ON THE

DISSEMINATION OF MICRO-ORGANISMS,

AND ON THE BEST

METHOD OF DESTROYING GERM EMANATIONS FROM SEWER GAS.

BY

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THERE are two characters of germ contagion, which may perhaps be best illustrated in the diseases of scarlatina and enteric fever.

In scarlatina we know that the contagion is largely conveyed by the desquamation.

In enteric fever the germs which are carried by sewer gas are supposed, with considerable force of evidence, to be a fertile source of spreading the disease.

In scarlatina we assume that the "Raft Theory," as Tyndall called it, plays an important part, whilst in the latter we must assume that the contagion is often carried with the vapours which emanate from the drains.

In my present communication I do not propose to deal at any length with the subject of the transmission of germs by the raft theory. It is fairly understood by most physicists and bacteriologists, but I may as well concisely describe it as most scientists understand it. Now we assume that the ordinary atmosphere, let us say at the sea level, is largely contaminated with a visible and ponderable matter which we term atmospheric dust. This atmospheric dust is found largely present in our homes, and also in the streets of populous towns. It consists of ponderable atoms,

[a] Read before the State Medicine Section of the Royal Academy of Medicine in Ireland, on Friday, April 30th, 1897.

which at an altitude of a few feet almost entirely consist of organic matter. This fact was conclusively demonstrated by Tyndall's beautiful experiments in producing what he called optical vacuums by the combustion of the organic matter. The coarser particles of this atmospheric dust act as floating rafts, and carry on their surface the finer structures of life. In the case of such a disease as scarlatina we can easily see how this raft theory plays an important part in the dissemination of the desquamation.

Even the smallest germs that our microscopes have yet revealed have a certain weight. This fact is shown by the absence of germs at high altitudes—such as Mont Blanc, or in a very still atmosphere, such as is found in the vaults of St. Michan's Church. I demonstrated this as far back as 1870, in an "Afternoon Lecture," delivered at the Royal Dublin Society. I showed that flasks placed all night in the vaults of St. Michan's Church were, when sealed next morning, optically empty, or free from atmospheric dust, and were therefore free from germs. We get in these vaults exactly the same result that we should find on the top of Mont Blanc. I believe this sterility of the atmosphere of St. Michan's Church has been the subject matter of one, if not more papers read before this Academy. I am sure it had escaped the author's observation that the ground had already been "prospected."

It is worthy of note that the greater part of practical bacteriology is now worked out by an observation which, I think, originated with Tyndall—that cotton wool was a perfect filter as regards this atmospheric dust, and that it not only acted upon the coarser particles but separated the finer micro-organisms.

I may be excused for still further referring to my own researches in this direction, mention of which will be found in the later editions of "Parkes' Hygiene," by De Chaumont. I was able to demonstrate that even the dust at the top of Nelson's Pillar contained over 29 per cent. of organic matter and that it was capable of setting up the lactic fermentation in a neutral solution of sugar of milk. Here is a solution of sugar of milk and lime, which although sterilised, when brought into an ordinary room containing atmospheric dust has fermented, and become solid by the formation of calcium lactate. The atmosphere at every yard that we rise from the ground becomes freer from the ponderous earthy constituents, but richer in germs. Of course, we at last come to an altitude where even the micro-organisms become scarce, and ultimately to such regions as the high altitudes of Switzerland where the germ is unknown. Even on the Mer de Glace the germs may be said to be absent.

So much for the raft theory, which will account for the dissemination of any germs, providing they have arrived at the dry condition, or that they can be attached to a dry particle. What can be more easy to conceive than the spreading of scarlatina by a process such as this. It is almost self-evident.

But there is another mode by which preventable disease is propagated which has never, to my mind, presented such a lucid explanation as regards its propagation. I refer to the theory which supposes that a certain germ, let us say like that accompanying enteric fever, cholera, or the poison of yellow fever, is capable of acting as a poison when evolved in sewer gas.

We have an organism which, when carried in water or brought mechanically to a receptive surface, is capable of producing disease, and yet we also find that it is capable of rising in a vapour as in sewer gas. I use the term "vapour" not in the vulgar sense, which assumes a non-permanent gas capable of condensation, but in the sense that means anything flying, or escaping off. In this sense atmospheric dust is volatile.

Two special diseases are supposed to arise from the air of sewers or fæcal emanations—typhoid fever and diarrhœa. Yet if these diseases are caused by bacilli how are they volatilised, for however minute, these bacilli are still organic structures developed in the liquid fæcal matter. A pathogenic germ is so small that our finest balance will not weigh it, and although it may only be $\frac{5}{1000}$ths of a millimetre in length, we might as reasonably conceive that the coarser microscopic life, such as rotatoria or entomostraca, which we can almost see with our eyes, would be volatilised as a vapour, as to conceive that pathogenic microbes would be so transmitted. Prof. Frankland has shown that liquid sewage matter is not likely to be scattered into the air, except by gas generated in it. He experimented with lithia, a chemical substance not volatile, but which could be easily detected by the spectroscope, and might be said to represent micro-organisms. He found that no ordinary agitation of the sewer water would produce indications of lithia in the air, but that directly gas began to be generated in the sewage, by decomposition, the bursting of the gas bubbles carried lithia into the air.[a]

Now, I think here is the clue to the dissemination of microbes, but not exactly in the direction which he indicated. Such a condition of sewage—*i.e.*, in active fermentation—is hardly conceivable in a general sense in the better constructed drains found connected with houses of a good class—the houses, in fact, where typhoid seems to luxuriate.

We must suppose, however, in a system of town sewage, certain spots in the mains, where, from the Frankland cause, the microbes are scattered into the air during fermentation, or let us say violent concussions breaking the sewage into spray. And then comes the question—how are they disseminated through the whole area of the air space of the system of drains? I can easily conceive that they are carried there by a condensed vapour, exactly represented by ordinary dew at certain hours of the night, just as we see the rising vapour settling as dew in a valley. I believe

[a] Proceedings of the Royal Society, 1879.

that the temperature of the water laden vapour of the sewer is lowered by meeting with the layer of cold night air through the open traps which determines a dew point in the sewers themselves. I find, from actual experiment that the temperature of the sewer water as it flows from the large sewers, or the temperature of the gas in the mains, is generally 2 or 3 degrees above the temperature of the night air. The gas mains bear a somewhat similar position underground to the sewers, and give a very good idea of this variation of temperature. A variation of as much as 10 to 15 degrees may be observed. Even a sudden rise in the barometer will just determine the deposition of the liquid portions of the gas in the mains, and in the same manner will also determine, even more energetically, a dew line in the sewers Each particle of dew becomes a raft which will carry microbes upon its surface, perhaps for miles, as long as this " dew " condition lasts; and as the sun's warmth dissipates the morning dew the water raft disappears, leaving the microbes suspended in mid-air—or, suppose that if the sewer dew is carried into a warm shaft connected with a dwelling-house, is not the assumption apparent that again we have the water rafts converted into permanent gas, whilst the now dry germs float about seeking whom they may devour?

I will just conclude by a few remarks upon sewage disinfection from this point of view. The disinfectants employed in sewage purification can hardly be viewed as actual germicides. The modes in which they are necessarily used create such an amount of dilution that they can be viewed only as retarders of the development of microbes. It is, no doubt, chiefly from this reason that they are not more extensively used in sewage purification. The return in results, as regards the prevention of diseases, is not commensurate with the great expense of oxidisers, such as permanganates and hypochlorites. They are not in favour, because unless they are used in overwhelming quantities they are worse than useless. They destroy myriads of microbes, but allow myriads to escape—and to the remainder they only seem to add fuel to the fire. It is true that at the pumping stations in London, manganate of sodium is used, or was used, but in such a case it is merely employed as a deodoriser at the end of the process, whilst the supernatant fluid is being poured into the river.

From the reason of cheapness crude carbolic acid (which may be considered to owe its virtue to phenol, cresylic acid, and a little naphthalene) is extensively used. Although not a very decided germicide, phenol still holds an important place as one of the most valuable retarders of germ development. Naphthalene is still more powerful, and may be looked upon as a germicide proper. Although very cheap, it has one objection, namely, its great insolubility.

I have here a fluid which I have used with some success for years in controlling or instantly stopping germ development: there are many occasions when the use of mercuric chloride is inadmissible.

It consists of:—

Crystallised Phenol	1 part.
Camphor	3 parts.
Naphthalene	½ part.

Coloured with rosaniline carbolate.

It will be observed that though these are all solids they form a fluid on rubbing together. One drop of this liquid will instantly arrest any tube of microbe culture in gelatine at a given point, and may be used with advantage to place on record comparative experiments with microbe cultures.

In such an experiment I have found it advantageous to use a little stiffer nutrient gelatine than that given in Crookshank's work. I increase the formula given there from 100 grammes of gelatine to 120 grammes (*vide* Crookshank's Manual of Bacteriology, 3rd edition, p. 83).

Now it is a similar preparation to the above preservative which I should propose for sewage purification, with one modification which I consider invaluable. Crude carbolic acid (phenol) is comparatively cheap, and naphthalene may be viewed as a waste product in the process of coal tar distillation. For the camphor I would substitute terebene, which may be looked upon almost as a liquid camphor. Where the sewers of a large city are being provided for, or where cost is a question of importance, the light oils of tar may be substituted.

Now I will describe the scientific theory, by which, I believe, this disinfectant can be made a trap for typhoid bacilli or germs of a like nature in sewer gas.

The principle involved consists in adding some liquid body which shall bring the specific gravity of the antiseptic below the gravity of the sewer water. When such a body is used the antiseptic fluid forms at once a fine pellicle of antiseptic material. All fluids that are volatilised or mechanically eliminated by the escape of gas must pass through the germicide layer. If carbolic acid or the crude phenol products are used by themselves, we find, in practice, that they immediately sink to the bottom of the flowing sewage which passes along over the top in a continuous stream of untouched pollution. The crude products obtained from the distillation of coal tar are specially suited to this purpose When coal tar is distilled in the first instance it is divided into two divisions—one is called " light coal tar oil," and the other " heavy coal tar oil." The first contains all the products which come over as long as they will float on water, and they are specially rich in the benzene, naphthalene and terebene series, all of which are powerful germicides. By substituting these oils for terebene we get an antiseptic fluid which immediately spreads on the surface of the sewage, locking in the deleterious vapours, and at the same time passing downwards the heavier antiseptics, such as the phenols, through the sewage by the simple act of solution.

This can be illustrated by the following simple experiment. If we pass, by a pipette, a layer of carbolic acid into a shallow dish of water, and after standing some little time draw off some of the supernatant water, we shall find on testing it with a little bromine water that it contains no carbolic acid. If, in a second experiment, we use such a mixture as I have specified, but which must have a specific gravity of ·850 to ·950, we shall find, on introducing it into the water with the pipette, that it immediately rises to the surface, and if we at once remove some of the water from the interior it gives, on testing with bromine water, a copious precipitate, showing that the carbolic acid has permeated at once through the fluid which represents the sewage. We should further find, on examining this fluid, that the powerful antiseptic naphthalene had been carried with it.

I have endeavoured in the above experiments to show why, in many cases, the use of carbolic acid has been a practical failure as a sewage purifier, and to indicate that, in dealing with such contagions as are diffused through sewer gas, a principle should be adopted in the use of antiseptics. This principle has not, as far as I know, been openly enunciated—namely, that we must disinfect from the surface of the flowing sewage, and not from the bottom.