THE

B A C T E R I O L O G Y

OF

S E W E R A I R

BY

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BACTERIOLOGY OF SEWER AIR.

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The bacteriology of sewer air is of very recent growth. The first published accounts are by Miquel of Paris in 1883. The only published observations in this country are by Dr. Robertson of Penrith, Drs. Carnelly and Haldane of Dundee, and Mr. J. Parry Law's Reports to the London County Council issued some three months ago. Drs. Carnelly and Haldane made a most elaborate examination of sewer air, chemically as well as bacteriologically both in London and Dundee; they also drew out elaborate tables of statistics comparing sewer air with the air of schools and dwelling houses of so many rooms. A few of the conclusions arrived at were as follows :-

1. The air of sewers is in a better condition than that of naturally ventilated schools, and with the exception of organic matter, better than mechanically ventilated schools.

2. Sewer air contains fewer organisms than the air of any kind of house, even fewer than outside air; less carbonic acid than in two, and one-roomed houses; but as regards organic matter the sewer air is only slightly better than the air of one-roomed houses, and much worse than that of other classes of houses.

3. They gave seven reasons to prove that the micro-organisms present in sewer air come entirely or nearly so from the outside, and few or none from the sewage (none unless there be splashing).

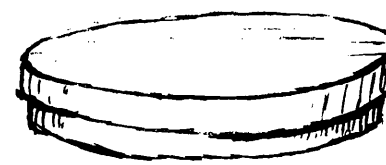
Mr. J. Parry Laws supports Drs. Carnelly and Haldane in all their observations in his report on Sewer air to the London County Council.

The Medical profession were much surprised at this de - cision as to the great purity and benign nature of sewer air; for in all large towns at that time it was, and still is considered by many to be the cause of almost all the ailments that flesh is heir to.

It was this great difference of opinion in the profession regarding sewer air, together with the favourable opportunities of making the necessary investigations that induced me to take this subject for my thesis for the M.D. degree.

METHODS OF COLLECTING THE MICRO-ORGANISMS.

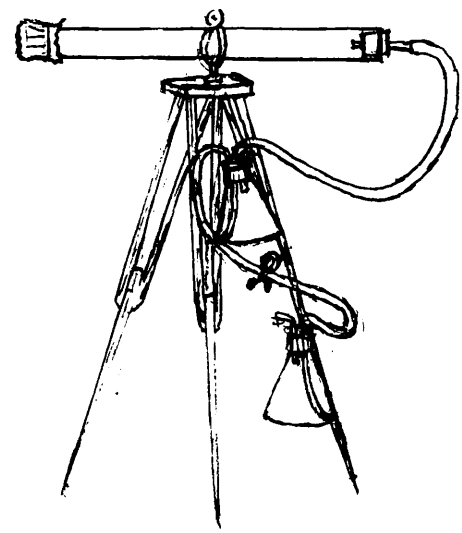
I will omit the history of the different instruments that have been used for this purpose, and will only mention those that are used at the present day, and give my reasons for selecting Sedgwick's tubes.



1. Petri's dishes are two circular flat glass dishes, the one fitting easily into the other. They are first steril - ised in a hot chamber for a few hours at a temperature of about 150° C. As soon as they are cooled, some melted sterilised nutrient gelatine is poured on to the bottom dish the cover being immediately applied. This takes advantage of Koch's

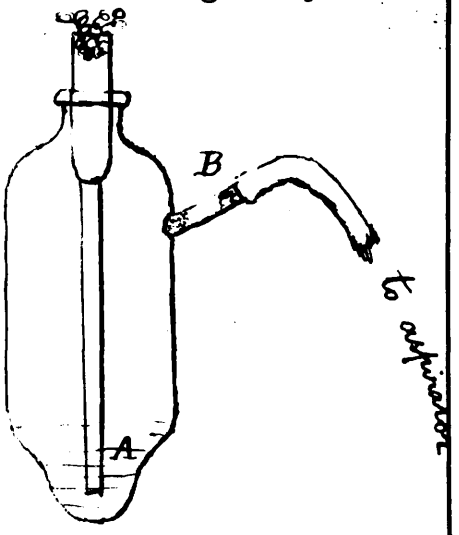
great discovery of 1881 in cultivating Micro-organisms on solid nutrient material. It is exceedingly portable, can be taken where required, the cover removed and the gelatine exposed for a definite length of time, and a tolerably exact collection of the micro-organisms present in the examined air thus secured. However good, this method is only qualitative and gives no exact information of the number of micro-organisms in a definite amount of air, and hence was unsuited for my purpose.

2. Hesse's Tube is a glass tube about 20" long and 1¾" in diameter lined internally with nutrient gelatine and supported on a tripod stand. The air is aspirated through this tube by the syphoning action of water in flasks of known capacity. The colonies which develop on the nutrient gelatine, show the number and character of the living organisms contained in the measured quantity of aspirated air. This was the method that Professor Carnelly used, and with care gives good results. The drawbacks to this instrument are its large size for manipulating in a sewer, the length of time required to aspirate the air; and the difficulty of knowing the exact angle the instrument should be placed when currents are present (Frankland).



3. Straus and Wurtz's method is very convenient and reliable

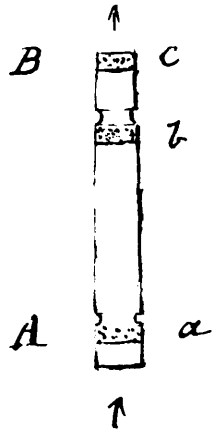
It consists of passing air by means of an aspirator through liquefied gelatine or agar agar. Two cotton plugs are placed in the aspirating branch B. After the air has been aspirated through the liquefied gelatine at A., the internal plug in branch B is pushed by a sterilised needle into the cavity. Finally the gelatine or agar is solidified upon the walls of the instrument by rotating it upon a block of ice, or under a stream of cold water. It is then placed in an incubator for development of colonies.



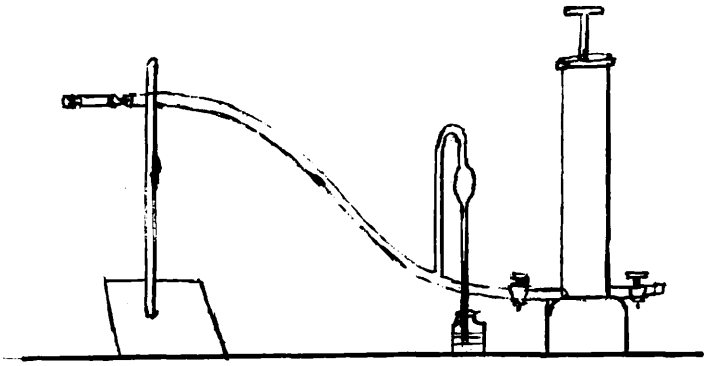
The principal objection to this method is the heat required to keep the nutrient fluid liquid during aspiration. Gelatine cannot be used as it foams when air is bubbled through it. It is said, however, this difficulty can be overcome by using agar to which a little olive oil has been added before sterilization.

4. Frankland's Flask Method.

Professor Percy Frankland of St. Andrew's University has done more work in examining the aerial micro-organisms than any other person in this country. Mr. J. Parry Laws used this method in his recent report on sewer air to the London County Council. He aspirates a definite quantity of air through a tube about 5 inches long and ¼ inch internal diameter shaped as sketched. The front end of the tube A is wider than the end B. The tube contains 3 plugs about the size of a pea in



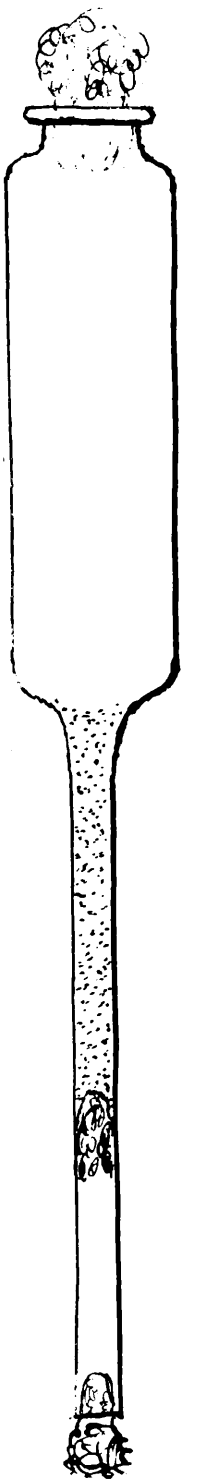
the positions shewn. The plug (A) is less dense than plug (B) and is constructed of a small quantity either of ordinary glass wool, or of glass wool which has been previously coated with cane sugar. Plug (B) is constructed of fine sugar or glass powder. After sterilization at 130° C for three hours they are used as shown in the illustration.



The tube is then broken into three parts, the plug (A) placed in a sterilised flask along with some sterilised gelatine rendered fluid by being slightly heated and the flask is gently rolled round in being cooled. The plugs (B) and (C) are treated in a like manner. The plug (C) acting as a control to the experiment. My reason for not employing this method was the necessity of having three flasks for each experiment, and the danger of contamination in removing the plugs to the cultivating flasks.

5. In Sedgwick and Tucker's tubes, the filter containing the granulated sugar, and the cultivating flask are one and the same instrument. As these were the tubes used by me in my experiments I will now enter more into detail regarding them. They are made of the best transparent glass, shaped as illustrated. The complete length is about 14 inches, the top and wider end being about 6" long and 1" in diameter; the lower and narrower part being about 8" long and a ¼ bore. The sugar is prepared by pulverizing loaf sugar

in a mortar and passing it through a sieve having 14 meshes to the inch. It is again passed through a much finer sieve, the coarser material only being kept, the particles of sugar are then about half a millimetre in diameter. Should the particles of sugar be finer than this, it cakes in being sterilised, preventing the admission of air during aspiration. Again, if the particles of sugar be too coarse they will not filter the micro-organisms. Great care is required in sterilising the sugar, it must be heated very gradually in thin layers in a porcelain dish, with the ventilating plug of the hot chamber open. Should there be a thick layer of sugar, and the temperature rise quickly, it is almost certain to melt, from the moisture not getting freely away. If care be taken, however, the sugar can be sterilised up to a temperature of 150° C. I have noticed that if the sugar be heated to near this temperature for several times on different days, it does not dissolve so readily in the warm gelatin.

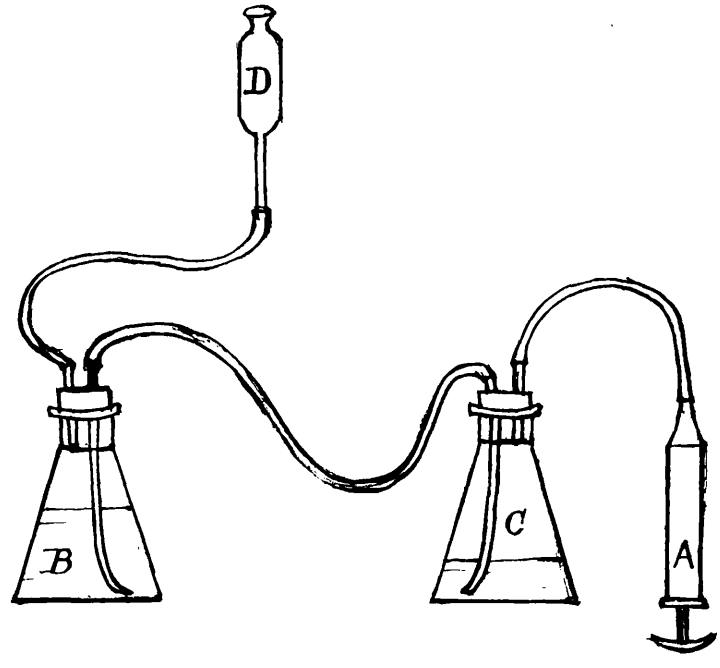


After the tubes and sugar have been sterilised in the hot

chamber for two hours, they are taken out, and a cotton wadding plug is pushed up the end of the narrow tube till within 3¼ inches of the larger part. The prepared sugar is then poured down the large end of the tube, the sugar resting upon the introduced plug, and filled up till it reaches the wide part. In the course of filling, the tube should be held perpendicularly and gently tapped with the finger from time to time. Cotton plugs are then put in both ends, and the tubes so prepared are again put into the hot chamber at a temperature of 130° C for three hours before they are ready for use. The quantity of air is measured by the litre flasks that accompany Hesse's tubes. The syphoning action of the flasks however is not sufficient to aspirate the air through the sugar.

This difficulty is overcome by using an air pump (A) in the following manner :-

The two flasks are placed beside each other on the same plane; and the tubes arranged so that the two free ends are fixed, one to the Sedgwick & Tucker's tube and the other to the air pump. When the litre of water has been syphoned from the flask

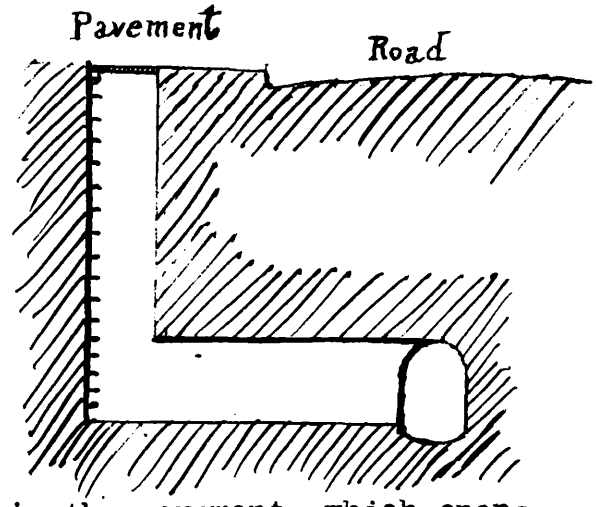


B to the flask C, and the atmospheric pressure equalized, the end of the india rubber piping fixed to the Sedgwick and Tucker's tube is changed to the air pump A; and the end of the piping attached to the air pump is changed to the tube D, and the syphoning action reversed by means of the air pump. The rate of the aspiration can be judged by the flow of the water in the flasks, and regulated by the action of the air pump. A little care is necessary when one of the litre flasks is nearly emptied, so that the atmospheric pressure may be equalised in both flasks: but by watching the glass dip-tube in the flask, whether its contents have a tendency to rise or fall, this difficulty is overcome. Before beginning these experiments I performed a blank one to test the efficiency of the sugar filter in keeping back the micro-organisms. I placed a column of sugar only 2½ inches deep in the tube; introduced an extra piece of cotton wadding between the two in the small end of the tube; drew through ten litres of ordinary laboratory air; put this medium cotton wadding plug in a sterilised flask with gelatin; and placed the flask in an incubator; and I found it sterile after five days. So that in my experiments no controls were necessary as I used a column of sugar ¾ of an inch deeper than this.

As soon as I reached the laboratory after the sewer ex - periments I applied new cotton wadding plugs to the ends of the tubes, lest they might have been contaminated when removed from the tubes during aspiration. The tubes were next held at a slight angle with the large end pointing downwards, and gently tapped with the finger till all the sugar rolled into the wider part of the tube. The sugar-supporting plug was then pushed up by a sterilised

copper rod, till it slightly projected into the larger end. About a third of a test tubeful of nutrient sterilised heated gelatin at 40° C. was now poured into the large end of the tube on to the sugar. The tube was then held horizontally and rotated slowly to coat the whole of the large internal surface evenly. (Should the gelatin be inclined to set before the whole of the sugar is dis - solved, the tube can be held for a few seconds over a steam bath. As soon as the gelatine and sugar solution is transparent, its solidification can be assisted by rotating the tube over ice, or under a water tap) The tubes were now placed in an incubator at a temperature of 16° C. In my opinion the advantages of this method are (1) Great portability (2) The filtering tube and cultivating flask form one instrument (3) The nutrient material is not clouded as it is by ground glass, or by using Petri's sand filter.

The sewer in which I made the following experiments is situated in Vere Street, Strand; was built some fifty years ago, and is shaped as illustrated. It is about 5½ feet high and 3 feet wide; the current is very slow and it is considered one of the worst sewers in the Strand district. Admission to the sewer is got by a manhole door in the pavement, which opens over a shaft about 16 feet deep. From the bottom of this shaft there extends a horizontal passage to the sewer about 5 feet high, three feet wide and ten feet long. The floor of this passage is



about 9 inches higher than the floor of the sewer. There is seldom more than 9 inches of sewage running in this sewer. The greatest depth during my observation was 6 inches on a very wet day; and on the other days only about 4 inches. There is a ventilator about 100 yards higher up, and another about 60 yards lower down. The manhole was originally used as a ventilator, but it was closed at the request of the School Board, as they thought the smell arising from it was dangerous to the health of the children at the adjoining School.

All the observations were made with the manhole door closed, unless otherwise stated. In each series of observations the number of micro-organisms present in the external air was ascertained near to the closed manhole door.

T A B L E I.

Five litres of air aspirated from different sources on 29th. January 1894; Barometer standing at 29·8 inches; cold dry East wind; Drain temperature 55 F., Time - 2 p.m. to 3.30 p.m.

SOURCE	MOULDS	BACTERIA	REMARKS
Outside air, Vere Street	10	50	No liquefaction of gelatine on 5th.day.
Sewer air, Vere Street	6	27	3 Liquefying colonies on 5th. day
Sewer air; splashing of sewage by treading 8 feet windwards of collecting tube.	2	33	Many liquefying colonies on 5th. day.
Sewer air, Vere Street manhole door open, gentle draught inwards.	15	61	Many liquefying colonies on 5th. day

TABLE II.

Five litres of air aspirated from different sources on 5th. February 1894, beginning at 2 p.m. and ending at 4 p.m.; Barometer 29·2"; gentle south west wind; Drain temperature 56° F. There was a drizzling rain during the whole of the observations and for 20 hours previously.

SOURCE	MOULDS	BACTERIA	REMARKS
Outside air, Vere Street.	1	14	No liquefying colonies on 5th. day.
Sewer air, Vere street	49	8	One liquefying colony only.
" " Confirmatory	40	5	
Sewer air; splashing of sewage by treading 8 feet windwards of collecting tube.	3	17	On 4th.day the bacterial colonies were very small, most of them liquefying the gelatine.
Bottom of ventilating shaft, manhole door open, gentle inward current.	17	90	Colonies could not be counted after 5th. day owing to liquefaction.

TABLE III.

5 litres of air aspirated from different sources on 12th. February 1894, beginning at 2 p.m. and ending 4.30 p.m.; Barometer 29·4; Drain Temperature 55° F., A gusty west wind blowing.

SOURCE	MOULDS	BACTERIA	REMARKS
Outside air Vere Street.	13	42	1 liquefying colony.
Sewer air, Vere Street	10	16	2 liquefying colonies.
Sewer air (No.2) Vere Street.	3	10	No liquefying colony.
Sewer air, violent splashing by treading 8 feet to windward of tube.	3	36	Began to liquefy on 4th. day.
Do. Do. No.2 Confirmatory.	2	33	Ditto.
Sewer air; manhole door open; strong gusty current of air inwards.	20	44	Many liquefying colonies.
Bottom of manhole shaft; current of air very gusty.	16	Innumerable.	Colonies so very numerous that some dust must have fallen down the shaft. Candle blown out
Upper part of manhole in Strand, 20 feet above sewer level. Air current passing outwards.	33	83	See Text.

It was necessary to go to the Strand to get a ventilator

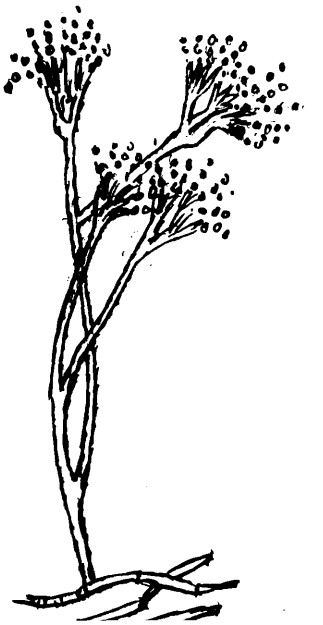
with an upward current, as all the ventilators in proximity to Vere Street were acting as inlets.

I. MOULDS.

From these tables it appears that the presence of moulds fluctuates to a much greater extent in outside air than in sewer air. In Tables I and III the experiments were made on dry days, when the number of micro-organisms found in sewer air was about half the number found in outside air. The proportion of moulds to bacteria was also much the same as in outside air. But in Table II the experiments were made on a dull day, it having rained incessantly for the previous 20 hours. There were 14 bac - teria and only one mould found in the outside air, whilst there was an average of 44 moulds and 7 bacteria found in sewer air at the same time, and for the same quantity of air.

Now the question naturally arises, from whence did these extra 43 moulds come? Evidently they could not have come from the outside air, but somewhere between the collecting tube and the sewer ventilator some 50 yards away.

This view seems all the more reasonable when one considers the morphology and habitat of moulds. The long projecting spore stalks from the mycelium project the spores well out from the walls of the damp sewer and so allow the free spores to be disseminated into the sewer air.



My opinion that moulds in

sewer air can come from other places than outside air, is not based upon Table II alone. It will be seen from all the tables that when the manhole door was open, converting the shaft into a ventilator having an inward current, there was always an increase of moulds and bacteria over the outside air; and when the current was outwards an increase over the moulds and bacteria of the sewer air.

Again, there is the further confirmatory proof in the greater variety of moulds collected. There were, for instance, collected in the outside air only Pencillium Glaucum, aspergillus glaucus and albus; whilst in sewer air in addition to these were aspergillus flavus and niger, and Mucor Mucedo.

I therefore contend I have demonstrated that the moulds at any rate in sewer air can be developed in sewers, and not, as has been believed, in outside air only.

II. BACTERIA

It is seen from all the tables that the number of bacteria in sewer air is about half the number contained in out - side air; further, that splashing experiments considerably increase the number of bacteria in sewer air, but never to such an extent as to make them equal the number in outside air, unless after prolonged rain, when the atmosphere contains very few micro-organisms. Also that splashing always decreases the number of moulds. Taking the average nmuber of bacteria from all the Tables in these experiments we find 20 in the sewer air, 43 in outside air, and 71·8 with manhole door open acting as an inlet ventilator. This gives an in - crease of 27·8 bacteria for every five litres of outside air that

passed through the ventilating shaft. It is thus proved that these bacteria came from the walls of the ventilator. Again, the ventilator in the Strand when acting as an outlet on 12th. February 1894 contained 50 bacteria in five litres of air, in all probability a great increase upon the average number in the sewer some twenty feet below. On the other hand, were this increase in the number of bacteria which takes place in the ventilating shaft, going on in the sewer, one would imagine there would be more bacteria in sewer air than outside air. But such is not the case; for as soon as the bacteria of the outside air and the bacteria from the ventilator walls enter the sewer, they begin to fall into the sewage or to stick to the damp sewer walls. In fact it is a form of Hesse's tube for collecting bacteria.

This is the point in my opinion upon which Professor Carnelly and other recent observers went astray. They argued that were bacteria produced in sewers there would of necessity be more bacteria in sewer air than in outside air; while there are only half the number.

Professor Carnelly and Dr. Haldane referred to a number of experiments performed by them of passing air through a moist tube 5 feet long and $1\frac{3}{4}$" in diameter, showing that half of the organisms were deposited in the passage in a current of air travelling at the rate of 1 foot per second. But I argue that a glass kept moist by running tap water, and a tube kept moist by putrid sewage are two totally different things. Were their reasoning correct, why are there any micro-organisms at all in sewer air?

Why should not all be thus deposited, if they can be reduced by a half in 5 seconds? The reason I submit is that some must be eliminated from the sewage or from the walls of the sewers: that in fact there is a constant deposition of micro-organisms, and a constant elimination of them from the sewers, the balance being seen by the number found in the sewer air.

The different levels at which observations were made in the shaft and sewer should be carefully noted, because the results obtained provided most striking evidence of the important bearing which gravitation has upon the number of bacteria in a given area. On referring to the tables it is seen that the number varied with the depth; and as a sewer is horizontal and its shaft vertical it is simply in accordance with reason to find the largest number at the bottom of the vertical shaft when the current was inward; and the largest at the top where the current was outwards. For instance, granting that 10 micro-organisms would be eliminated from every foot of length of the shaft, one of 14 feet would eliminate $10 \times 14 = 140$ into the area of the bottom of that shaft; whilst the same process happening in the sewer itself, would only give 10 in each foot of length of the sewer.

Sternberg (Bacteriology, page 550) states :- "The moist " mucous membrane of the respiratory tract constitutes a most effi- " cient germ trap. Although there are organisms inhaled, there " are none exhaled. There are no germs in the atmosphere over the " ocean, and it is only upon approaching land that they become mani- " fest." In my opinion sewers are places where micro-organisms must revel, as they have abundance of food, warmth, and moisture

for their complete development. Being however placed in such a moist trap as a sewer, it is a matter worthy of consideration how it comes about that the sewer air contains so many. It is easy to see that the increase of bacteria at an outlet ventilator is caused by the upward current of sewer air, containing its micro-organisms, plus those growing upon the side of the ventilator, gravitation at this place being overcome by the current. Naegel asserts, " That very slight upward air currents are enough to prevent floating bacteria from settling down. The condensed watery vapour " that surrounds them tends to maintain their buoyancy. Friction " also retards their fall." My observations as far as they were similar agree with those of Drs. Carnelly and Haldane, and the more recent ones of J. Parry Laws, published three months ago. It is only in the deductions from these observations that we differ. I hold that their observations prove my case, whilst their deductions cannot explain my observations. These experiments prove that as far as number alone is concerned, bacteria can be disseminated from sewers; and that the bacteria present in sewer air, do not come from outside air alone.

To come now to study the etiology of sewer bacteria from another point, viz; Qualitatively; the most cursory glance at the cultivating tubes shows the great difference between outside air and sewer air, especially as observed on splashing. The colonies of the outside air had apparently not liquefied the gelatine on the 5th. day, whilst on the same day, the gelatine of the tubes that contained the ventilator air were quite liquid and could not be counted. I further made an attempt to compare the bacteria found

in sewer air with those of the external air. I carefully examined the colonies in the cultivating chamber of Sedgwick and Tucker's tubes with an inch objective, noting their size, colour and form, whether the edges were smooth, serrated, or scolloped and whether they liquefied the gelatine or not. I then inoculated gelatine tubes with each different colony, both of the external air, and the sewer air. These tubes of gelatine were placed in the incubator, and examined daily. When the colonies were sufficiently developed I made cover glass preparations from them stained with gentian violet to examine their form and size; also drop cultures to notice their motility. These results were compared with the descriptions from current bacteriological works especially Crook - shank's, Sternberg's, Flugge's and Sims Woodhead's. In cases of doubt I was kindly assisted by Dr. Howlett of King's College Bacteriological Laboratory. I originally intended to give illustrations both of the microscopic appearances of all the different micro-organisms and the naked eye appearances of the colonies and test tube cul - tures, but after having performed the task I found it would be a mere recapitulation from the text books. So I give the Table containing the names of the organisms I found, without any description.

MICRO-ORGANISMS FOUND IN OUTSIDE AIR.

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1. Micrococcus Aurantiacus (Cohn).
2. Micrococcus Candicans (Flugge).
3. Sarcina Lutea (Sckroter).
4. Micrococcus Flavus Desideus (Flugge)
5. Bacillus Subtilis (Ehrenberg)

- MOULDS -

1. Pencillium Glaucum.
2. Aspergillus Glaucus
3. Aspergillus Albus.

- Micro-organisms found in sewer air:-

1. Micrococcus Aurantiacus
2. Micrococcus Candicans
3. Sarcine Lutea
4. Sarcina Aurantiaca
5. Diplococcus citreus Conglomeratus
6. Micrococcus Ureae (Pasteur)

- BACILLI -

1. Bacillus Subtilia
2. Bacillus Fluorescens Liquefaciens
3. Bacillus Ochraceus
4. Bacillus Acidi Lactici

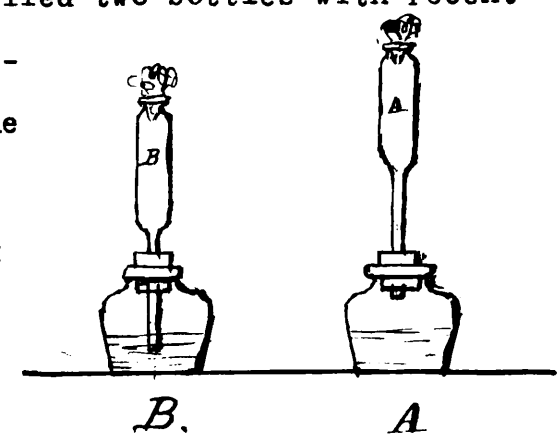
- MOULDS -

1. Pencillium Glaucum
2. Aspergillus Glaucus
3. Aspergillus Albus.
4. Aspergillus niger
5. Aspergillus flavus
6. Mucor Mucedo.

This list of micro-organisms is rather misleading, as there were only three observations with outside air, whilst there were fourteen observations with sewer air. There can be little doubt had there been the same number of observations with outside air, the list of organisms would have been larger. There is a well marked preponderance of bacilli in sewer air, compared with their scarcity in outside air. Roscoe, in his examination of sewage, found only one micrococcus (Philosophical Translations 1892) All these specimens however have at one time or another been found in the outside air; most of them also grow in water, as well as being often present in air. Yet the presence especially of Bacillus, Fluorescens Liquefaciens, and Micrococcus Ureae points strongly to a sewage origin. But as Sternberg states, "The pre-" sence of micro-organisms in air is to be regarded as accidental, " and so far as we know there is no bacterial flora properly be - " longing to the atmosphere."

Since it has been proved that micro-organisms in sewers can be disseminated into sewer air, the question arises, "How is this accomplished?"

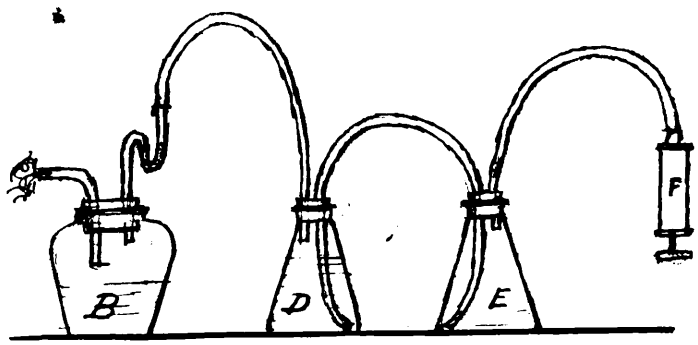
In order to form an opinion on this subject I performed the following experiments. I half filled two bottles with recent sewage, and placed over them as illustrated, Sedgwick & Tucker's tubes, the large ends being coated with nutrient gelatine the small end of one dipping into the sewage, and the small end of



the other about two inches above the sewage. The two flasks were then placed in an incubator, having a temperature of about 16° C. At the end of 14 days there were no colonies in tube A., two in tube B., (Pencillium Glaucum amd Micrococcus Candicans), their presence in all probability being experimental, considering that there would be millions of bacteria in each c.c. of the sewage.

The sewage was then poured out of the flask A and the cork and Sedgwick tube again inserted, the whole again being placed in the incubator at a temperature of 16° C. At the end of ten days, there were no colonies, though the damp sewage was by that time dry. These observations agree with Tyndall's experiments on sterilisation of air by subsidence; and also Hesse's, which show that when a room is left quiet, the micro-organisms settle in a few hours, so that the air becomes comparatively sterile.

These experiments were then modified by passing a definite quantity of air (10 litres) over the sewage as shown in the illustration. The micro-organisms of the air were prevented by a plug of cotton wadding (A) from passing into the sewage chamber. Any micro-organisms that might pass from the sewage chamber B, were kept back by the sugar filter in the glass bend (C). D and E are flasks containing a litre of water between them, and form the means whereby the quantity of air aspirated over the sewage by the air pump F is measured.

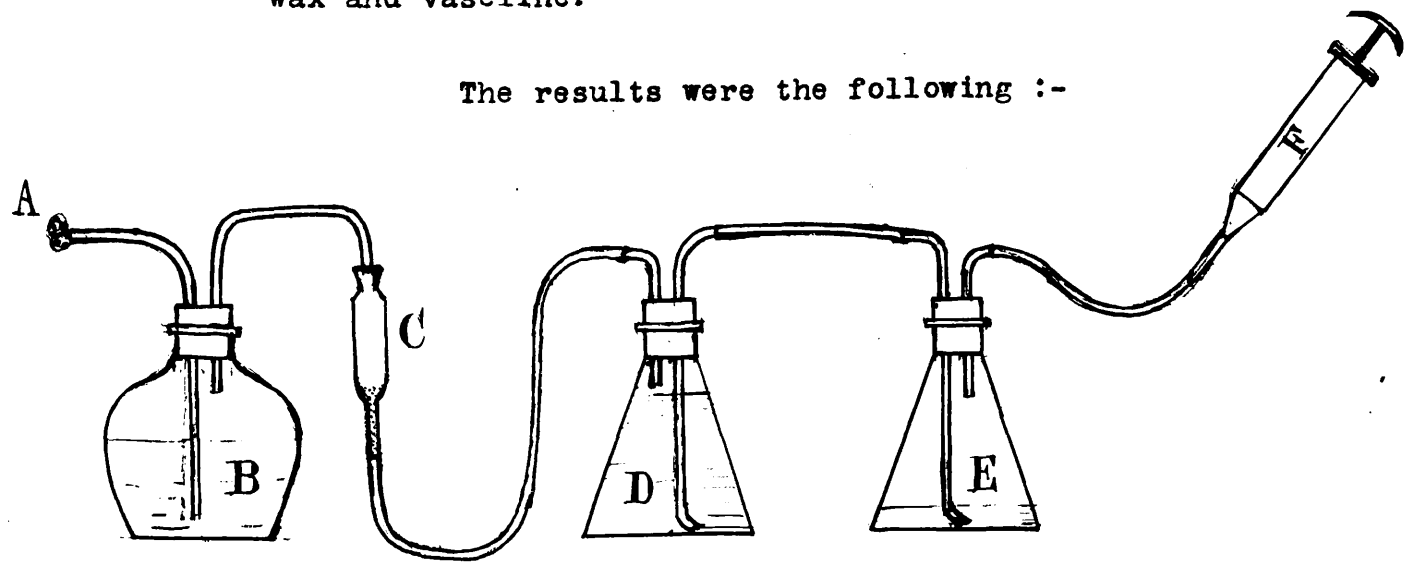


A similar experiment was performed, only having the external air tube (O) connected with the sewage chamber B dipping into the sewage, so that during aspiration there would be a continuous bubbling of the sewage in chamber B.

These two experiments were not of a satisfactorily nature, owing to the moisture coming from the sewage, wetting the first part of the sugar filter to such an extent, that the sugar after the experiment could not be got from the bent glass tube, without breaking it, and wiping the sugar out with sterilised cotton wadding. The introduction also of the sugar, in parts, to the cultivating flasks rendered the experimental error rather high. Two control experiments were therefore made by using the sugar filters of Sedgwick and Tucker's tubes; but having the lower ¼ of an inch of the larger part of the tubes also filled with sugar, as any surface wetting would do no harm.

In all these experiments all joints were covered with bee's wax and vaseline.

The results were the following :-



	MOULDS	BACTERIA	TOTAL
Ten litres of air aspirated from surface of sewage; microbes collected by sterilised sugar in bent glass tube.	4	0	4
Ten litres of air, bubbling through sewage; microbes collected by sterilised sugar in bent glass tube.	3	3	6
Ten litres of air from surface of sewage, microbes collected by Sedgwick's tube.	2	1	3
" " Control	1	0	1
Ten litres of air bubbled through sewage slowly; microbes collected by Sedgwick's tube.	2	1	3
Ten litres of air bubbled violently through sewage, microbes collected by Sedgwick's tube.	2	4	6
Ten litres of air drawn over slowly dried sewage, microbes collected by Sedgwick's tube.	2	3	5
One litre of air drawn over broken up dried sewage		Innumerable.	

The few micro-organisms found are probably an experimental error, as the sewage flask was not sterilised. The air over the sewage was the ordinary air of the laboratory, this itself would

account for at least three or four micro-organisms. Again the organisms found - Pencillium Glaucum, Aspergillus Glaucus, Micrococcus Candicans and Sarcina Lutea, were such as one may find in ordinary laboratory air. What surprised me most was the very slight increase of the micro-organisms caused by the bubbling experiments, for I aspirated the air through the sewage at as rapid a rate as the sugar filter would allow. The sewage however never went into a foamy mass, the bubbles bursting close to the surface of the sewage only.

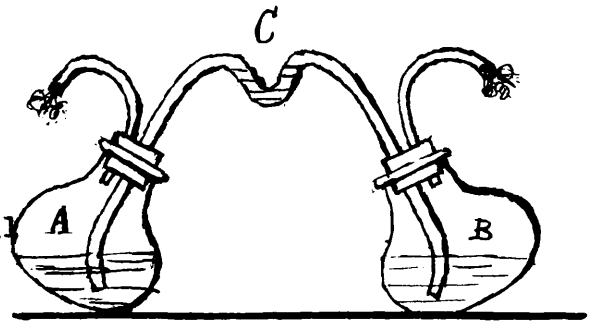
Again, the sewage flask A, which had contained sewage for 14 days, and which then had the liquid part poured off and kept in an incubator at a temperature of 16° C. for ten days, till it had dried, was treated in a similar manner, and only 5 micro-organisms were found.

I now passed into the flask a glass rod, the end of which was covered with sterilised cotton wadding, and broke up the crusty sewage coating of the flask. In aspirating the air through this flask in a like manner, I could now see the dust leaving the flask, so I only aspirated one litre. The gelatine in the tube at the end of the third day was liquefied and the colonies were innumerable.

These results only confirm Buchner's observations "That " even strong currents of air are insufficient to sweep bacteria " from a liquid; and even then in the case of dried up masses " containing fungi the fungi are not set free unless the surface is " actually broken." As all these experiments therefore did not show how bacteria passed from the sewage to the sewer air, I made

the following with the object of testing their motile powers.

I had two flasks one third full of broth culture, connected by a glass tube about ¼ of an inch bore as shewn in illustration. Into each flask there was put a bent air pipe, plugged at the external end with cotton wadding to filter the air that might enter the flasks. All the joints were covered with bee's wax and vaseline. The contents of the flasks were sterilised by boiling for five minutes during three consecutive days. The tube C was coated with organic matter by pouring the broth from one flask to the other. After the contents of the flasks were cool, and the trap C. full of the nutrient broth , the flask A was inoculated with typhoid bacilli, and the whole placed in the incubator.



In three days the contents of the flask A were cloudy. After 21 days the fluid in the trap became cloudy; and seven days later, the fluid in flask B became also cloudy. Drop and cover glass preparations were made from flask B, when the typhoid bacilli were found. This was further confirmed by tube cultivations in gelatine and agar agar, by Dr. Hewlett.

This experiment shows most conclusively that typhoid bacilli have the power of moving along a nutrient moist surface, and this, therefore, must also be true of a great many other bacteria in sewage. Microbes can thus be disseminated into sewer air from sewers:-

(1) By Splashing

(2) By Bubbling from fermentation

(3) By Motility.

I. SPLASHING.

Drs. Carnelly and Haldane have performed a large number of experiments in splashing, in all of which the agreement is so wonderfully marked, that no one can doubt the accuracy of their conclusions.

They got 370 bacteria per litre of aspirated air on the second day of cultivation, by pouring putrid matter into sewage from a height. After the second day the bacteria were too numerous to count. In my own experiments where there was gentle splashing with the sewer man treading the sewage eight feet to windwards, the bacteria were doubled in number. These results clearly point to the necessity of preventing drains entering the crown of sewers, or of having weirs or waterfalls in sewers.

II. BUBBLING.

In my experiments the results were all negative, doubtless because it was fresh air which was aspirated through the sewage. I am strongly inclined to believe that had the bubbles been caused by the products of putrefaction, more bacteria would have been disseminated.

All.Authorities agree that Bubbling due to putrefaction disseminates the microbes of sewage. But if sewers are laid with a proper fall, and regularly flushed there can be no collection of sludge to putrefy; so that in modern-built sewers there is no bubbling caused by putrefaction and few, if any, micro-organisms given to the sewer air from such sources.

III. MOTILITY.

No one to my knowledge has ever mentioned this means, by which sewage microbes find access to the air of sewers. The bacteria of the sewage may move along like those of typhoid, up the walls of the damp nutrient sewers, so that they may be literally alive with them. Moulds here also grow with great proliferation. In their struggle for existence they will often be covered with bacteria, and in shooting forth their spore stalks must carry some bacteria out with them. When the spore heads are sufficiently long to project from the damp sewer walls and have become ripe for dissemination, the clinging bacteria and their spores will become liberated along with those of the moulds. The liberated mould spores and Bacteria or their spores, will be wafted with every air current; many will gravitate to the sewage; others will stick to the damp sewer walls; others will be carried up the ventilators to the outside air, and not a few may find entrance to dwelling houses having no traps, or traps that have become useless from evaporation, and thus lay the susceptible occupants low. This to some extent would account for the numerical relation that exists between moulds and bacteria in sewer air for there is not the same numerical relation in outside air, when it is wet, the number of moulds being comparatively few. This shows that it is principally aerial walls of sewers that disseminate bacteria, and not as has

been supposed the sewage itself or the side coating of sewage which had served to indicate the different levels of the sewage in the sewer. So that periodic flushing of well-laid drains with a proper fall is unnecessary.

What is required is that the aerial parts of the sewer should be scrubbed down at regular intervals, and some preparation applied to the sewer walls to prevent moulds growing, and hinder the movements of Bacteria. With such treatment the sewers would practically become sterile chambers.

I have thus shown that micro-organisms present in sewer air have other sources besides the outside air; and that they cannot be eliminated from fresh sewage; nor yet from damp walls without moulds. I have moreover put forward my view of the mode in which micro-organisms are chiefly disseminated into sewer air.

In cities, all houses are connected by sewers and drains to each other. Into these sewers the discharges from all kinds of infectious diseases are emptied. A large number of these bacteria can grow, thrive, and multiply in the sewers, and in various ways get access to sewer air. Hence it behoves us to do all in our power to keep this contaminated sewer air from our dwellings. For even although it contain only half the number of micro-organisms of outside air, some of these may be those of typhoid, Diphtheria &c. This is also the opinion of the large bulk of Medical Officers of Health, as well as of the rank and file of Medical Practitioners. Stevenson and Murphy

state in their Treatise of Hygiene and Public Health Vol. 1. page 839 "There can be but little doubt that the sewer air in contact with such infected materials also becomes imbued with specifically contagious properties." "There are also the records of specific contamination of drinking water in cisterns and mains by such air."

With the ordinary gulley disconnection and water traps, it is almost impossible for micro-organisms to enter a dwelling house unless by accident. Such an accident happened in a friend's house this winter. During the frost the bottom of the soil pipe became blocked. The water closet was used as usual until there was an overflow. Next morning the floor over the sitting-room was wet and dripping. Five days later the daughter was suffering from Diphtheria, and two other members of the house felt ill, and had sore throats. In this case evidently the sewage in the room became dry, and, agitated by movements in the house the germs were set free and wafted about with air currents, to be doubtless finally inhaled, with the usual result.

The Practical Deductions to be drawn from these experiments are

1st. Have the sewer as small as possible, with a good fall, even though it should be necessary to have a pumping station for the low parts of a town. This would do away with the necessity of flushing.

2nd. Clean the aerial parts of the sewers twice yearly and at the same time have them pitched, tarred, or treated in some such manner.

3rd. Make the ventilating shafts circular and smooth and let them be cleaned every quarter, and white-washed, tarred or treated in some such manner.

4th. Let no drain pipe enter the crown of a sewer, but somewhere at the lower third, and preferably under the Level of the sewage.

An alternative and in my opinion a much better scheme is the following:-

Let all the drains entering the sewers be below the sewage level, and close all the dangerous and disease-giving street ventilators. The sewers could then with safety be ventilated by mechanical means, the extracted sewer air being treated by cremator furnaces placed at such distances as might be deemed necessary.