing still.

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

The beds require raking once from twice to twice (twice weekly), to remove the slime which forms on the surface, as well as to promote 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 with the use of secondary beds forming a much better limit, than that ofعنzero the depth of the single bed.

These contact beds are very generally called aerobic beds, but, as for many of the impurities in sewage, anaerobic processes must be gone through before the aerobic bacteria can be free. 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 bed is clear with but little, if any, odor.
The amount of sewage which can be treated by a superficial wash of the coke bed has been estimated by Dr. Clowes, as 370,000 gallons per acre, for one single fitting daily, of the 4 ft. coke bed, and 673,400 gallons 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 gallons 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 bed. When filtrations through the beds are continuous, 250 – 400 gallons 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 materials. But it was not till in Cameron of Fetter introduced his Septic Tank, that these matters could be satisfactorily dealt with.

The installations in this system, which have been introduced since, have been many and types 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 bed; so that it is really the combined systems of Cameron & Dibdin.

The tank may be made by any impervious material and closed in with an arched roof, a man-hole is usually built to allow for inspection.
A grit chamber retains the waste 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 sand grit, enter into the tank and are then liquefied or turned into gas 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 on Oct. 1899, and the idea presented itself that the probability was, that the tank would fill up with debris; or by passing a stick
down to the bottom there seemed to be a good thickness of sludge. 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 undigestible scum forms on the surface and bubbles of escaping gas carry to the surface solid particles only to let them sink again when the bubbles burst.

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

The effluent from the tank is very ammoniacal and very little pure than the sewage entering. Some of the 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 forces for pumping. The outlet aperture is at the
deepest level of the tank floor, which is sloping, and by removing a valve
the contents of the tank are forced out into a slumping hole and are
carried by distributors spread on to the beds by means of automatic
feet, till the coke is all submerged.

The process is then very similar to bleeding in the contact beds.

A scheme has recently been
submitted to deal with a flow of
12,000,000 gallons per day, the chief
details of which are 6 tanks, each
some 375 ft. long by 21 ft. wide,
and 8 ft. deep below the springing
gage of the roof arches. And 24 contact
beds, each 100 ft. long by 95 ft. wide,
filled to a depth of 3/4 ft. with
furnace clinker.

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

On this other hand, the peat from a
country policemen's estate 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 patents have been taken out for illustrations on similar principles to the Dibdin Lamarri 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 precipitative methods 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 this is so slight that a year's accumulation is hardly worth removing.

When screens are used in
in the drain system, there is a certain amount of matter which must be removed, but this must be compared with that left by chemical processes.

The septic tank at Belle Dale, Ohio, has taken the sewage, instantaneous screening from 1500 people for over 4 years; no mineral residue has yet been removed and the small quantity of matter in the tank is now in an interface with the effluent.

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 was efficient as a 6 ft. bed.

Treatment through secondary beds produces 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 matter, 
the secondary bed can exert all 
its power in further vitrification. 
The use of materials

...fule the beds in very varied,
but it has been found, that probably
fragments of ordinary gas works
coke, about the size of a walnut,
are most suitable. The comparatively
large size increases the

capacity of the beds and enables
them to be filled and emptied more
rapidly, as well as avoiding
venting.
The secondary beds should be
filled with a smaller size of coke
bricks, crushed chippings, balls,
sand, gravel or other material.
The material and the size of the individual fragments of
that material must 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. Hunter, the following advantages over chemical precipitation processes are claimed by the Dihedri system.

1. It requires no chemicals.

2. It produces no offensive smell, but only a slight deposit of sand and vegetable tannin which requires no odor. It is reasonable to hope, that, by the additional use of the peptic tank previously to the sewerage 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 50% thereof.

4. It affects the removal of 51.3% of the dissolved oxidizable and putrifiable matter, as compared with only 17% removed by chemical treatment. By the use of secondary beds an additional purification of about 19% is secured.
"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 and physicists have been engaged upon the problem and although they did not recognize the labors of the benevolent ricer, do 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 laws upon which we are still attempting
its solution.

This 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 done 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 outcome of the old land filter of 1834.

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

The author selected various plots of land, which he levelled and suitably underdrained to 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: "Speaking of intermolecular filtra- 
tion, I refer to the concentration of sewage, at regular 
intervals, on an acre of land so well absorbed and cleansed 
without preventing the production of vegetation."

Dr. Frankland, at a very early date, 1870, reported that "an acre of suitably constituted soil well and deeply undersaturated, with its surface 
levelled and divided into 4 equal plots, each of which in succession would receive the sewage of 6 horses, 
would cleanse the sewage of 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 even for a long period, which would entail an 
very large amount of land necessary for the disposal of the 
sewage of a large community.
Sewage, unless previously treated with some chemicals or other process, usually slowly and partially clings to the walls of the tank; as the dissolved and fine little of the organic matter is removed.

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

**Grand Irrigation**

Knowledge of the geology of a district is essential in determining the most suitable site for irrigation. A fair amount of provision is necessary. It would be little use to establish a new artificial surface, as an artificial surface would have to be prepared at a great cost. On the other hand, if the clay had a good leaching of some porous substance, as said...
degraded or loamed, such a site would be unuitable.

In determining the site again it is highly desirable to consider any surrounding waters, if the surrounding waters, if the surrounding waters, if the pollution should occur.

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

Experiments were made on the filtering power of the soil and the convection of bacteria by the ground water, by Abba, Orlando and Rondelli of Jibin and published in a recent number of the "Zeitschrift für Hygiene und Infektionskrankheiten" vol. xxx, 1889, p. 66. What 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 Methylene Blue, and
2. by adding a strong solution of containing *P. Prodigiosum*.
This organism was selected as being harmless, growing well on ordinary substrates, easily recognizable from its chromophores and not generally present in farm waters.

The object of the investigation was "to test the filtering power of the ground above and in each side of the sub-drain drains, and to determine 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 sub-drain drains laid underneath the natural plots of soil selected for the experiment.
Their results:

The coloring materials were a less delicate test than the Peanuts, 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 measuring years. (1897, 1898)

The large Pitton 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
I acre to every two inhabitants. This pumping is necessary till the sewage reaches the farm. The manager is an experienced hand, for 15 years he has conducted the farm.

There are no offensive and injurious emanations from the land and no parases known to pollution of the subsoil water.

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

Still broad irrigation, as it is not present conducted, does not seem to offer a final solution to the sewage disposal difficulty, on account of its inapplicability in view of the majority instance.

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 while the dry weather flow for 24 hours.

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

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

But such a farm even although it does not pay expenses may still, in the instance where land is cheap and fairly 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 drainage. Yet the difficulty of securing land suitable and sufficient in area to deal with the sewage of a large city, especially when manufactures are added to the sewage, puts the process out of reach 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 fills and require much less space to acquire. 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 and discharged.

And the effect, although the initial outlay may in some instances be greater, is probably in the whole less considering that few farms pay effluents 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 tons' falls a day, at £ 624. 10. 6; as against Mr. Siddins' £ 1000 per acre of artificial contact beds at Sutton; or £ 2000 according to Mr. Sauter Grimp's estimate for Barking; or £ 9, 166 according to Mr. de Coninck Meade's estimate for Manchester.

An acre of artificial contact beds at Siddins' beds can successfully treat 1,000 tons' falls 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, insist upon effluents from bacterial beds being finally treated by passing through land. The area of land required depends on its character. But it is suggested that land might be obtained at the rate of 1 acre per 1,000 population.

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

It applies to all schemes where loans are necessary to carry out this work, and 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; and it is only after the sewage has passed through the contact beds and therefore fallen some 14-18°, 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 insufficiency 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 and also to prevent the sewage from being discharged into the river, determined to use a system of contact beds. Thus, after passing through the contact beds, an unusually pure effluent is obtained.

But in order still further to satisfy the U.D.C., who had granted a loan, they have to pass the effluent over land, to which they have to transport 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 disinfection from who has seen the Dupont tanks and also the contact beds, which are being more widely adopted, must admit that much purification 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 treating methods.

The water capacity of any contact bed at starting is assumed to be 40% of its total capacity.

But this is quickly reduced to 33% after the first few applications of the crude sewage. So that only
The gross capacity of the bed can be reduced further. 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 1/3%, it means that taking an 8 hour 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 chinker, burnt ballast, or gravel, must be provided in addition to the above, to treat a further quantity of storm water, equal to 2 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, in the result of their enquiry:

That the manufacturer's refuse sewage was not able to be satisfactorily disposed of, if the sewage were first subjected to treatment in the septic tank and then in the contact beds.

The recommendations were to the effect that the sewage be screened and then passed through the percolation tanks that these tanks should be provided with submerged walls of floating reed boards, so as to retard the flow of the mineral and 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 biochemical treatment of the sewage of Manchester, act forthwith, 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 heavier nature of the 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
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 rate of sewage 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, either to this diminished purification apparently to be referred to the presence in the sewage of undue proportion of chemical refuse, derived from gas works and 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 manufactures
which is by a special fluid in the case of Manchester, and large quantities of which are admitted to the sewer, does not tend to decrease the total number of the bacteria found in crude sewage.

Now 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 sewage 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 sewage refuse although it disposed 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-coupled waste compounds from manufactures
have no marked detrimental 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 and easily, and proving in a very marked manner the efficiency of the bacterial process, as certainly the other process has approached success in this respect before.

Debich's system depends for its efficiency on the fact that the distribution of the sewage to the beds is intermittent.

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 qua non, and has been agreed to as such by the Royal Commission.
on Metropolitan Sewage Drains in this report, p. 46, and also by all subsequent investigators including the
advice to the Manchester Corporation.

Now it has been recognised from the first and indeed in beyond question, that the Chemical Change on which purification depends is
oxidation, and whether this is affected by purely chemical or biological
agency (hydrolysis), in a manner which does not seriously affect
the principle, which should underlie the construction of a
Contact-bed. That is to bring the sewage-tails into the most intimate
contact possible.

In order to ascertain whether
the surface of the coke particles
were fully separated between the
intervals of discharging or refilling,
the Bowers 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 CO₂.

The results indicated that, even after the air had been in contact
with the lower strata of the coke (13 ft.) for 90 hours, it still contained
an average of about 75% of its original oxygen and the average
amount of CO₂ did not exceed 3%.

The depth from which the air was abstracted at the intervals of
time allowed to lapse 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 surviving org-
anism, that they ever can attain
their maximum efficiency.

Even although the crude sewage
has been strained or even rendered
potable in the aeration tank previous

to its being pressed on to the contact
heats, the bulk of liquid displaces
the air to a very great extent from
the beds hence being practically
oxygen free, we have hardly the
ideal conditions for utilisation.

It requires time that on
streaming off the sewage from a bed
the majority of the vitriifying organ-
isms may remain in the interstices
of the coke, but to enable them to
vitrify 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 beds?

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
confining to the surface of the bed
and to the neighbourhood of such
air as is here them 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 minimal 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 opposed to the sun's rays, especially during summer, having surface organisms destroyed or at any rate rendered functionless by those direct rays and so depriving the bed of much of its productive efficiency?

A fermentation process, such as the oxidation of sewage, should not require any intermittent.

It ought to be a continuous process, if the necessary mechanical conditions for the existence of the vitalizing organisms are attended to.
These conditions might 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. 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.

W. Wallis Stoddart in the Public Health

[Signature]

F. P. E. 1900
in describing this process of sewage purification by means of the "Stoddard Improved Sewage Filter", brings this point out very strongly.

He holds that the "filter" should be composed of a coarse medium, the limits of depth depending on the circumstances.

It's results show that the greatest depth, the highest per cent, amount of separation, but the essential point to be observed was that the sewage should never be admitted so rapidly but the "filter" as to "coalesce into a continuous layer".

The sewage and air are admitted simultaneously and in his "Stoddard" 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, he, must be maintainable for year together, without, if possible, any human interference.

With particles half an inch in diameter, the amount of nitrogen oxides would appear to amount 2500 lbs of pure 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 Hotfield, nr. Bristol and another in a suburb of Bristol.

He points out that the previous removal of impounded matter is imperative to the application of sewage to any "pills" and does not therefore claim for his patent that it constitutes a complete system of sewage disposal, but only that it...
is an improved "filler", in which the errors of conditions to which sewage beds, either dry or in a state, have been subjected are corrected.

The peptic tank is therefore requisite as a preliminary means.

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

1. Flow uninterrupted
2. Capacity 200-250 gallons per day
3. Costly construction of foundations, walls, etc.

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

Like the forces, his tends to work, which is anaerobic and aerobic, and if these organisms demand different conditions for their effective 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 it becomes necessary 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 submergence in a debitter chamber, before the sewage reached the beds. While the vegetable organic matter is of such nature that microorganisms find unsuitable as a palatable. It is composed mainly of tannic acids, which are the terminal products of a long series of changes. These began in cellulose and consequently are not susceptible to an
appreciable extent, such as animal organic matter would be.

This vegetable debris finds itself detained in the septic tank and must reach the beds, at the same time, that does not prove that it is produced by the anaerobes, probably it forms much of the deposit in the tank. Decaying matter contains very few organisms.

Dr. Clowes has issued a supplement to his 2nd Report on the Peacoking and Crossmore 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 decreased at the rate of about 1% of the original capacity.
pe week. Obviously with me a decrease, the life of a contact which 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 and expensive labor. Moreover 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 acetolytic bacteria to deal with it.

To overcome the system of rapid precipitation, before allowing the sewage to pass through the contact beds, finds that the process of chating can be reduced to nearly one half.
The index of the efficiency of a system is to be found by estimating the percentage purification of the effluent, as compared with the raw clarified sewage, both from a chemical and bacteriological point of view, and whether the effluent uniformly falls within a chosen standard of purity.

The great variation in the strengths and character of the sewage in different localities makes it impractical 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.

Where 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 as the effluent varies to a great extent. The least satisfactory results being obtained during the very hot weather, when the rainfall is practically nil.

Parkman there is the case of the Rentgen Commission 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 combustible 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, it is clear that we can estimate the percentage purification calculated on the raw sewage.

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

Dr. Clowes gives in his 2nd Report to the London County Council many results of the examinations of effluents both from the single 4½ ft. coke-bed and from the primary- and secondary 6½ ft. beds, at Berkley Cross, as follows:—

**Relative purity of clear sewage, chemical effluent, coke-bed effluent, and lower river water.**

"The relative amounts of dissolved and suspended matter in the sewage, chemical effluent and coke-bed effluent, as determined by the oxygen which they absorb from permananate, are as follows:—"
Oxygen absorbed in 4 hours at 80° F. calculated on raw sewage

<table>
<thead>
<tr>
<th>Description</th>
<th>Oxygen Absorbed</th>
<th>Percentage Purification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Sewage</td>
<td>3.696</td>
<td></td>
</tr>
<tr>
<td>Chemical Eff.</td>
<td>3.070</td>
<td>16.9</td>
</tr>
<tr>
<td>Coke bed Eff. (single)</td>
<td>1.799</td>
<td>51.3</td>
</tr>
<tr>
<td>Coke bed Eff. (double)</td>
<td>1.137</td>
<td>69.2</td>
</tr>
<tr>
<td>River water (high tide)</td>
<td>0.350</td>
<td></td>
</tr>
<tr>
<td>River water (low tide)</td>
<td>0.429</td>
<td></td>
</tr>
</tbody>
</table>

A comparison of these numbers with one another shows that by substituting a single coke bed treatment, the effluent sewer discharged into the river would be completely free from suspended impurity, and would possess a purity as regards dissolved putrescible matter of 31.3, 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 mechanical action contained in the river would rapidly bring the...
the purity of such a liquid into a condition equaling 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, Detroit.

In an average of 6 examinations of the crude sewage, the tank filtrate and coke-bed effluent, we get these figures, by J. H. Pearmain and C.G. Riwar, M.A.

\[
\text{Raw Sewage} \quad 4.3 \\
\text{Tank Effluent} \quad 1.4 \\
\text{Cocked Effluent} \quad 0.33
\]

This final effluent chemically resembles 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, and I think it has been proved, the prospect for this method is the best.

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

<table>
<thead>
<tr>
<th>Process</th>
<th>Ammonia</th>
<th>Nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehler-Thudichum</td>
<td>63.2</td>
<td>80.9</td>
</tr>
<tr>
<td>Dupré</td>
<td>84.9</td>
<td>88.3</td>
</tr>
<tr>
<td>Pearmain-Nawa</td>
<td>80.0</td>
<td>90.0</td>
</tr>
<tr>
<td>Perkins</td>
<td>64.4</td>
<td>78.7</td>
</tr>
<tr>
<td>Ridgekopf</td>
<td>77.0</td>
<td>82.0</td>
</tr>
</tbody>
</table>

"Organic nitrogen.

The results of chemical analysis of Claude sewage, tank filtrate, and Dodgen's effluent, respectively, are given in the table below, for pure, fresh, and clove.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Value</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage</td>
<td>6.39</td>
<td>Oct 3rd, 1898</td>
</tr>
<tr>
<td>Tank Filtrate</td>
<td>1.218</td>
<td></td>
</tr>
<tr>
<td>Filter Effluent</td>
<td>0.490</td>
<td></td>
</tr>
</tbody>
</table>
The bacteriological plate of the effluent.

A critical study of the comparative results of bacteriological examination 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 liquefying 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. intestitidis, which are so characteristic of sewage origin.

Further, although the experiments with reference to the other species of bacteria have not been sufficient, it allows 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 number or species. Still further research is necessary before any definite statistics on this score can 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 not satisfactory, as compared with the results attained by older and older methods, and it is to be considered, whether an effluent rich in bacteria, but low in organic impurity, is an irresistible 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
of edible organic matter it contains, as well as its component bacterial impurities, 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 Roehampton outfalls, May 9 - Aug 9, 1898, by Dr. Houston, as tabulated by him in his report to the London County Council.


<table>
<thead>
<tr>
<th>Crude sewage</th>
<th>6140,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of</td>
<td>(average of 10 experiments)</td>
</tr>
<tr>
<td>1. bacteria, per cc</td>
<td>4 ft. coke bed</td>
</tr>
<tr>
<td>2.</td>
<td>(ast. of 8 experiments)</td>
</tr>
</tbody>
</table>

Showing a per centage reduction of 27.7.

<table>
<thead>
<tr>
<th>Number of Spores</th>
<th>Crude sewage</th>
<th>407 (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. of bacteria, per cc</td>
<td>4 ft. coke bed</td>
<td>252 (8)</td>
</tr>
</tbody>
</table>

Showing a per centage reduction of 38.
Number of bacteria, per c.c.

Crude average 860,000 (av. of 10 experiments)

Showing a percentage reduction of 11.3.

Spores of P. Intermedius, Spirochaeta, per c.c.

Crude average 10-1000, but normally more than 100.

Herterobacteria 10-1000.

Percentage reduction practically nil.

Number of E. Coli, per c.c.

Crude average more than 100,000.

Of E. Coli, the same, showing practically no reduction.

Microorganisms other than the above.

Although these results, give a per-
centage reduction in the total number
of bacteria of 24.7, yet the resulting
effluent is still exceedingly rich.
n organisms, and an effluent might be judged, not only by the per-
centage purification, but by the actual state it is in.

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

2. With regard to the number of
spores or bacteria, 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
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 retarded when its surroundings are unfavorable to its growth.

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

With regard to the dejecting bacteria, the averages are 860,000 : 762,300 : 250,000 in the crude sewage : 47° bed : and 6° bed respectively, giving a percentage reduction of 11.3 in the case of the 47° bed, and 70.9 in that of the 6° bed, but the latter again in the result of only 2 experiments.

The reduction is very small
indeed in the case of the 4 7th bed, and as compared with the reduction in the total number of microbes and in sewage is still greater.

Taking the figures—
6. 140,000 : 4. 437,500 : 4. 150,000.
as representing the total number of bacteria,
404 : 252 : 390,
the number of spore of bacteria,
860,000 : 762,500 : 250,000,
the number of pessifying bacteria in 1 c.c. of an average sample of Sewage—waste sewage, the effluent from the 4 7th bed and that from the 6 7th bed respectively; the ratios between these figures is as follows—

<table>
<thead>
<tr>
<th>Spores of bacteria</th>
<th>Total number of Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in 15,086</td>
<td>4 7th bed</td>
</tr>
<tr>
<td>1</td>
<td>17,609</td>
</tr>
<tr>
<td></td>
<td>6 7th bed</td>
</tr>
<tr>
<td>1</td>
<td>10,641</td>
</tr>
</tbody>
</table>

Pessifying bacteria

| 1                  | 7.1                     |
| 1                  | 5.8                     |
| 1                  | 16.6                    |

Aube Sewage

4 7th bed

6 7th bed
It would seem that there is an increase in the number of spores in the 64th hour 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 47th hour on an average of 8 experiments.

There is also an evident relationship between the rise of spores 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 whatsoever between the total number of bacteria, the number of spores, liquefying organisms in the Crude sewage and in the effluent from the 4 ft. beds.

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

We have seen, that in Chironomus and Brauner sewage, the spores of B. Intestinalis Spores were present in numbers varying from at least 10 to about 1000, the average being over 100 per cc.
And B. Coli and its forming species were present in numbers usually exceeding 100,000 per cc, which is a large proportion to the total number of bacteria estimated.

On this 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 forming Coli - Staphylococcus & Intestinal - may be much nearer the truth, on account of their very varied growth characteristics.

The spores of B. Intestinalis being detected in some instances in .001 cc. crude sewage (Bartholomew), while the B. Coli was found in .000025 cc. crude sewage (Bartholomew) (p. 211, 14th. Report of 5th. and 4th. respectively)

While as many as 200,000 spores of Coli have been counted in 1 cc. Crocker's sewage (Sept. 11th. and 18th. 12th. Report p. 6.)
Turning to the effluents from the Contact beds in the examination of the sewage from Draining Rooms, 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 sewerage, 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 sewerage and in the 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, in 3 occasions the organisms were found in the coke bed in excess of those in the crude sewerage; in 3 the process holds good, and in 2 only they were equal.
The question naturally presents itself: if the effluent contains 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 mines or into an estuary in which shell fish are raised from which they are removed for the purpose of sale?

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

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 virulent 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 communities.
The argument that the pathogenic anaerobic bacteria tend to become crowded out by the many forms of rapidly growing saprophytic species, must have supportly further if the 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 substrate much to their taste and are apt to be crowded out by the enormous number of non-pathogenic species and thus fail to obtain recognition on our plate cultures, but by careful adjustment of the method of culture we may be certain to avoid this.

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

Now, as we have seen, the smallest quantity of sewage containing the spores of Entobacteria, can be detected in an effluent or for that matter in water. So much so, that it has been put forward as feasible, that the circumstances, coupled with the prime 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 Entobacteria or for that matter of many other virulent pathogenic species, if admitted to a water supply, which issued for domestic purposes, becomes a source of danger.

These spores of B. Entobacteria 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 infection.

The *P. Cali* is probably ubiquitous, and may be found in water, which could not have been contaminated by sewage, such as deep wells carefully protected. Probably the only explanation is, that, 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 revolving dead organic matter, but still an organism characteristic of social disease.

The mere demonstration of *P. Cali* in water is not therefore unimportant, especially as it is itself non-pathogenic, but it becomes of great importance when it is present in considerable numbers.
an direct pollution with objectionable organic matter in the only human source. The same remarks apply with even greater truth to the organisms of Entrobacteriaceae, except that it is a mere pathogenicity. Some organisms appear to be present in every sample of sewage, though not nearly in such large numbers as the E. Coli, and possibly from being anaerobic. They are rarely found except in sewage or excremental matter. They show great persistence, as Dr. Houston has found them in samples of soil, which had not been manured for a long period, when even the E. Coli was absent.

The mere presence of either of these organisms alone, would hardly seem to utterly condemn a water, without a careful examination of the source of the water, but should they be present together, and especially in large numbers, it would indicate excremental pollution.
It is of very great importance therefore, that a record should be kept of the average four-centuries of P. coli, and of those of ketolisis, at sewage disposal works, so that a knowledge of their numbers in the sewage may be arrived at.
Dr. Houston, in a recent supplementing
report on the examination of the deposit
which has been choking the leads
at Croome & Barling, informs us
that the deposit contained
1,800,000 bacteria in each gramme
the spore of tuberculosis being
particularly abundant.

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

Some of them appeared to be
true Tubercle, since in one instance,
a pus-sick pig, inoculated with the
deposit dried 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 Bacillus 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 oxidized products - 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 per centage of oxygen absorbed and yet is quite unfit for bacterial support and is not nutritious.
One would have assumed that as the available 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 Cromer, St. Austell, etc., 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 oxidation of all the dissolved putrescible matter.

As long as the foodchain is present, multiplication of the bacteria will take place and the effluent is rich in them. Where there is a lack of nutritive material they on the other hand will certainly die out and decrease.
Here it must be noted that the contact beds are evidently not pro-
tective 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 unquestionably, because
it may be argued, that the large
number of bacteria present
would certainly complete the work
of nitrification in any water course
into which the effluent was emitted.

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

Whether the ultimate passage
of the effluent through land, as
suggested 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 works leading further contact in the secondary beds would, as far as our inadequacies in such works, lead 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 tanks, 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
pedimentation.

Again in the final conclusions and recommendations of the R.P.

p. 57, we have these words—"In order that a mechanical

bed may exercise its full power of purification, it is necessary

amongst other things that the sewage applied to it should, as far as

possible, be free from suspended

matter."

Care must be taken to avoid advertising any particular combina-

tion of plants or apparatus, or even of any individual pipeline

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

amongst other considerations, such as cost, have a very direct

influence upon their choice of any

dystem.
But the results of analyses show that, even although perfect purity is not obtained by bacterial agency, yet the complete dissolution of that profounded matter, the comparative high percentage of chemical purification, without 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 an preliminary measure.

Notwithstanding the fact that, from a bacterial point of view, the same comparatively high state of purity cannot be claimed.