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SEWER GAS AND HEALTH.

DEDICATED

TO

SIR THOMAS WRIGHT,

TO WHOSE FORETHOUGHT, WISE COUNSEL, AND PERSEVERANCE THE TOWN OF LEICESTER IS INDEBTED FOR MANY SANITARY AND OTHER IMPROVEMENTS, AND WHO HAS FOR A GREAT NUMBER OF YEARS GIVEN FREELY OF HIS VALUABLE TIME FOR THE BENEFIT OF HIS FELLOW-CITIZENS.

AS A MARK OF HIS VERY HIGH ESTEEM AND REGARD.

THE AUTHOR.

SEWER GAS

AND ITS

INFLUENCE UPON HEALTH.

TREATISE

BY

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PREFACE.

Although a great deal has been written at one time or another about the influence sewer gas exerts upon health, yet, in the author's opinion, the published information has dealt invariably only with one or two aspects of this question, and not with the whole, and the student of sanitary science was left to grope his way in the dark, as it were, and without guide through this apparent chaos, emerging therefrom probably after having formed a very one-sided opinion.

This state of things the author has endeavoured to remedy in the treatise before the reader, and although he is fully aware that great gaps still exist in our knowledge concerning the subject, he hopes he has succeeded in shedding some light upon it, and upon the way that will lead to its ultimate elucidation.

Questions affecting Nature and the processes by which she works her marvellous changes should, in the author's opinion, not be looked upon from one standpoint only, but ought to be viewed in their entirety and with their surroundings, otherwise one is apt to exaggerate the importance of one or more symptoms and leave others—equally important, or perhaps more so—altogether unobserved. It is therefore to the harmonious working together of a number of specialists—such as the chemist, the medical man, the bacteriologist, botanist, and engineer—that the author looks for the true answer concerning a number of questions affecting the health of individuals and communities.

In the search for material wealth this age has at times apparently forgotten scientific research, which did not promise some immediate material return; but there are hopeful indications that such temporary neglect is passing away, and that in future the scientific side of many practical sanitary questions will receive due consideration. It is then to be hoped that full light will be thrown upon many subjects at the present still shrouded in mystery.

Since writing the treatise the author's attention has been drawn to two explosions which have occurred in the "septic tank" at Exeter. In the first, the City Surveyor of Belfast narrowly escaped; and in the second, the City Surveyor of York is said to have received severe burns, and such a shock to his nervous system, that he has been obliged to keep to his bed at an Exeter hotel for some days.

As the "septic tank" is, like its predecessor in title, "the old cesspool," a place for the manufacture of rank sewer gas on a large scale, containing considerable quantities of hydrocarbons, such as marsh gas, one cannot be surprised to hear of explosions, but it is sincerely to be hoped that the practical demonstrations of the dangerous character of the gases forming in the septic tank will not be lost sight of, and that the lessons thereby learnt will be utilised in future to prevent loss of life.

To all those who have been kind enough to supply him with information and particulars, the author wishes to express at this place his best thanks. He hopes he may continue to receive information on the influence of sewer gas upon health from those interested in the subject, with a view to making a second edition more complete than the first.

If in the opinion of some he has not dealt fully enough with the subject in places, the author hopes this may be excused; but the leisure at his command for this work was limited, and only obtainable at intervals that were often very far between.

H. Alfred Roechling.

Leicester,
January, 1898.

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PART I.

General Considerations.

CHAPTER I.

Introductory Remarks.

The subject chosen by the author for his treatise has been very hotly discussed for years past, both in scientific assemblies and in the public Press, and many and various are the opinions which have been expressed upon it in this country as well as abroad. In fact, perhaps it is not too much to say that the subject has been clothed in many forms, some of them of an almost mysterious construction, and that it has created a great deal of confusion in the public mind.

To those who are more intimately acquainted with the matter, this can, perhaps, not be surprising, as the cause of it is undoubtedly to be found in our imperfect knowledge up to the present time of sewer gas and its influence upon health. Both those who strongly maintained the pathogenic character of sewer gas and those who as strongly opposed it were unable to support their belief with scientific proof, for want of sufficient knowledge of these matters. But within the last four years further light has been thrown upon this abstruse subject, and the author thought that it might not be out of place to critically review it in the light of our increased knowledge, with a view, if possible, of clearing up the question, and lifting the veil somewhat behind which it has been hidden up to now.

Our century is fast sinking into its grave, and it must be our aim to do what lies in our power to disentangle questions of great public importance, and hand them over to the next century in a clear shape, so that they may be easily understood by all.

Apart from these considerations, it has appeared to the author that a rather one-sided interpretation has been given in this country to the very able reports of Messrs. Laws and Andrewes for the London County Council, which have been published within the last four years. But, as will be shown later on, these reports must be accepted with certain reservations, the chief amongst them being that they do not cover the whole subject of sewer gas and its influence upon health; that, on the contrary, they only deal, as it were, with one phase of it—viz., the microbes. If, therefore, these limitations are lost sight of, there is the danger that the conclusions drawn from these researches are one-sided also, if not altogether wrong.

With a view to avoid such a mistake being made, the author intends, amongst others, to draw attention in the treatise to the very painstaking investigations made about four years ago by Dr. G. Alessi, in Italy, into the question of putrid gases as predisposing causes of typhoid infection. As he considered these researches of the greatest importance, he had them translated; and the Sanitary Institute, sharing his views, was good enough to publish this translation in its volume for 1895. These investigations supplement those of Messrs. Laws and Andrewes, and ought to be carefully studied with them in order to get a complete insight into the whole question.

There is yet another reason why the author ventures to think that the bringing forward of the question in the form of a short treatise may not be inopportune.

When suggesting on the Continent various alterations in the house-drainage arrangements, he had to run the gauntlet of a fairly hot opposition in reference to the injurious character of sewer gas, and when trying to refresh his memory by reference to the published information, he found the greatest difficulty in doing so, as it is scattered about in many places and not easily available. He thought, therefore, it might be a considerable advantage to put the subject into such a shape as would afford an easy reference even by those members of his profession with whom to live means work and to work life. With a view to attaining this end, he has attached to the review several appendices, in which he has given some of the information contained in a great many different sources and reported in different languages.

The public mind lends itself as easily to an unlimited sense of security as to a gross and unreasoning panic, but in the judgment of the author either of these should be avoided, and those who make and control public opinion in hygienic matters should not err in the direction of either extreme, as sooner or later a collapse or a reaction is sure to set in, which will sweep everything clean before it, and tend to make the pendulum swing to the other extreme of its amplitude. But by such a course nothing is gained, and the words of Ovidius ("Medio tutissimus ibis") seem to indicate to the author the right course to be adopted in this question.

CHAPTER II.

History of the Sewer-Gas Controversy.

Before entering upon the subject in detail, it might be convenient to give a general outline of the history of this question, which has caused many a severe conflict of opinion.

The opinion that filth and disease go hand in hand is practically as old as the hills, and might be said to underlie the Mosaic Law. From it, no doubt, in times long gone by sprang the conviction that the emanations rising from filth, especially from decomposing organic waste matters, were capable of producing certain diseases, but it was not till about the middle of the present century that this doctrine was applied to the putrid exhalations proceeding from our sewers, cesspits, privies, etc.

It had been noticed by various observers that typhoid fever frequently broke out in houses, the air of which had been rendered impure through the emanations from sewers and cesspools, and this gave rise to the theory that this disease was the result of a putrid process, and caused directly by these emanations. In this theory, which was called the "pythogenic theory," it was endeavoured to establish the self-produced, or spontaneous generation, of typhoid fever, and amongst its chief supporters were men such as Murchison (see A-45, Appendix I.) and Riecke.

It was not long, however, before men like Budd (see A-17, Appendix I.), and others, assailed it. Whilst admitting the facts observed by Murchison, Budd maintained that the disease was not spontaneously generated, but that putrid substances were only capable of producing typhoid fever in the presence of a specific contagion.

Each school of thought endeavoured to support its own theory by advancing facts observed, and the controversy raged at one time somewhat fiercely, without, however, apparently clearing the air. As time went on, the list of diseases observed to have been caused by emanations from cesspits or sewers increased, and at the present time nearly all the zymotic diseases, and several others besides, are attributed to this cause, such as typhoid or enteric fever, diarrhœa, dysentery, diphtheria, scarlet fever, erysipelas, cholera, malaria, yellow fever, puerperal fever, hospital gangrene, inflammation of the lungs, gastro-enteritis, etc. Without expressing any opinion at this point, it cannot be denied that this is a very formidable list, and at any rate goes to show how widespread the mischief from sewer air, etc., is supposed to be.

In our day, when the daily Press takes a deep interest in the doings and sayings of scientific men, it cannot be surprising that it endeavoured to place before the general public the opinions entertained amongst professional men in reference to sewer gas—hence the great interest taken generally in this question. This interest has not always been a well-defined one, and as the connection between sewer gas and disease was somewhat shrouded in mystery, it cannot be surprising to find that the general public has come to look upon any smell proceeding from cesspits or sewers as dangerous to health and poisonous. No doubt this conviction in the public mind of the dangerous character of sewer gas has at times given rise to exaggerated fears, but at any rate it has had the good effect, by bringing pressure to bear upon our sanitary authorities, of vastly improving the hygienic conditions and surroundings of our houses and towns. In fact, it has been stated—and in the author's opinion very properly—that this conviction has attributed more to the advance in the sanitation of our houses and towns than any other theory or cause.

But the history of the sewer-gas controversy would not be complete without a short reference to the stages through which it has passed in foreign countries. Fortunately, the laws of Nature do not follow arbitrary political lines, but are the same, with but slight local modifications, throughout the globe; hence, he who wants to understand the importance of any question connected with them must be able to follow its various phases in the various countries of the civilised world. This, no doubt, entails a great amount of labour, as it frequently happens that simultaneously investigations into the same subject are carried on in three or four countries, which are afterwards reported in the various scientific periodicals.

Notably has this been the case of late with the newly-founded science of bacteriology, where observers seem to have sprung up like mushrooms in nearly every part of the civilised world, and practically showered their frequently most contradictory observations upon the scientific public to such an extent that it was almost impossible to keep pace with them. In the general interest and in the interest of this science itself, it is sincerely to be hoped that this pace will considerably slacken in future, and that every observer will only publish his results after the most careful scrutiny.

In Germany, the sewer-gas theory was utilised by those who were opposed to the water-carriage system for fæcal matters as an argument against it. According to them, a system from which these dangerous emanations arose could not but be a standing danger to the public health—

hence it ought not to be carried out; and in its place was recommended one form or other of the conservancy system. In their zeal against the water-carriage system, these advocates of the conservancy system forgot entirely that putrid gases are perhaps more easily formed in cesspits, tubs, privies, etc., which, owing to their concentrated nature, are more injurious to health than those formed in sewers, and that in this country, to which frequent reference was made, the conviction that the putrid gases rising from sewers were dangerous did not lead to the abolition of the water-carriage system at all, but to its perfection by causing sanitary engineers to be doubly careful in excluding these gases from our houses.

This controversy was hotly fought out in many towns, but perhaps in none more so than in Munich, where, on the advice of Prof. Pettenkofer, the late Joseph Gordon had been asked to prepare a combined drainage scheme. It would lead much too far to go into details, as whole volumes have been filled with this controversy; it must suffice to say that the advocates of the water-carriage system made light of the sewer-gas theory, and endeavoured to show that sewer gas had not the influence assigned to it in this country. Such a course was, perhaps, but very natural, as the causal relations between sewer gas and typhoid fever, for instance, could not be proved; and the conviction had grown amongst professional men and others that the water-carriage principle was greatly to be preferred to the conservancy methods.

The German Association of Public Health convened in September, 1881 (see B-55, Appendix I.), with a view to settling this question, a congress at Vienna, at which the late Prof. Soyka read a paper on the influence of sewer gas upon health, and submitted the following resolutions to the meeting, which it would appear, however, were not accepted by the same:

1. The positive proof of the connection between sewer gas and the spread of epidemic disease has not been established.
2. The investigations made up to the present time admit, on the contrary, in the majority of cases, the conclusion that the spreading of epidemic diseases takes place quite independently of sewer gas, and that towns have better mortality figures after the carrying out of sewerage works than they had before. The same difference has been observed between the sewered and non-sewered parts of one and the same town.

Soyka tried to prove these resolutions with the aid of experimental facts and epidemiological data taken from a number of typhoid fever outbreaks, including the Croydon outbreak in 1875.

In 1882 Prof. Renk published a pamphlet (see B-46, Appendix I.) in which he sums up his remarks on the hygienic importance of sewer gas as follows:

"We summarise our opinion on the importance of sewer gas by stating that we look upon it as one of the factors which cause the pollution of air in our houses, and hold it responsible for the effects of this pollution.

"We cannot, however, admit that it exerts a special influence upon the distribution of infectious diseases, or that it predisposes the constitution for them, but consider that its injurious influence upon health consists in the nauseating effect which it produces in the whole nervous system.

"Although we make these reservations, we consider the keeping of sewer gas out of our houses an important task. . . ."

According to Soyka and Renk, then, sewer gas has no epidemiological importance; and, further, according to the latter observer, the influence of sewer gas upon health must be considered from the point of general hygiene.

For at a certain concentration the gases contained in sewers form a most poisonous combination, and numerous fits observed amongst sewer-men lead one to suppose that it is a question of the noxious influence produced by ammonia and sulphuretted hydrogen. The prolonged action of these gases gives rise to a chronic poisoning, which is accompanied by disturbances of the organs of digestion and nutrition, and in the end leads to attenuation, and physical and intellectual weakness. When the air is very impure and saturated with ammoniacal vapours, it obstructs breathing, and violently irritates the mucous membrane of the eyes and nostrils.

If these conclusions of Renk were correct, it would follow that the longer these gases are breathed the more would the constitution become undermined, until in the end collapse would take place. However, against this hypothesis the observations of facts and daily experience bear witness ; these teach us that sewer-men, tanners, manufacturers of glue, labourers in manure works, and other workmen, who are forced to live for the greater part of the day in foul air, end by not feeling its noxious influence at all. Instead of getting weaker and weaker, these workmen seem to become gradually immune to the influence of putrid gases; and to this extent, at any rate, Renk's theory cannot be correct.

As is frequently the case, those who shared the views of Soyka and Renk went a great deal farther than their authors, and freely stated that sewer gas is perfectly harmless. In this opinion they were supported by the bacteriological results obtained so far, which seem to be against the probability that sewer air carries the germs of infectious diseases such as typhoid fever.

In September, 1894, the author was invited to read a paper before the German Association of Public Health at Magdeburg, on the "water supply and drainage of houses," in which he very shortly referred to the dangerous character of sewer gas. This gave rise to a discussion, and the impetus given to this question by the author's paper led the council of the association to set the subject down again for discussion at the next yearly meeting at Stuttgart, in September, 1895. The title of the subject was somewhat altered to "Injurious Character of Sewer Gas, and how to keep it out of our Houses"; and two gentlemen (Dr. Kirchner, professor of hygiene at Hanover, and Mr. Lindley, late borough surveyor of Frankfort-on-the-Maine) expounded their theories, which were somewhat similar to those of Soyka and Renk.

The author opened the discussion, which extended over several hours; but in the end the resolutions proposed to the meeting by Messrs. Kirchner and Lindley, and which were as follows, were not accepted by the same:

1. The theory that sewer gas causes such epidemic diseases as typhoid, cholera, and diphtheria, is not in keeping with our present knowledge of pathogenic germs.
2. However, the putrid gases, which are formed in street sewers and house drains, are dangerous to health, not so much directly as indirectly, especially during long exposure, as they cause nausea and tend to lower the general vitality,

and with this reduce the power of resistance of the body against disease.

3. The formation of these gases and their accumulation in the sewers can be reduced to a minimum through proper arrangements, such as regular flushing, cleansing, and sufficient ventilation.
4. Therefore, neither foul water nor air ought to be allowed to stagnate in the public or private sewers, nor should suspended matters be allowed to collect in them.
5. In order to avoid the entrance of noxious gases from the sewers and drains into the air of the subsoil and of our houses, it is necessary that all drains and pipes in, under, and by the side of our houses should be perfectly air and water tight, and that all water-closets, sinks, etc., should be provided with proper traps which are protected against anti-syphonage and evaporation.
6. House drains can only remain permanently efficient if the whole arrangement is simple and can easily be inspected.
7. For these reasons the direct connection of house drains and street sewers is preferable to the disconnecting system, because the latter makes the flushing and ventilation very difficult, necessitates very complicated ventilating arrangements, and causes the accumulation of decomposing matters in the immediate vicinity of our houses.

It will be observed from these resolutions that the meeting was asked to pronounce against disconnecting traps in house drains.

Looking back upon the result of these two years' discussions, the author is of opinion that the conviction is gaining more and more ground on the Continent that the gas formed in the sewers must be excluded from our houses on account of its injurious influence upon health.

In America similar views to those held in this country have always prevailed, and though at times opinions have been expressed that there is no connection between sewer gas and infectious disease, they have not been generally accepted.

The author is not very intimately acquainted with the views generally held in France concerning putrid gases, but he may point out in this place that after very careful consideration, extending over a number of years, the city of Paris has decided to abandon the conservancy methods so far in vogue, and to make a change to the water-carriage principle, and that further, by the new by-laws which came in force on the 8th day of August, 1894, the disconnecting trap has been made compulsory for all houses. Article 15 of these by-laws is as follows:

"Each drain, before it passes out of the house, is to be provided with a disconnecting syphon, the seal of which shall not be less than 2·75in., so as to ensure a permanent and air-tight barrier between the house drainage and the street sewer.

"Each disconnecting syphon is to be provided above the bend with an inspection pipe with air-tight cover.

"The models of these syphons and apparatus are to be submitted to the authorities for their approval."

It may be inferred from this by-law that sewer gas is, in Paris, considered injurious to health.

Concerning Italy, the author has already mentioned that Dr. Alessi has made some very interesting researches (see A-4 and D-2, Appendix I.) into the causal relation between sewer gas and typhoid fever. After a very painstaking enquiry, this observer has arrived at the conclusion that these gases predispose the constitution for the reception of this disease; but as full particulars of these investigations will be given later on, nothing further need be said at this point.

CHAPTER III.

Definition of Terms Used.

It might not be out of place to explain here shortly the meaning of the terms used in this treatise. Such a course might prevent misunderstandings.

The general term of "Putrid Gases" includes all gases arising during the process of putrefaction of organic matters; it therefore includes all the gases forming in sewers, cesspits, vaults, privies, privy middens, ashpits, etc.—in fact, it is the collective description of all gases and combination of gases forming in the decomposition of the matters of the animal and vegetable kingdom which have served for the food and sustenance of man.

The terms "Sewer Air" and "Sewer Gas" are taken in this paper as identical expressions, and denote the air and the gas in sewers or drains. Various writers, and especially some of those who have endeavoured to prove the harmless nature of sewer gas, have made distinctions between these terms, using the term "sewer air" for the air when it is devoid of smell, and the term "sewer gas" for the air when it is charged with noxious smells. Such a distinction is, however, in the author's opinion somewhat arbitrary, as the difference between the two, if it exists at all, is at the best one of degree only. Of course, there is a great deal of difference in this sense between sewer air and sewer gas as far as our nasal organs are concerned, but whether the same difference exists as far as our health is concerned is, to say the least, by no means certain, the weight of the evidence collected so far being apparently against any difference.

The terms "Cesspit Air," "Cesspit Gas," "Privy Gas," etc., will not be much referred to in this treatise, but where they occur they will be used as identical expressions denoting the air in cesspits, privies, etc., which is always more or less charged with gaseous compounds.

The term "Decomposition" shall be generally used only in reference to the process of *complete* oxydation or mineralisation—that is, that process in which the organic matter in the presence of an ample supply of oxygen is converted into such products as water, carbonic acid, nitrous and nitric acids, without the creation of foul smells.

The term "Putrefaction" shall generally be applied only to the process of *incomplete* oxydation—that is, that process in which, in the absence of oxygen, the albuminoid bodies are first peptonised, and then split up into a great number of chemical substances, notably fatty acids, trimethylamine, ammonia, ammonium sulphide, sulphuretted hydrogen, indol, scatol, etc., and under certain conditions also into poisonous alkaloids (ptomaines). This process mostly gives rise to very foul smells which poison the atmosphere.

A rough-and-ready distinction between decomposition and putrefaction is, therefore, the absence or presence of foul smells, although, strictly speaking, it is not quite correct.

CHAPTER IV.

The Present State of our Knowledge of the Changes Fæcal Matters Undergo After Evacuation.

Before considering the causal relations between sewer gas and health, it might be opportune to describe shortly the changes fæcal matters undergo after leaving the body.

It is to be greatly regretted that our knowledge of these changes is still very limited; we know that they ultimately become mineralised through bacterial activity, but we know very little as to the progress and the various stages of this change, as to the kind of bacteria at work, and their life products. This oxydation or mineralisation proceeds quicker and at a more active rate in the pores of the soil than in water, owing, most probably, to the more abundant supply of air, especially in very porous subsoil; and, in fact, all the investigations made so far seem to prove that the amount of oxygen available during decomposition is the most important factor in this process.

In the processes of decomposition and putrefaction of organic matters three different kinds of bacteria may be distinguished, which are subject again to further sub-division—viz.:

1. The aërobes, or those bacteria which, as their name expresses, can only exist and work in the presence of oxygen.
2. The facultative anaërobes, or those bacteria which exist and work in the presence of oxygen, but do not altogether cease work in the absence of this gas; and

3. The anaërobes, or those bacteria which, as their name expresses, can only exist and work in the absence of oxygen.

It will be seen from this enumeration that the facultative anaërobes form the connective link between the aërobes and the anaërobes; and it might be said that the former are the bacteria of decomposition, the latter those of putrefaction.

Concerning the products of activity of these different forms, it is now generally supposed that those formed by the aërobes are more or less harmless, being products of complete oxydation, whereas those formed by the anaërobes frequently contain ammonia, sulphuretted hydrogen, and strong poisons of an alkaloidal nature, being products of incomplete oxydation.

Probably the following is a picture of the process of decomposition, followed eventually by putrefaction: At first the aërobes, assisted to some extent by the facultative anaërobes, carry on the work satisfactorily until the oxygen of the medium becomes more and more consumed, when such products as carbonic acid, water, nitrous and nitric acids, are formed. In this way, the amount of oxygen available is still further reduced, and, if not supplied afresh, the aërobes must cease their work. At this stage decomposition proper ends and putrefaction sets in, frequently accompanied by very foul and injurious smells when the decaying matters are invaded by the hordes of anaërobes, which commence at once their dangerous activity, and continue it until they finally perish in the ever-increasing quantities of carbonic acid, or in other substances of their own making.[1] Then this process may be said to have come to an end.

[1] For particulars of the products of incomplete oxydation see the remarks made in the definition of the processes of putrefaction.

Such, then, is in very general outline a probable picture of the processes which take place when the waste matters of the animal and vegetable kingdom are reduced and split up through bacterial activity. But before it will be possible to give a complete and accurate description, much more will have to be ascertained, and a great many gaps in our knowledge will require to be filled up. Although this is the case, it ought, on the other hand, to be acknowledged with pride that within the last few years much has been done to make us better acquainted with the processes of decomposition and putrefaction; and the knowledge gained, that in the same bacteria play a very important part, has to some extent lifted the veil which covered so long this phase of the cycle which Nature in her marvellous wisdom has ordained for the benefit of mankind.

In passing, it might be remarked that it has lately been established that the process of nitrification in the soil is the work of two separate microbes, of which the first converts ammonia into nitrous acid, whilst the second transforms the nitrous acid into nitric acid.

So far, no mention has been made of the swarms of bacteria which are found in the dejecta even in a fresh condition, their number in the case of a grown-up male having been calculated at 34,000 millions.

Some of these, and perhaps by far the greater portion, do not seem inimical to life, but there are also others which appear of a doubtful nature, and finally those to which a pathogenic character has been attributed. Amongst the latter may be mentioned Koch's comma bacillus (the bacillus of Asiatic cholera) and the bacillus of typhoid fever, which are always found in the stools of those suffering from these diseases. What becomes of these in the process of decomposition has not yet been fully elucidated, but it is frequently held that, by the law of the survival of the fittest, the pathogenic germs, being of a more delicate nature, succumb after a while in the struggle for existence with the swarms of other microbes. How long these pathogenic germs retain their power for mischief is not clearly established, and the most contradictory statements have been made in this respect, but the observations seem to point in this direction, that for about a week or ten days, when in sewage, they may exert their baneful influences.[1]

Even if the products formed by the aërobes should eventually be proved to be perfectly harmless, it will be clear from the foregoing remarks that it must be the aim of all true sanitation to remove these waste products as quickly and as completely from our surroundings as possible, so that even in the absence of pathogenic germs putrefaction may not take place in the vicinity of our dwellings, with all its attendant evils in the form of dangerous gases, ptomaines, etc. Experience has over and over again proved the wisdom of such a course.

[1] See also the remarks in Chapter VI.

CHAPTER V.

The Conservancy and the Water-Carriage System.

In these days, when the sanitary advantages—not to mention the pecuniary and administrative advantages—of the water-carriage system over any other system appear to be almost universally recognised, it might seem sheer waste of time to compare it—even though it be but very briefly—with the conservancy methods; but as voices are still heard from time to time in ardent support of the latter, it may not be out of place to make here a few remarks concerning this subject.

In the conservancy methods all fæcal matters remain in the house or on the premises for more or less time, during which they have a chance to do mischief, and undoubtedly putrefactive changes have set up in them before they are removed. But it has been shown above that it is just those changes which we ought to avoid taking place in our surroundings, and that the excreta ought to be removed from our houses, as soon as possible after evacuation, in a fresh condition.

Further, it is frequently found that the various forms of application of the conservancy system, especially such as cesspits, vaults, privies, and privy middens, were constructed a great many years ago—long before the sanitary importance of these arrangements was fully understood—and are consequently very defective; hence they afford frequently readier means for the systematic pollution of soil, air, and water than drains and sewers, which are, comparatively speaking, of more recent date.

However, it might be said that the forms of the conservancy systems just mentioned—cesspits, vaults, privies, and privy middens—are happily dying out, and that against the only form remaining in this country—viz., the tubs or pails—no such accusation could be sustained. In support of this, comparisons might and have been made between the death rates in towns with the tub and in those with the water-carriage system, and conclusions drawn therefrom that, so far as the public health is concerned, no difference exists between the two systems. But in the author's opinion such comparisons between towns and towns ought only to be undertaken with the greatest care—otherwise, owing to the many points of difference between them, the conclusions will be worse than useless and only misleading, and it will generally be better and more reliable to compare with each other different parts of one and the same town where tubs and sewers exist. This has lately been done, and, for instance, in Leicester, Newcastle-upon-Tyne, and Birmingham, observations have been made as to the bearing of tubs and water-closets upon the prevalence and spread of typhoid fever.

For Leicester[1] it has been shown that the number of typhoid-infected houses is greater in those districts where the fæcal matters are collected in tubs than in the sewered portions of the town. Further, during a local epidemic in Navigation-street in 1894 the number of typhoid-infected houses with tubs was five times as large as the number of infected houses with water-closets.

Similar experiences are reported by the medical officer for Birmingham,[2] who states that in 1894 the typhoid incidence was 1½ times as great in houses with pails as in houses with water-closets, and that, as regards second cases, one occurred in every 14 houses

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[1] See "Public Health" for May, 1895, pages 280 to 285.
[2] See "Public Health" for May, 1895, pages 280 to 285.

with pails, but only in every 22 houses with water-closets.

Dr. H. E. Armstrong mentions that in 1894 enteric fever was twice as prevalent in Newcastle-upon-Tyne[1] in households on the pail-closet system as in households on the water-closet system.

The author does not know whether similar facts have been observed in other towns, but at any rate it will not be disputed that these figures cannot be quoted in recommendation of the last remaining form of the conservancy system.

Apart from this, it ought not to be forgotten that nearly all towns in which this system is still in vogue are experiencing the greatest difficulties with the disposal of the excreta, and that these difficulties have become so accentuated in the last few years, that towns like Glasgow, Manchester, Birmingham, Nottingham, Leicester, etc., have decided to abandon the pail system altogether, and establish the water-carriage principle pure and simple, although they had previously expended great sums of money in introducing the former.

In passing, the author would also mention here that, in a report lately issued by the medical officer of health for Nottingham, and which deals with 78 towns, the following passage occurs (see "Report on the Conservancy and Water-Carriage Systems," by P. Boobyer):

> "One note of encouragement to us at the present juncture, running through almost all the answers I have received, is the very general and growing discontent with the so-called conservancy systems, from whatever standpoint they are viewed. In only four of the towns on my list (78 towns in

[1] See "Public Health" for May, 1895, pages 280 to 285.

all)—Hull, Rochdale, Warrington, and Darwen—is their continuance openly advocated in any form."

If attention is now directed to the water-carriage system, it has been stated that it does not completely remove the fæcal matters, but deposits portions of them on the sides and bottom of the sewers and drains, and that especially house drains are great offenders in this respect. In fact, it was stated on the Continent two years ago with great pertinacity, as an argument against disconnecting traps, that house drains were, as a rule, in a much fouler condition than the public sewers in the streets.

The author's own experience is opposed to this statement concerning house drains; and although he has known foul house drains, yet in the majority of cases, where they were of modern construction and under rational and intelligent supervision, he has frequently found them entirely devoid of smell and deposit.

Apart from the consideration that the quantity of fæcal and other matters passing through house drains is considerably smaller than that carried away in a main sewer, it needs no great effort to see that house drains can be kept in a clean and sanitary condition with much less trouble than street sewers. There are, further, plenty of means to attain this end, amongst which a systematic ventilation, a good automatic flush from water-closets, and a careful supervision, may be mentioned.

There would, therefore, appear to be no reason why house drains should still be permitted to remain in a very foul condition, and the author cannot help thinking that where this state of things—which perhaps might be called antiquated—still is the order of the day, the authorities have been somewhat soundly asleep, and require waking up a little in reference to house-drainage requirements.

Concerning street sewers, it cannot be gainsaid that, especially in the early days of sewering, great mistakes were committed, as it was sometimes thought that anything in the nature of a hollow underground passage would do; but, thanks to the untiring and well-directed efforts of Sir Robert Rawlinson, such ideas have long been abandoned, and in a system of sewers constructed according to modern notions but comparatively little chance is given to the fæcal matters to deposit in the sewers and gradually fill them up.

However, this must not be misunderstood as if it was impossible for gases to form in modern sewers. All those intimately acquainted with the subject know, of course, that it is not possible to prevent the formation of gas altogether, and that all that can be done is to reduce the chances favourable to these formations to a minimum.

A very sad instance of the truth of this happened on July 1, 1895 (see A-25, Appendix I., and 10, Appendix VII.), at East Ham, near London. In this case five men lost their lives in a sewer which, as the surveyor stated at the inquest, had not been at work for more than 3½ years, the sewerage of the district having only recently been carried out.

Although the formation of dangerous gases cannot be altogether avoided in modern systems of sewers, there is absolutely no need for the gases when formed to enter our houses, as we possess plenty of means to prevent this, perhaps the most effective of them being the keeping of each house drain clean and sweet, and its disconnection from the street sewer.

It will be clear from all the foregoing remarks that the water-carriage principle possesses a great many advantages over the conservancy methods; and, further, it may safely be concluded that the gases formed in privies, cesspits, etc., are, owing to their concentrated nature, considerably more dangerous than those formed in street sewers, especially if the latter are well ventilated.

CHAPTER VI.

Notes on the Etiology and Epidemiology of Typhoid Fever.

It may not be out of place before going further to make a few remarks at this point concerning the causation of typhoid fever.

Although, as previously stated, a great many diseases have at one time or other been traced to sewer gas as their cause, such as typhoid or enteric fever, diarrhœa, dysentery, diphtheria, scarlet fever, erysipelas, cholera, malaria, yellow fever, puerperal fever, hospital gangrene, inflammation of the lungs, gastro-enteritis, etc., it will not here be necessary to refer to any other but typhoid or enteric fever, as the connection between sewer gas and the other diseases is not sufficiently elucidated.

It will not be attempted in the following notes to deal minutely with the etiology and epidemiology of typhoid fever, as such a course would be out of place in this treatise, and would also lead too far, this being a question on which volumes and volumes have been written. Conflicting opinions have been put forward and defended with great pertinacity, and the fight around them has frequently been very severe. To those who were not in the front line of battle, it has not always been an easy task to wade through a very voluminous literature, especially as not only the conclusions but also the observations leading to them have been challenged and contradicted by each opposing side. What is received with exultation to-day is to-morrow put into shade through a new investigation; and although the severe fight has this advantage that it is conducted on all sides with great skill and astuteness, which in the end is sure to lead to the full truth being found out, yet it seems that at the present time we are still far from that goal.

It has already been stated on a previous page that about the middle of the present century abdominal typhoid was considered to be the result of a putrid process. Murchison and others held that putrefying substances were the specific cause of this disease, and that it could be generated spontaneously by their emanations, such as sewer gas.

A little later the idea was gradually gaining ground that infectious diseases were caused through a specific contagium animatum of a parasitical nature, and it cannot be surprising, therefore, that Murchison's theory was strongly assailed by Budd, who maintained that putrid gases were capable only of producing typhoid fever in the presence of a specific exciting cause.

It was then suggested that this specific contagion or germ was probably spontaneously generated in putrid gases, which were afterwards able to spread this disease.

A host of other theories were propounded, but it would lead too far to mention them here; suffice it to say that it required a great deal of very skilful labour to prove that William Harvey's great word, "omne vivum ex ovo," was as true for the world of large animals and plants as for the world of the most minute beings.

Although by no means universally accepted, it is now generally held that the typhoid-exciting cause is the bacillus typhosus, a microbe which was discovered probably by Eberth, Koch, Meyer, and Gaffky.

Another theory has also been advanced, according to which the bacillus typhosus is not the cause, but the product, of the disease, the latter having converted the harmless bacterium coli into the pathogenic typhoid germ; but it would appear as if this theory was not supported by the results of bacteriological investigations up to the present time, which seem to show that the microbes of infectious diseases are specific germs which spring from their like and only create their like. At any rate, for the purposes of this treatise, it shall be assumed that the exciting cause of typhoid or enteric fever is the typhoid bacillus of Eberth and Gaffky.

A great deal has been written about this bacillus, and the most contradictory opinions concerning it have been advanced by different observers, which is no doubt due to the fact that the identification of the bacillus typhosus is a matter of some considerable difficulty, as there are other bacilli, such as the bacillus coli communis, a normal inhabitant of the intestines, which are very much like it, and which have often been erroneously taken for it. Therefore the published results must be received with caution. But allowing for this, the following facts appear to be somewhere near the truth.

The bacillus typhosus is found in the stools and urine of typhoid patients, and retains its vitality in them for a considerable time—according to Uffelmann, several months. But sewage does not appear to be quite such a favourable medium, as it would seem that this bacillus loses in it its power of mischief after a period ranging probably from one to two weeks. The experiments concerning the vitality of the germ in well and river water have given very different results, but it would appear that it may live in these media for several months. It appears to be less sensitive to acids than to alkalies, and Liborius has shown that it can exist without oxygen. It seems to perish tolerably quickly under the influence of direct sunlight, but retains its virulence in soil for some considerable time. A temperature of 60° C. = 140° F. will kill it within 10 minutes, but it seems to be able to withstand a temperature of − 10° C. = 14° F. for a considerable time even during alternate melting and freezing. Dunbar states in reference to the tenacity of the typhoid bacillus, that it does not make great demands on its nutritive medium; and that even without forming lasting spores, it manages to maintain itself in our climate outside the human body and to survive the winter.

Concerning the media through which this bacillus is disseminated, it seems now established that it may be carried in the air in fine dust particles, in the water, and milk. Other means of distribution are linen, clothes, dirty hands, instruments, etc.

Before proceeding to investigate the composition of sewer air and the germs contained in the same, the author thinks it will be more convenient to mention first some of the forms in which sewer gas has exerted an injurious influence upon health. In doing so, frequent references will be made to the appendices, in which full particulars of the various cases mentioned are given, as such a course will be more convenient than to have embodied these latter in the treatise itself.

PART II.

Observed Cases of Injury to Health from Sewer Gas.

CHAPTER I.

Cases in which Outbreaks of Typhoid Fever have been Traced to Sewer Gas.

(See also Appendix IX.)

In Appendix IX. the author has mentioned first Buchanan's historical cases at Worthing in 1865, in Caius College, Cambridge, in 1874, and at Croydon in 1875, and has then given a number of other cases, such as the outbreak in 1880 at Melton Mowbray, in Sherborne in 1882, and in York in 1884, all of which have, after careful examination, been held to have been caused by the emanations from the sewers.

Further interesting cases are the outbreaks of enteric fever at the Foundling Hospital, St. Pancras, in 1891, which was very carefully investigated and reported upon by the medical officer of health for St. Pancras (Dr. J. F. J. Sykes), and at the Leeds Fever Hospital.

In Germany, too, several outbreaks of typhoid fever have been attributed to sewer gas, and the late Dr. Uffelmann, professor of hygiene at Rostock (B-60, Appendix I.), perhaps one of the most careful and painstaking observers and investigators, maintained that houses into which sewer gas entered periodically were frequently visited by diphtheria, malaria, and typhoid fever. At the meeting of the German Association of Public Health in 1895, the late Dr. Goepel (B-23, Appendix I.) reported a very interesting case from

Frankfort-on-the-Oder, where in a house the typhoid fever ceased after the pipe through which the sewer gas entered it had been seen to. Dr. Lissaur (see B-36, Appendix I.) also reports an interesting case of typhoid fever from Dantzic.

A great many other cases might have been quoted, as there is no lack of them, but the author does not consider it necessary to go beyond a few typical instances. Those who deny the existence of a connection between sewer gas and typhoid fever are bound to assume that all the numberless trained and untrained observers, who have pronounced in favour of this connection, have made serious mistakes both in their observations and conclusions.

In some of the outbreaks mentioned above, those who investigated them attributed the cause to the inhalation of sewer gas, whereas in others it was thought that sewer gas polluted the water supply, and thus brought about the epidemic.

It will not be attempted here to explain the relation between sewer gas and typhoid fever, as there will be a special opportunity for this later on, but it might be pointed out that the sewer-gas theory has been taken advantage of to such an extent as to bring it practically into miscredit. It has been attempted to explain cases by it in which sewer gas seems to have played no part whatever, and this over-zeal on the part of some indiscreet advocates has been utilised by the opponents to hold the whole theory up to public scorn and ridicule. But be that as it may, the fact is now generally admitted, even by those who look upon sewer gas as comparatively harmless, that putrid gases and typhoid fever are frequently found side by side, and it is important to clearly bear this in mind in the future remarks.

CHAPTER II.

Notes on the Coincidence between Typhoid Fever and Faulty Drains, as Demonstrated by the Smoke and Other Tests.

(See also Appendix XI.)

In support of the facts just mentioned, it might not be out of place to refer here shortly to the experience gained in several towns as to the relation between defective drainage and typhoid fever.

Formerly it was not always possible to prove the entrance of sewer gas into our houses, but now, since the introduction of the smoke, hydraulic, and scent tests, such a proof is, comparatively speaking, an easy matter.

In this connection the author would like to point out that the smoke test is not under all circumstances a completely reliable test, as there are cases, especially of underground leakage, which can only be demonstrated by the hydraulic test. In his own experience the author has had cases where, suspecting defects, he could not discover them with smoke, although he made repeated trials, and where he only succeeded in localising them after the application of the hydraulic test. It would, therefore, be incorrect to conclude that in all cases where the smoke test has shown no defects, sewer gas could not possibly find its way into the interior of the house, and in such a case, if necessary, recourse should be had to the water test.

In Appendix XI. the author has given the observations made at Leicester, Bristol, Hornsey, and Leeds. He would have been glad to have been able to add to these those made in other towns, but they were not in his possession.

In Leicester the percentage of all typhoid-infected houses with defective drainage, as ascertained by the smoke test, was 31·25 per cent. in 1893, and 45·18 per cent. in 1894.

For Bristol reports the medical officer of health that during the five years 1890 to 1894, 29·38 per cent. of 548 typhoid-infected houses showed drainage defects on the application of the smoke test.

In Hornsey, there were nine typhoid-infected houses tested with smoke between 10th August and 30th December, 1893, all of which showed drainage defects. In 1894 the number of typhoid-infected houses with drainage defects was 19.

Particular mention deserve the interesting observations made by Dr. J. Spottiswoode Cameron, the medical officer for Leeds, in connection with the testing of the drains of 1,121 houses in which typhoid or diphtheritic disease was supposed to be present, and 30·51 per cent. of which were found to have faulty drainage arrangements. For full particulars see 4 of Appendix XI.

The author is of opinion that the statistics just quoted support the statement previously made, that putrid gases and typhoid fever are frequently found in close proximity.

CHAPTER III.

Birmingham Sewer-Gas Case.

(See also Appendix IXa.)

A case of blood-poisoning by sewer gas was tried in August, 1896, at Birmingham before Mr. Justice Collins, and as it contains many interesting points, the full report of the trial, together with two sketches taken from the *Contract Journal*, are given in Appendix IXa.

The executors of the late T. H. Smith brought an action against the King's Norton Urban District Council for damages for his death, caused, as they alleged, by sewer gas, and the judge gave judgment for £2,875 against the District Council.

A case of diphtheria attributed to cesspit gas, in which damages to the extent of £50 were awarded by Mr. Justice Wills, is also given in the appendix above referred to.

CHAPTER IV.

Mephitic Poisoning through Sewer Gas.

(See also Appendix VII.)

It is well known that gases such as ammonia, carbonic oxide, carbonic acid, and sulphuretted hydrogen—which are frequently found in sewer air—are highly poisonous, and have, in consequence, when inhaled, an injurious influence upon health, the degree of which seems to depend on the amount so taken into the system. If the dose is small, then the poisoning is of a mild form; but if the dose is large, then the poisoning is frequently very acute, and instantaneous death may be the result.

It will not be necessary here to dwell upon the nature of this injurious influence; it will suffice to say that this influence is universally admitted.

In the further remarks, therefore, the mild form of poisoning will be distinguished from the severe or acute form.

A. Mild Form of Mephitic Poisoning through Sewer Gas.

The effect which the breathing of small doses of sewer gas has upon the constitution varies considerably. It is generally more marked in persons of weak health, in persons suffering or recovering from illness, in women and children than in men. The following disorders have been attributed to this cause: languor, loss of appetite, vomiting, diarrhœa, colic, prostration, headache, malaise, insomnia, and feverishness. Children seem to feel the effects of the inhalation of sewer air most—

they lose appetite, become pale and languid, and suffer from diarrhœa.

If the inspiration of sewer gas is allowed to continue for some time it may lead to the chronic derangement of the digestive and nutritive systems, to anæmia, nervousness, neuralgia, etc., and, by lowering the vitality, will reduce the power of resistance of the body to injurious influences from outside. In this way the prolonged action of sewer gas tends to render the constitution more perceptible to the entrance of pathogenic germs ; and the causal relation between sewer gas and typhoid fever has been explained in this way; but the author is inclined to think that such an explanation is only partially correct.

This action of sewer gas has frequently been attributed to carbonic oxide, carbonic acid, ammonia, and sulphuretted hydrogen ; but as this subject will later on be referred to in detail, it will not be necessary to say more at the present stage.

Further particulars concerning the mild form of mephitic poisoning are given in Appendix VII.-11, where, according to Hankel, the mild form, the fairly severe form, the severe form, and the chronic form are distinguished.

B. Severe Cases of Mephitic Poisoning through Sewer Gas.

There are a great number of cases of acute poisoning through sewer gas on record, but as they are scattered about in the literature of several countries, the author has given some of them (10) in Appendix VII. for convenience of reference. It must, however, be borne in mind that the cases mentioned do not by any means comprise all those reported in the papers, as probably the yearly number of deaths from this cause in all countries is considerable.

In most cases of acute mephitic poisoning death is practically instantaneous, the victim perishing through asphyxia. Some observers have attributed this to the presence of carbonic acid, others to that of sulphuretted hydrogen in sewer air.

A very severe and at the same time very sad case of mephitic poisoning happened on the 1st July, 1895, at East Ham, near London, in which five sewermen lost their lives. (Appendix VII.) The widow of one of the men brought an action against the Urban District Council, and at the second trial—the Court of Appeal having granted a fresh hearing of the case, as Mr. Justice Cave had non-suited the plaintiff in the first trial—judgment was given for the plaintiff, with £225 damages.

Another recent case is that mentioned by Hankel, where a plumber perished in thawing up a frozen water-closet. (Appendix VII.-12.)

It is very disappointing that the post-mortem examination in both cases was not able to throw further light upon the cause of death.

CHAPTER V.

Health of Sewermen.

(See also Appendix VI.)

In connection with this subject it will be necessary to make a few remarks about the health of sewermen, as they have frequently been quoted in support of the harmless character of sewer air. (See Appendix VI.)

It is greatly to be regretted that the statistical information concerning the health of sewermen is generally very incomplete. No proper continuous records appear to have been kept anywhere, and, when required, facts and figures have had to be collected probably years after the dates to which they refer, and that, too, in a somewhat haphazard manner. The results of such enquiries are therefore in most cases not based upon a proper system of notification, and must be received with a certain amount of caution.

Further, the information generally only deals with the workmen whilst employed in the sewers, but gives no clue as to their health after leaving this employment, which, of course, is a point of the greatest importance when considering the influence of sewer gas upon health.

The information in most cases also refers only to the days lost through sickness, but does not give any idea as to the state of the health of sewermen before actually becoming unfit for work.

In the case of the Munich sewermen, for instance, the information collected by Prausnitz (see Appendix VI.-5) goes to show that out of the total number of 42 men so employed, 43 per cent. remained on an average only 20 months in the sewers. It would have been very interesting to ascertain the cause of this, and whether their state of health compelled the workmen to leave this work.

With these reservations the author agrees with the generally expressed opinion that workmen connected with fairly well ventilated sewers do not show any excess of sickness. The same can, however, not be said of those who have to work in ill-ventilated sewers, as they seem, according to Gaultier de Claubry and Hankel (Appendix VI.-3 and 4 and Appendix VII.-11), to suffer in their health from the evil effects of the gases they encounter, asphyxia being a common disease amongst them.

Complaints of sore throats and rheumatic affections seem to be pretty common amongst sewermen, but the opinion of Murchison and Peacock, that typhoid fever was not uncommon among them, does not seem to be supported by the experience of other observers.

Further particulars concerning the health of sewermen are given in Appendix VI.

CHAPTER VI.

Septic Poisoning through Sewer Gas.

(See also Appendix VIII.)

Cases have from time to time been reported in which food that had been exposed to sewer gas has caused illness in those who have partaken of it.

A very remarkable and interesting case of this kind has quite lately been reported by the medical officer of health for Sutton Coldfield, near Birmingham, full particulars of which are given in Appendix VIII.-1.

In this instance, soup, which had been gratuitously distributed, appears to have caused a sudden outbreak of poisoning amongst about 100 persons at the end of 1894. Dr. Bostock Hill in vain endeavoured to trace the poison in the soup and its source, and finally, after one patient had died, he sent a portion of it to Dr. Klein for bacteriological examination, who summed up his report as follows:

"In conclusion, from the foregoing observations, the following conclusions can be drawn :

"1. The soup contained microbes which were derived from sewage, and it is thereupon highly probable that the soup had been polluted with sewage. Amongst the microbes present in the soup, the bacillus mentioned as a variety of the bacillus coli is possessed of virulent properties on account of its extremely rapid multiplication at the body temperature, and the poisonous substance it elaborates. It is most probable that this microbe caused the consumers of the soup the ill effects

> and the disease. This bacillus, it will be remembered from the foregoing paragraph, was present in the soup in enormous numbers."

The soup had been prepared in an outhouse of an hotel in an iron boiler, which was under the same roof as a stable, and only separated from it by a wooden partition in which there was a door. On the floor of the stable there was a drain grating, and at the end of the outhouse, near the boiler, ran up the ventilating pipe of the house drain, while about 20ft. away and up the side of the hotel itself, there was a large ventilating shaft connected directly with the main road sewer. This latter sewer was notoriously a very stinking one, and to obviate the nuisance caused by it to residents and to those travelling along the road, the crown ventilator at this point had been stopped up, and, by permission, a large 6in. ventilating shaft erected against the wall of the hotel. Dr. Bostock Hill relates that offensive gases had been given off by this ventilating shaft, and the proprietress of the hotel had complained that foul smells had been noticed in a room close to where it was fixed.

The soup had been allowed to stand in the boiler for about 18 hours, including one night, and it is just possible that during this time or in the operation of its distribution to the poor it became polluted by sewage, either by handling it with dirty fingers or in some other way; but Dr. Hill is evidently not of this opinion, as he sums up his interesting report as follows:

> "I have previously remarked that the night was a cold one, so that the sewer gas coming from the top of this shaft would become heavier as it cooled, and would thus tend to sink lower in the atmosphere; and my belief is that this sewer gas

> in question did gain access to the outhouse by way of the chimney, and that in this way the soup was contaminated with those micro-organisms which were found by Dr. Klein. I do not by any means lay this down dogmatically, but after a very careful consideration of all the local circumstances, I see no method more likely of contamination of the soup with the micro-organisms of sewage."

It is by no means an uncommon thing that the gases escaping from the top of a ventilating shaft descend again, and the author has frequently made the same observation when testing drains with smoke.

The medical officer of health for Coventry also reports two similar cases of poisoning.

Further particulars will be found in Appendix VIII.

CHAPTER VII.

Explosions in Sewers and Cesspits.

(See also Appendix V.)

Now and again cases are reported in which explosions are said to have happened in sewers and cesspits, and the author has mentioned three such cases in Appendix V.

There is but little doubt that in some of these coal gas was the cause of the explosion, but in others the presence of hydrocarbons, such as marsh gas, which are formed in the decomposition of organic matters, may account for it.

After having now dealt with the effects sewer gas has upon health, it becomes necessary to examine into the cause of this.

PART III.

Contents of Sewer Air.

CHAPTER I.

Poisonous Gases Contained in Sewer Air.

(See also Appendix II.)

The quantity of gas that can be formed by a given quantity of fæcal liquid has been variously calculated by different observers.

Concerning the air in cesspits, Lévy (see C-3A, Appendix I.) mentions an analysis, which shows a reduction of oxygen by 2 per cent. and an increase of carbonic acid by 4 per cent. over the normal state.

Erismann made experiments in the Hygienic Institute at Munich, and came to the conclusion that 1,000 gallons of cesspit contents, consisting of human dejecta and urine, were capable of developing the following quantities of gas in 24 hours:

Table I.—Poisonous Gases in Cesspits.

Carbonic acid	315·0	gallons, or about		43,376	grains.
Ammonia	149·0	,,	,,	7,912	,,
Sulphuretted hydrogen ...	1·2	,,	,,	140	,,
Hydrocarbons and volatile fatty acids	579·0	,,	,,	29,124	,,
Total quantity of poisonous gases	1,044·2	,,	,,	80,552	,,
	Equal, say, 11·5lb.				

It will not be denied that these are very considerable quantities of some highly poisonous substances.

Parent Duchâtelet found the air in a choked-up sewer in Paris to contain in 10,000 volumes only 1,379 volumes of oxygen, and as much as 299 volumes of sulphuretted hydrogen.

Gaultier de Claubry, who also examined the Paris sewers, states that the minimum amount of oxygen in 10,000 volumes of sewer air was 1,740 volumes. On an average he found that sewer air contained in 10,000 volumes 230 volumes of carbonic acid and 81 volumes of sulphuretted hydrogen, whilst the greatest amounts met were 340 volumes of carbonic acid and 125 volumes of sulphuretted hydrogen.

It may fairly be assumed that the foregoing analytical results were chiefly obtained in old sewers, which, perhaps, had not been constructed according to proper principles. At any rate the analysis of the air in sewers of more recent date do not show such an alarming amount of poisonous gases.

Letheby, who examined the air in some of the London sewers, states that it contained 53·2 volumes of carbonic acid in 10,000 volumes, a considerable amount of ammonia, and traces of marsh gas and sulphuretted hydrogen; he also calculated that a gallon of sewage containing 128·8 grains of organic matter, when excluded from air, gave in "nine weeks 1·2 cubic inches of gas per hour, consisting of 73·833 per cent. of marsh gas, 15·899 per cent. of carbonic acid, 10·187 per cent. of nitrogen, and 0·081 per cent. of sulphuretted hydrogen."

Russell, who also analysed the air of some sewers in Paddington, found it to contain 51 volumes of carbonic acid, 2,070 volumes of oxygen, and 7,880 volumes of nitrogen.

Carnelley and Haldane state that the air in the sewers at Dundee and Westminster Palace contains on an average only 7·5 volumes of carbonic acid in 10,000 volumes, but in the Bristol sewers this amount ranged from 9·1 to 20·7.

Laws, who in 1892 made a series of analyses of London sewer air, states that in a normal state it contained on an average in 10,000 volumes 8·95 volumes of carbonic acid; in the case of the Fulham-road sewer, however, this amount reached the abnormally high figure of 93·10 volumes.

The Munich sewers contain, according to Beetz, on an average in 10,000 volumes of air 31·4 volumes of carbonic acid and 2·2 volumes of ammonia.

Lévy and Miquel, who now periodically examine the air in the Paris sewers, state that on an average of their observations between 1891 and 1893 it contained in 10,000 volumes only 4·8 volumes of carbonic acid and 1·2 volumes of ammonia.

Further particulars are given in Appendix II., where also, for convenience of reference, some analyses of the gases dissolved in raw sewage and of the vapours in disused and unventilated cellar dwellings are given.

From these analyses it is clear that the air in modern, well-constructed, and well-ventilated sewers does not contain the same amounts of poisonous gaseous substances as that in old and foul sewers. It is clear therefore that to a very large extent the state of the air in any one particular sewer depends on the state this sewer is in. If it contains no deposits and is well ventilated, we may very properly assume that in most cases the air contained in it will also be comparatively free from gas; but if, on the other hand, it is very foul and badly ventilated, then most probably its air contains a very high percentage of these dangerous mixtures. Hence it must be the aim of all those who design and superintend sewers to see that ample provision is made for the fulfilment of these two essential conditions: no deposits and an ample supply of fresh air; for it will not be denied by anyone that in the absence of deposits the formation of gases in them will not be great, and that the safety against the nefarious influence of gaseous mixtures lies in their ample dilution. How these two requirements can best be carried out in a sewerage system is outside the scope of this treatise, but the author is afraid of late a tendency has set in not to provide for the dilution of the gaseous mixtures, but only for their escape in cases of need, overlooking at the same time that under pressure these gases will escape at the point of least resistance, whether that be through the appointed channels or through house drains, water seal of traps, etc. The author has lately examined a system of new sewers in which the provision for ventilation was totally inadequate, hence each manhole, forming, as it were, a dead end for the accumulation of gas, emitted a most horrible stench of sulphuretted hydrogen on the cover being removed.

In considering this subject it is necessary to bear in mind that normal atmospheric air contains on an average in 10,000 volumes only three volumes of carbonic acid, 2,090 volumes of oxygen, and 7,910 volumes of nitrogen, and that in the case of sulphuretted hydrogen, from 10 to 12 volumes of this gas in 10,000 have been considered a rapidly fatal dose.

The question of the organic vapour in sewer air need not be discussed here, as it will be referred to later on in connection with the experimental researches of Dr. Alessi.

These few remarks must suffice to show that the gaseous mixtures in sewer air are of a highly poisonous nature, which will exert a powerful influence upon health if they are allowed to accumulate; and there can be little doubt that the cases of mephitic poisoning mentioned in a previous paragraph (see also Appendices VI. and VII.) were due to this cause. Although in modern sewers with good supervision the formation of such gases as carbonic oxide, carbonic acid, sulphuretted hydrogen, ammonia, volatile hydro-carbons, and fatty acids may be to a very large extent avoided, it ought not to be assumed that their formation is altogether an impossibility, as the sad case at East Ham on the 1st July, 1895, painfully demonstrates; even their entrance under pressure into our houses is by no means excluded, as the sad case reported from Glauchau by Hankel on the 18th January, 1895, proves.

CHAPTER II.

Micro-Organisms in Sewer Air.

(See also Appendix III.)

The introduction of methods enabling us to study the micro-organic life in air is of comparative recent date, hence it follows almost as a corollary that they are still somewhat crude, and that our knowledge concerning these micro-organisms is still far from perfect. The author is far from wishing to underrate the value of the present methods for the examination of air, but, on the other hand, as it is by no means an uncommon thing to hear opinions expressed in a way as if these methods were infallible, he thinks it is but right to call attention to their comparative primitive character. In support of this the almost daily improvements may be quoted which tend towards the exclusion of accidental errors and errors inherent to former methods, and which entitle us to the hope that ultimately we may ascertain the true state of the air around us and in our sewers. But how soon this goal will be reached, or how near we are to it, is impossible to say; sometimes it seems a long way off yet.

It is necessary, therefore, in dealing with the subject of the micro-organic life in sewer air, to make due allowance both for our imperfect methods of investigation and our incomplete knowledge.

So far as known to the author, about six sets of investigations into the bacterial flora of sewer air have within recent years been made in various towns, as is shown in the following table:

TABLE II.—Investigations into the Micro-organic Life in Sewer Air.

No.	Name of Observer.	Sewers in which Investigations were made.	Year of Investigations.
1	Lévy and Miquel ...	Paris sewers.	Periodical investigations commenced in 1891, and continued since.
2	Petri	Berlin sewers.	—
3	Uffelmann	—	—
4	Smith	Sydney sewers.	1893.
5	Carnelley and Haldane	Sewers at Dundee, Westminster Palace, and Bristol.	1887.
6	Laws and Andrewes	London sewers.	1892-1894.

In Appendix III. full particulars of each set of investigations are given, and on reference to this place it will be seen that in the main points the various observers practically agree. These for convenience of reference may be stated as follows:

1. The number of germs in sewer air is small and less than in outside air. Whereas outside air contains on an average 15 germs per litre, sewer air has not more than from two to nine germs per litre. Only in the case of the Sydney sewers was a considerably higher number found, ranging from 7 to 2,260 germs per litre.[1]
2. The micro-organisms of sewer air are related to the micro-organisms in the air outside the sewers, but not to the micro-organisms of the sewage.
3. The only pathogenic germ found up to the present in sewer air is the staphylococcus pyogenes aureus, the cause of suppuration, which was identified by Uffelmann B-30, Appendix I.)

The results of their investigations having so far,

[1] 1 litre = 1,000 cubic centimetres (ccm.); 1 ccm. of sewage contains frequently 5,000,000 germs, and at this rate 1 litre of sewage would contain 5,000,000,000 germs.

apparently, demonstrated the absence of pathogenic germs, with the exception of the germ of suppuration, various observers endeavoured to find out experimentally whether there was a possibility of the pathogenic germs being separated from the liquid, and then carried away by the air currents prevailing in sewers.

They therefore tried to ascertain whether these germs could pass into the air from the liquid under the following conditions:

a. Under ordinary circumstances;

b. Through the bursting of bubbles;

c. Through splashing; and

d. From the slimy surface of the sewers;

and whether the germs, after passing into the air, could remain suspended there for some time and be carried away by the current.

Naegeli has shown that it is not very likely that germs pass under ordinary circumstances from a wet surface into the air B-39, Appendix I.)

Prof. Frankland (A-28, Appendix I.) has shown that the bursting of bubbles disseminated particles of lithia solution, and, therefore, presumably micro-organisms. Carnelley and Haldane made laboratory experiments which completely justified Frankland's inference; and the possibility, therefore, exists that germs can thus pass from the sewage into the air. But it is urged that in those places in the sewers where, through the formation of gas, bubbles rise to the surface of the liquid and burst, it is hardly likely that pathogenic germs, even if they are present, will retain their virulence for any length of time, as it may safely be assumed that here the sewage swarms with immense numbers of saprophytes, and that in the struggle for existence with these the pathogenic germs will soon perish.

Hence the probability that germs could thus be disseminated could not be considered great.

Concerning splashing, Carnelley and Haldane have observed in several cases in sewers that it disseminates germs from the sewage. These results were corroborated by their laboratory experiments, and they therefore came to the conclusion that large numbers of germs may be thrown into the air in this way. Laws states that it has been shown by some observers "that if the splashing is sufficiently violent to produce a very fine state of division of the sewage, organisms will be carried some distance, even 50 to 60 yards." He concludes therefore that splashing, such as is caused by a house drain discharging its contents into a sewer through an opening in its crown, should not be permitted. From his own experiments it would follow that sewage, falling from a branch drain into an egg-shaped sewer 11ft. high by 9ft. wide from about the middle of its height, produces practically no effect upon the number of micro-organisms in the sewer air.

It has been stated that the slimy skin, which is practically a thin layer of bacteria, and which lines the inner walls of a sewer, cannot give off germs, as it cannot get sufficiently dry owing to the moisture contained in sewer air, the latter being always for its temperature sufficiently saturated with aqueous vapour. This seems to be supported by the experiments of Laws in London and Ficker in Breslau. Laws made his experiments on an experimental 9in. sewer of 80ft. in length, but, of course, it might have been that the period allowed for his observations was not long enough to form a skin of the same thickness and consistency as is formed in sewers which have been at work for 20 years and more. At any rate he states:

"It is really remarkable to find that no organisms are given off from the walls of a sewer which has been empty and open to the air at both ends for such a lengthened period as 12 days. The sewage with which the sewer had been kept full for several periods of 24 hours would contain no less than three to four million organisms per cubic centimetre, and immense numbers of these must of necessity have been clinging to the walls of the sewer. . . . The velocity of the air current used in the above experiments was 5ft. and 15ft. per second respectively, the latter being far in excess of any current that would normally obtain in a sewer."

Ficker remarks that in his experiments in the Hygienic Institute at Breslau a current of air, with a velocity of several metres per second, was not able to lift up specific germs from half-moist soil, and that a current of the same strength was not capable of carrying away germs which had dried on several substances and adhered to them.

Various experiments have been made with a view to ascertain how far germs can be carried away by air currents in pipes and sewers. Hesse, who first investigated this point, took a 2in. glass tube about one yard long, the inside of which he had covered with a layer of nutritive gelatine, and sucked air through it at a slow rate. When examining the tube afterwards he found that a large number of bacteria had settled in its first fourth, that that number was somewhat less in the second fourth, that it still further decreased in the third fourth, and that no bacteria at all had settled in the last fourth. In these experiments, therefore, the bacteria were not even carried the distance of one yard. But against any conclusions drawn from these investigations might be urged that the tube employed was far too small to provide for the proper passage of germs through it. Similar experiments with similar results were made by Carnelley and Haldane. As already stated, Laws reports that former experiments have shown "that if the splashing (in a sewer) is sufficiently violent to produce a very fine state of division of the sewage, organisms will be carried some distance, even 50 to 60 yards."

Ficker used for his experiments a 4in. tube, which he placed upright, and at the bottom of which he caused bubbles of a liquid highly charged with specific germs to burst. Then, forcing air through it at the rate of 0·196in. per second, he found that the germs had been carried as high as 23ft. into the air.

It cannot, however, be said that any of the experiments mentioned in the last series afforded conclusive evidence against the possibility of germs remaining suspended in air for some time and being carried away by the currents.

It may not be out of place to summarise now the various results obtained.

1. It is held that all pathogenic germs which reach the sewers in the fæces, urine, sputa, in the water from baths and lavatories, in the house refuse, in the rain-water from streets, etc., meet with conditions there that are not favourable to them, and prevent their propagation.

2. Amongst these unfavourable conditions is perhaps the struggle for existence with the myriads of other germs that crowd the sewage, and ending in the survival of the fittest—the most unfavourable one. Hence the life of pathogenic germs in sewage is of comparatively short duration, and the death being a gradual one they

lose their virulence—*i.e.*, their power of mischief—some time before this event actually takes place.

3. It is further held that pathogenic germs, like other germs, cannot rise from liquids and moist surfaces under ordinary circumstances, and that although they may become disseminated in sewer air through the bursting of bubbles and through splashing, they cannot be carried very far by the air currents, but, following the law of gravitation, soon fall back into the sewage. Hence it is not all likely that pathogenic germs are carried about suspended in sewer air.

4. The experimental results then, so it is argued, go to explain the cause of the comparative absence of germs from sewer air, and confirm the conclusions drawn from its examination.

5. Further, it is argued that the air is but seldom the carrier of infectious germs.

Therefore concludes Kirchner (B-30, Appendix I.) a passage in his paper on the injurious influence of sewer gas, "we are entitled to say with a probability bordering on certainty that presumably pathogenic germs will never be found in sewer air."

But where the cause is absent—it is here assumed that there can be no typhoid fever without the typhoid bacillus—the effect will also be absent, hence sewer air or sewer gas is not capable of producing typhoid fever.

Against these conclusions, however, it has been urged by those who support the theory that sewer gas is capable of propagating typhoid fever, that it is by no means conclusively established that the bacillus typhosus is the *vera causa* of typhoid or enteric fever; further, as has already been stated, that our methods of investigation are still very imperfect and admit of a great many errors, and, finally, that the chances of finding the typhoid germ in such a vast labyrinth of underground conduits as the London system of sewers is, are practically nil.

Assuming for the sake of argument that the bacillus typhosus is the true cause of typhoid fever, it must not be thought that it is present in every litre of sewer air, but being only an occasional and periodical inhabitant of it, it will be found only in isolated places. It is, therefore, a mere accident if the experimenter happens to take his samples of air in a locality where the typhoid germs are and just at the time they are passing his place of observation in an air current; the next moment they might be wafted away and beyond his reach. Further, in a large sewer they might pass round his instruments, and so escape him. It is clear therefore that their chances of not being taken in isolated samples of sewer air are innumerable, and the chances of catching them extremely remote.

These or similar circumstances may account for the fact that only one observer (Uffelmann) has up to the present been able to discover the pathogenic germ of suppuration in sewer air.

How very difficult it is to catch the typhoid germ even in sewage is clear from the report of Messrs. Laws and Andrewes. Although these experimenters employed the greatest care, they were not able to find this germ once in ordinary London sewage. They then tried the drain that takes the sewage from the typhoid-fever block of the Eastern Hospital at Homerton at a point inside the hospital grounds, and although this sewage must have contained a vast number of typhoid germs at the time, they were only able to find two colonies of it. Later on they tried the sewer which takes the drainage of the hospital at a point about a quarter of a mile below this institution, and did not find a single colony of the bacillus typhosus. Therefore, in spite of all their most painstaking investigations, Messrs. Laws and Andrewes found only two colonies of the typhoid germ in London sewage.

Further, it is by no means a new thing to attribute an outbreak of cholera or typhoid fever to water without having been able to discover the specific germs of these diseases therein. For instance, the late severe cholera epidemic at Hamburg in 1892 was traced to the water supply although no cholera germs were found in it. Likewise were two typhoid epidemics at Berlin in 1889 and 1893 attributed to the water without the bacillus typhosus having been found therein. On the contrary, there are only a few cases on record where this specific germ has been found in water in connection with an outbreak of typhoid fever, and it was considered a feat worthy to be recorded when, at Berlin, where perhaps the most elaborate and painstaking searches have been and are still being made for this germ, it was found for the first time in the public water supply by Loesener on the 27th February, 1894. Therefore those who look upon sewer air as capable of carrying the typhoid germ are in no worse position than those that hold the water responsible for some outbreaks of typhoid fever.

It will not be denied that arguments such as these in favour of the sewer-gas theory cannot in the present state of our knowledge be fully contradicted by those who are opposed to it, but, looking at the whole case and making all due allowances, it appears to the author that the chances of typhoid fever being brought about through the conveyance of the bacillus typhosus in sewer air are somewhat remote.

What then is the connection between sewer air and typhoid fever? This question the author will endeavour to answer in the following paragraph.

PART IV.

Experiments on Animals with Sewer Air.

CHAPTER I.

Experimental Researches into the Causal Relations between Sewer Air and Typhoid Fever.

(See also Appendix IV.)

As it had frequently been observed that domestic animals which are exposed to typhoid infection in almost the same degree as human beings never showed symptoms of illness during or after a typhoid epidemic, or even pathologic-anatomical changes, which could be considered at all identical with those found in typhoid fever, the opinion gained ground that the lower animals do not suffer from typhoid fever in the sense in which it is recognised in man. When, therefore, the bacillus typhosus was discovered, various experimenters at once set to work with a view to ascertain whether it could produce typhoid fever in the lower animals.

Gaffky, who was perhaps the first to carefully and methodically investigate this matter, was not fortunate in settling it, as all his numerous experiments on 5 monkeys, 1 calf, 16 rabbits, 13 guinea-pigs, 7 rats, white and grey mice, pigeons, and fowls led in no case to illness or even to changes which could have been attributed without doubt to the infection. Shortly after him, however, Fraenkel and Simmonds were able to report that they had succeeded in producing an acute fatal disease in guinea-pigs, grey house mice, and rabbits by injecting large quantities of the typhoid bacillus (from 1 to 2 ccm. of broth culture and more) into them. Since then numerous other observers have been able to observe the same results after inoculating animals with large doses of the bacillus typhosus, and it can, therefore, no longer be doubted that this bacillus can produce very acute illness and death in animals provided the doses given are large enough ; in many cases death took place within from three to four hours after the inoculation. But this disease—and here all observers practically agree—is not of a specific nature, and does not resemble in its clinical and anatomical appearances those observed in typhoid fever in man; moreover, it can be brought about by the injection of various other microbes.

In passing, it may not be out of place to quote here what Stern says in reference to the action of the typhoid bacillus upon animals :

> "We must imagine that the animals experimented upon can withstand, if the injected quantities of culture are below a certain standard, which latter varies according to the virulence of the bacilli, the amount of poisonous matter introduced at the same time, and have still strength left to deal successfully with the bacilli themselves. If, however, the injected quantities of culture are above this standard, then the great amount of poisonous matter tends on the one hand to reduce the power of resistance of the body against the injected bacilli, and on the other hand the greater number of the latter will be able to break down all the quicker the protective forces of the body which oppose their growth. Then follows the secondary augmentation of the bacilli, which, of course, can

attribute very essentially, through the production of more poisonous substances alone, to the fatal issue."

What these protective forces of the body are, whether they are the leucocytes of Metchnikoff or not, and why the acute disease produced in the body of the animals through the injection of large quantities of typhoid bacilli is not of a specific nature and cannot be compared with typhoid fever in man, are questions which are outside the scope of this treatise. Suffice it to say that before they are solved our investigations will have to be pushed a great deal farther, so as to obtain full explanations of a great number of other processes which at present are still shrouded in mystery. For our purposes, therefore, it will be sufficient to bear in mind that under ordinary circumstances small doses of the typhoid bacillus will not produce ill effects in animals, but that large doses cause very acute disease and rapid death.

After this slight detour it will be necessary to return to our subject and consider some of the investigations which have been made with a view to ascertain, through experiments on animals, the causal relations between sewer gas and typhoid fever.

Dr. Parkes reports in his "Manual of Practical Hygiene" that Dr. H. Barker exposed three dogs and one mouse to the influence of sewer gas. The animals were put into a box and lowered down over a cesspit, so that they were forced to breathe the gases formed through the decomposition of organic matters. The mouse died on the fifth day, and all the dogs suffered from vomiting, purging, and a febrile condition, which Dr. Barker says "resembled the milder forms of continued fever common to the dirty and ill-ventilated homes of the lower classes of the community." But the effects required some time and much gas for their production. Dr. Barker attributes the results, not to the organic matter, but to the mixture of carbonic acid, hydrogen sulphide, and ammonium sulphide, and specially to the latter two.

The best and by far the most elaborate researches into this question have been made in Italy in the Hygienic Institute of the University of Rome, by Dr. Alessi (see A-4 and D-2, Appendix I.), full particulars of which are given in Appendix IV. Alessi experimented in all on 408 animals, as is shown in the following table:

TABLE III.—Particulars and Numbers of Animals Experimented on by Dr. Alessi.

Treatment of Animals.		Rats.	Guinea-pigs.	Rabbits.	Totals.
Putrid gases	Exposed to	49	111	19	179
	Not exposed to ...	41	79	13	133
Special mixture of gases	Exposed to ..	48	8	—	56
	Not exposed to ...	34	6	—	40
Totals		172	204	32	408

The plan which he adopted in conducting his researches was the following:

He exposed 49 rats, 111 guinea-pigs, and 19 rabbits to putrid gases, including sewer gas, for a time, then injected into them small doses of attenuated typhoid bacilli and bacterium coli, carefully noted the results of this operation, and after death made searching post-mortem examinations. At the same time he kept as a control of the foregoing experiments 41 rats, 79 guinea-pigs, and 13 rabbits under ordinary conditions and injected into them exactly the same doses of typhoid bacilli as before, so as to have all the conditions the same save the exposure to sewer gas. This formed the first set of his experiments.

With a view to ascertain now whether the result of his first set of observations was brought about by the action of those chemical substances which are commonly given out in the form of gas from putrid fermentations, he started a second set of experiments. Taking in all 48 rats and 8 guinea pigs, he exposed them to such substances as retilindol,* ammonia, sulphuretted hydrogen, methyl sulphide, carbonic acid, carbonic oxide, and ammonium sulphide, and after a time injected doses of typhoid bacilli into them. As a control of the foregoing experiments he injected the same doses of typhoid bacilli into 34 rats and 6 guinea pigs, which had been kept under ordinary circumstances. These two sets of experiments enabled him to arrive at certain final conclusions which are given later on.

Concerning the doses of typhoid bacilli injected into the various animals, it ought to be stated that they were very small, amounting only to from 0·25 to 0·50 ccm. Other observers, in order to bring about fatal results, had been obliged to use doses as large as from 2 to 4 ccm., and above that; therefore, their doses were from four to eight times larger than Alessi's maximum dose.

Further, the cultures used by Alessi were far from being virulent. Concerning his culture A he says: "its virulence might be considered almost nil," and concerning his culture B he states that "it had a certain virulence."

The exposure to putrid gases was made in the following manner: The rats were put into a box with a wire

* Retilindol (Scatol) is a strongly smelling product of putrefaction of albuminous substances, and is, therefore, easily found in the intestines.

bottom, which was so placed over an untrapped water-closet that it closed its aperture. The rabbits and guinea-pigs were likewise placed into a box with a wire bottom, but the latter was placed over a vessel which contained excrementitious substances.

In reference to the bacterium coli commune which Alessi used for some of his inoculations, it might not be out of place to state that it is now considered a harmless inhabitant of the intestines. It is very much like the typhoid bacillus, and has frequently been mistaken for this pathogenic germ; some observers call it bacillus coli communis. It is always found in fæcal matters, and consequently in sewage, hence its presence in a liquid indicates contamination by sewage.

The experiments throughout were conducted with the greatest care, and cannot fail to carry conviction to all those who read them; certainly Dr. Alessi appears to have spared no pains to arrive at reliable conclusions.

The results obtained in the first set of experiments are given in Tables I., II., III., and IV. of Appendix IV., from which it is clear that from 75 to 100 per cent. of all animals inoculated with small doses of attenuated typhoid bacilli and bacterium coli after exposure to sewer gas perished, whilst practically not one of the animals which had been kept under normal conditions succumbed to the inoculation. These figures are highly significant, and speak for themselves.

It is not necessary here to dwell on the changes brought about by the inoculation in the organs and tissues of the animals as revealed in the post-mortem examinations; it will suffice to say that bacteriological research was able to prove the almost exclusive presence of large numbers of typhoid bacilli in the organs and tissues in every case excepting those animals of course into which the bacterium coli had been injected, where this latter germ alone was found. In reference to this point Alessi remarks: "By the distribution then of the typhoid bacilli in the various tissues, and by the alterations which they have caused in them, I am justified in concluding that they have caused death in these animals following upon the predispositions which the latter had acquired by breathing putrid gases."

From these experiments it is clear that through the exposure to putrid gases, including sewer gas, the animals experimented on lost their natural immunity to small doses of the typhoid bacillus, and acquired a predisposition to the pathogenic action of this germ to such an extent that they succumbed to small doses of attenuated typhoid bacilli in periods ranging on an average from 23 hours to 5 days and 3 hours. How very great the influence was which the breathing of putrid gases exercised on the animal organism is further demonstrated by the fact that even the harmless bacterium coli was capable of killing 83 per cent. of the animals into the bodies of which it had been injected.

The period in which this predisposition or great susceptibility to the pathogenic action of the bacillus typhosus was obtained by the animals varied on an average from 3 days to 22 days, and was also different for the different species, rats showing a greater resistance than guinea-pigs, and guinea-pigs than rabbits. Alessi remarks: "It appears that generally the animals acquire the predisposition to infection more easily during the first two weeks than after that time. In fact, 90 per cent. of the animals inoculated in the first two weeks died, and only 76 per cent. of those inoculated in the following weeks. This fact may in a certain degree explain how it is that some individuals who habitually breath air from sewers or in whatever way corrupted, end by becoming habituated to it, and are no longer attacked by intestinal infections."

After having studied the predisposing action of putrid gases taken in their entirety, Alessi set to work to ascertain whether the chemical substances which are commonly given out in the form of gas from putrid fermentations can also exercise separately a similar influence on the animal organism.

The number of animals and the various substances used in these experiments have already been stated. It will only be necessary to add here that both the gases and the animals were placed inside a bell glass, which was closed in such a manner as to make change of air impossible. It is of course well known that the substances employed are of a highly poisonous nature to man and animal, and produce very rapid deleterious effects. Alessi therefore only used very small quantities, certainly smaller than the minimum fatal dose.

The results of this second set of experiments are given in Table V. of Appendiv IV., from which it follows that out of a total number of 56 animals which had breathed the various gases and gaseous mixtures only three in all died, and, as Alessi remarks, these three died from other causes, which it was impossible for him to define. He therefore comes to the conclusion that neither the gases taken separately nor in mixtures, exercise a predisposing influence over the animal organism. "For which reason," Alessi continues, "I may be allowed to suppose that both the exhalations arising from fæcal matter and the exhalations arising from organic matter in putrefaction, are not composed of simple mixtures, but are much more complicated than might be believed. And the predisposing cause might also have its seat in those fœtid substances of neutral character which it is impossible either to understand or determine, whether from their small quantity, the insufficiency of analytical methods, or from the imperfection of those which we already have. In any case, from my experiments can be drawn this useful lesson that the above-mentioned gases or vapours can be breathed in small doses without their predisposing to typhoid infection."

The final conclusions at which Alessi arrived are the following:

"1. The inspiration of putrid gases predisposes the animals (rabbits, guinea-pigs, and rats) to the pathogenic action of even attenuated typhoid bacilli and of bacterium coli.

"2. This predisposition is due to the combination of gases given out by putrid fermentations, and not to anyone separately; and

"3. It is probable that this experimental predisposition is diminished by prolonged breathing of the said gases."

It can, perhaps, not be surprising that those who consider sewer gas comparatively harmless have endeavoured to find fault not only with the conclusions derived from Alessi's experiments, but also with the way in which they have been carried out. According to them these researches cannot be applied to human beings, as in the first instance these will never be exposed to such strong doses of sewer gas as were applied by Alessi to his animals. Those whose good or bad fortune it has ever been to have to examine the ramifications of house drains that have been laid more than 20 years ago will know from their own experience whether this objection is true or not; at any rate, so far as the author is concerned, he has met with cases in which the escape of sewer gas was in every way as bad as in these experiments, and where the doses inhaled cannot have been much less. But even granted that in the generality of cases, though the amount of sewer gas escaping through faulty places or untrapped water - closets, etc., may be as great as in Alessi's researches, the exposure to these gases is not as continuous as in them, this will only make a difference as to the time in which this predisposition is acquired, not to the predisposition itself. At any rate Alessi's experiments show very clearly what a powerful influence putrid gases, including sewer gas, can exert upon the animal organism under unfavourable circumstances; and who shall say in so important a matter as health what the dose is an individual may inhale without detriment, and for what length of time! Social hygiene has too often and too painfully shown that some constitutions are quickly affected by sewer gas, whereas others are more slowly but none the less surely conquered by it. In the author's opinion, therefore, this first objection to Alessi's experiments springs from an under-estimation of the real condition of things.

Further, it has been urged that the fatal disease produced by Alessi in his animals does not correspond to typhoid fever in man, and that therefore it is wrong to conclude from the predisposition to this disease in animals a predisposition to typhoid fever in man through the breathing of sewer gas. Let us see whether or no this objection carries more weight than the former.

The author has shown that rodents and all lower animals are immune to small doses of the typhoid bacillus. He has further shown that in Alessi's experiments the animals after inhaling putrid gases for a greater or less time lost this immunity, and became so susceptible to the action of the typhoid bacillus and even the harmless bacterium coli that small doses of attenuated typhoid bacilli and of bacterium coli were capable to set up rapidly fatal disease. He has finally mentioned that in the organs and tissues of the dead animals only the bacillus typhosus and in one experiment the bacterium coli was found, so that there cannot be a doubt but that these germs caused the death of the animals. This being so it matters not for the purposes of this treatise whether or no the pathogenic action of the typhoid bacillus is the same in animals as in human beings, the only point of importance being the fact that the breathing of sewer gas did render the animals more susceptible, or in other words, predisposed them, to the pathogenic action of this germ. Therefore, if from experiments on animals we may form opinions as to the effects on human beings—and this will hardly be denied—we are entitled to conclude that the breathing of sewer gas will predispose human beings as well to the pathogenic action of the bacillus typhosus. Hence, in the author's opinion this second objection cannot be maintained.

Alessi's experiments then offer an explanation of the causal connection between sewer gas and typhoid fever, a connection which, though foreseen epidemiologically by some observers, had been disputed by others, and which social hygiene has practically and painfully confirmed in many instances.

PART V.

Conclusions as to the Influence of Sewer Gas upon Health.

CHAPTER I.

INFLUENCE OF SEWER GAS UPON HEALTH.

Conclusions from the foregoing Chapters.

It will now be necessary to summarise shortly the influence which sewer gas exerts upon health.

It has been shown in the foregoing remarks that, broadly speaking, sewer gas is able to cause instantaneous death through asphyxia, and to predispose the constitution to the action of the typhoid bacillus. Therefore, although such a classification is not entirely correct, we may for convenience of reference distinguish between a direct and indirect action of sewer gas upon health.

Concerning the direct action, it is highly probable that this is brought about through such gases as carbonic oxide, carbonic acid, and sulphuretted hydrogen acting either in combination or separately, as they are known to be highly poisonous substances. If the quantity of sewer gas inhaled contains large doses of these gases, then the severe form of mephitic poisoning will be the result—viz., instantaneous death through asphyxia; if, on the contrary, these gases are only present in small quantities, then the mild form of mephitic poisoning will take place, which, if the exposure to sewer gas is continued for some time, will lead to derangements in the digestive and nutritive organs. This direct action has, therefore, sometimes been called the mephitic action of sewer gas.

The cause of the indirect action of sewer gas is still shrouded in mystery, as we do not know the nature of the poison which renders the constitution susceptible to the pathogenic action of the typhoid bacillus. Whether it be the combination of gases given off by putrifying organic matters, or whether it be a mixture of some of them, or whether it be one of them only which has been called organic vapour, or whether this cause has its seat in those fetid substances of neutral character which it is impossible at the present time either to understand or determine, we are powerless in the present state of our knowledge to ascertain. But, nevertheless, the fact remains that this predisposition exists, and must not be overlooked, as has been done by those who, for want of being able to specify the cause, have disputed the effect. This indirect action has by some been called the predisposing action.

We have therefore the direct or mephitic action and the indirect or predisposing action of sewer gas, and though these definitions are, strictly speaking, not quite correct, they admit at any rate of an easy reference. Whether or no it will eventually be found that they both spring from one and the same cause is a matter of mere speculation at the present time, and therefore outside the sphere of practical consideration.

Concerning the direct infective action of sewer gas, the author has already pointed out that, in his opinion, the chances of typhoid fever being brought about through the conveyance of the bacillus typhosus in sewer air are somewhat remote, and for this reason he has not taken any note of it in the previous remarks.

Up to the present time the point whether the predisposing action of sewer gas extends to other zymotic diseases as well has, so far as the author is aware, not been investigated experimentally, but if such a predisposition should be proved eventually it would afford an easy explanation for the connection which has been observed by various observers to exist between sewer gas and such diseases as diarrhœa, cholera, erysipelas, puerperal fever, etc.

It has frequently been stated that if sewer gas was capable of exercising a predisposing influence to typhoid infection, this influence ought to make itself strongly felt on sewage farms, where the sewage is spread over large tracts of land, but as the latter was not the case, sewer gas could not possess the power of rendering the system susceptible to the action of the bacillus typhosus. In the author's opinion such a conclusion is not correct, as the reason of this fortunate state of things is to be found in the nature of the prédisposing poison, and not in its absence from sewer air. If this poison were an organised one, or if sewer air did carry a large number of typhoid germs, then one might expect that an epidemic in town would be followed by an outbreak on the sewage farm, but as the predisposing poison does not appear to be an organised one (probably a chemical one) it becomes diluted with air to such an extent on the farm that it loses its powers of mischief. Hence this objection cannot be maintained.

In passing, the author would like to remark that the experience of all well-conducted sewage farms goes to show that they do not act injuriously to the public health, and that, for instance, the epidemic of typhoid fever which visited the city of Berlin in 1889 was not followed by an outbreak on the very large sewage farms.

Against the predisposing action of sewer gas has further been advanced that sewermen do not suffer to any extent from typhoid fever, but are practically immune to it. The author has already pointed out that the statistical material available for the consideration of this question is very meagre, and requires care in using. But even granted that such is the case, it does not appear to militate against the theory of predisposition, for Alessi's experiments make it probable that with a prolonged exposure to sewer gas the predisposition becomes diminished. Hence the experience with sewer-men appears to show that it is possible to become immune to the predisposing influence of sewer gas, but not that sewer gas has no such predisposing influence. It is greatly to be regretted that this subject has not been more fully and systematically investigated, as it would be of considerable interest to ascertain what are the conditions and particulars under which this immunity is obtained.

Concerning the cases of septic poisoning through sewer gas which have been mentioned by the author (see also Appendix VIII.), it is difficult to offer any explanation, as we know too little about them. In the case quoted by Dr. Hill from Sutton Coldfield it appears that the poison was an organised one, and it is possible that it was carried in sewer air.

Before concluding this treatise the author thinks it might not be out of place to draw attention to one or two further points of interest which, in his opinion, bear intimately on the connection between sewer gas and health.

PART VI

Allied Subjects.

CHAPTER I.

Difference between Waterworks and Sewerage Works in their Influence upon the Public Health.

(See also Appendix X.)

If, as has been stated, there is no connection between putrid gases and typhoid fever, then it would undoubtedly be correct to assume that the carrying out of sanitary improvements, which aim at the prevention of the formation of these gases and their exclusion from our houses, such as a systematic sewerage of a town, combined with a rational house drainage, would not affect the mortality from typhoid fever. But that such a conclusion is opposed to the universally observed facts will be known to all those who have given this matter some consideration however small.

Ever since the memorable and classical report of the late Sir George Buchanan in 1866 on the influence of sanitary works upon the health of towns, in which this original and skilled investigator for the first time drew public attention to the fact that in a large number of English towns the typhoid mortality had considerably decreased since the carrying out of water and sewerage works, this lowering of the typhoid rates, coincident with, and consequent on, the introduction of a systematic water supply and sewerage, has been but universally observed not only in this country, but practically in all other countries, so that we have now come to look upon it almost in the light of an axiom.

How far this reduction in the typhoid rates is due to the execution of works for the supply of good water and how far to the carrying out of proper sewerage works had been decided by Buchanan in favour of sewerage works, and from his and further careful investigations by Continental observers it may safely be concluded that sewerage works contribute to it in a more prominent degree than waterworks.

Besides the researches of Soyka (B-55, Appendix I.) it may not be out of place to mention here the investigations by P. Baron (B-2, Appendix I.) in 1886. After selecting for his purposes 10 towns which in his opinion were comparatively free from objections, and after examining the statistical material in reference to them, Baron states: "We are therefore not entitled to attribute the reduction of the typhoid mortality in the 10 towns above enumerated to the introduction of the water supply."

Very striking is the difference in this respect between the water supply and drainage works in the case of Berlin, of which full particulars are given in Appendix X. It appears that the waterworks were opened in 1856, and the operations for the sewerage of the city commenced in 1875, or 19 years later. In Table I. and Diagram I. of Appendix X. can be studied the movement of the typhoid-fever rates since 1854, and from these it is clear that, whereas these rates very gradually declined in the first 19 years since the introduction of a public water supply, they take a very remarkable leap downwards from the year 1875, in which the sewerage of the city was started. The same downward movement since the year 1875 may be observed in Diagram II., which deals with the general death-rates of Berlin, although, as was to be expected, it is not so marked in this case.

Therefore, in the case of Berlin, the introduction of a public water supply has not been accompanied by the same beneficial results to the public health as the commencement of the sewerage works, which has been followed by a most marked improvement in the death-rates.

It is, of course, not contended here that to this state of things only the sewerage works of a town have contributed—far from it, as undoubtedly a great many other factors have helped to lower the death-rates; but what is maintained is this, that so far as we can judge from the death-rates, especially from those of typhoid fever, sewerage works have had as a rule a more decided influence upon their reduction than waterworks.

After having thus settled the question of the reduction of the typhoid rates in favour of sewerage works, Baron goes on to mention several towns, such as Berlin, Dantzig, and Hamburg, where the introduction of a systematic sewerage has been followed by a great reduction in the typhoid mortality, and finally compares the typhoid rates for nine years in 46 towns with good drainage, with those in 37 towns without drainage. His conclusions are as follows:

1. The heaviest typhoid mortality occurred in towns without drainage;
2. Average rates occurred more frequently in non-sewered than in sewered towns; and
3. The lowest typhoid rates were by far more frequently observed in sewered towns.

Baron then further sub-divides the towns into those with the highest and those with the lowest typhoid rates and finds:

4. Out of 70 towns with the highest yearly rates, 51, or 73 per cent., were not sewered; and
5. Out of 51 towns with the lowest yearly rates, 36, or 70 per cent., were sewered.

Summarising all his results, Baron concludes: The lowest yearly typhoid rates occurred in 36, or 78 per cent., of the 46 sewered towns, and only in 15, or 40 per cent., of the 37 towns without sewerage.

Hueppe (B-27, Appendix I.), who investigated the same subject, came to similar conclusions as Baron.

The foregoing facts then can only be interpreted as follows: Towns with a systematic sewerage have as a rule lower typhoid rates than towns which are not sewered at all; and, further, the systematic sewerage of a town is generally accompanied by a corresponding reduction of the typhoid rates.

This being so, it may well be asked in what manner does the carrying out of drainage works beneficially influence the public health?

This question, in the author's opinion, admits in the main of but one answer—viz., by preventing the systematic pollution of the air under our houses and in their vicinity through decaying organic waste matters. No doubt this answer could be extended by including such factors as the permanent lowering of the subsoil water, etc., but for our purposes such a course need not be adopted.

In the days of cesspits, vaults, middens, privy middens, pails, large uncovered ashpits, etc., the air in the vicinity of our houses was methodically polluted through putrid gases rising from the stored-up putrefying organic waste matters; hence people were forced to inhale continually strong doses of these gases, and became more or less predisposed to the action of the typhoid germ, which then found the ground already prepared for its destructive work. This state of things was, however, altered with the introduction of a systematic sewerage, the main aim of which is to carry away from our houses as quickly and as completely as possible such organic waste matters as excreta and all refuse waters, which are always more or less charged with organic matter. The systematic pollution of the air through putrid gases being thus prevented, a reduction of the typhoid rates followed as the natural consequence.

As an instance of the gradual decline in the typhoid rates coincident with, and consequent upon, the carrying out of various sanitary improvements aiming at the prevention of the formation of putrid gases and their exclusion from our houses, might be mentioned the town of Munich. From the particulars given in item 2 of Appendix X. the reduction of the typhoid rate can be traced step by step coincident with the carrying out of various sanitary improvements, with this result, that, whereas it stood at 24·20 per 10,000 inhabitants in the period 1852-59, it had gone down to 1·75 in the years 1881-1885. It will not be disputed that this is a very marked and large decrease.

These facts then, which are derived from daily observation and common experience, go to show that there exists in nature, as apart from experimental results, a connection between putrid gases and typhoid fever, and they further show that the conditions prevailing in the conservancy methods are more favourable to this disease than those brought about by the water-carriage system, which is an undoubted improvement in this respect.

Those observers therefore who dispute the connection between putrid gases, including sewer gas, and typhoid fever, either overlook the facts just enumerated altogether, or endeavour to explain them away in a manner that cannot inspire great confidence.

But perhaps the most remarkable statement has lately been made by an opponent who, after mentioning the conclusions at which Baron arrived and admitting their correctness, goes on to say that if there was a connection between sewer gas and typhoid fever such a state of things could not exist, as then with the introduction of a sewerage scheme typhoid fever would increase instead of decrease. It will hardly be necessary to deal seriously with such a statement, as it springs (firstly) from a gross exaggeration of this influence, and (secondly) from a sad want of knowledge of the state of things previous to the introduction of the water-carriage principle and of this principle itself.

CHAPTER II.

The Dilution of Sewer Gas and its Escape in the Centre of Roads and Streets.

(See also Appendix XII.

It may not be out of place to make here a few remarks concerning the dilution of sewer gas, as the question of noxious smells from manhole covers has considerably agitated the public mind and has caused sanitary committees in various towns to adopt such measures as the closing of the open street ventilators, the ultimate sanitary effects of which are to say the least very doubtful.

Without entering into details concerning the ventilation of the sewers, it has been stated that if we wish to reduce the injurious effect of sewer gas upon health we must take care that it is absolutely excluded from the interior of our houses, and that at those places where it is allowed to escape it becomes at once diluted with large volumes of fresh air, if indeed it is not already diluted within the sewers themselves. This appears to be a wise rule, and is certainly based on general experience and universally observed facts; for sewer gas, like other poisonous gases, loses its injurious effect upon health in the ratio of its dilution with fresh air.

Acting upon this principle, the gases forming in our sewers were prevented from passing into private house drains through a disconnecting trap, and allowed up to now to escape through the open manhole and lamphole covers in the crown of streets and roads. However, owing, no doubt, to the complaints in the public Press and elsewhere about noxious smells from these covers, a movement has lately set in to close the open street ventilators and replace them wherever possible by ventilating pipes up the sides of houses.

So far as the author is aware, no attempt has yet been made to prove that such a change is beneficial to the public health, and as it is, of course, of the greatest importance to know whether this is so or not, it may not be out of place to put here on record the observations made in Leicester, as they are perhaps somewhat unique. For this purpose the author has compiled Appendix XII., where full particulars concerning these points are given.

On reference to it, it will be seen that, so far as the ventilation of the Leicester public sewers is concerned, three periods may be distinguished—viz.:

1. The period before the year 1881, when the sewers were very foul and not ventilated;
2. The period from 1881 to 1886, in which a great length of the old sewers was cleaned out and ventilated by open covers at street level; and
3. The period since 1886, in which practically two-thirds of the open covers at street level were closed, about 300 ventilating shafts erected, and the old main sewers replaced by larger and better constructed ones.

If we now compare the typhoid rates in these three periods as shown in Table I. and Diagrams I. and II. we find that the average rate for the second period was practically only half that of the first period, but that this decline was not continued in the third period, the average rate for it being, on the contrary, somewhat higher again than that of the second period. The same upward movement in the third period can be observed in the diagram showing the number of typhoid certificates received.

This rise in the typhoid death-rates since 1886, the year in which the closing of the open street covers was commenced, is all the more remarkable, as since that year the new main sewers (their cost, including pumping station and sewage farm, amounted up to 31st March, 1895, to nearly £330,000) and a large number of other sanitary improvements have been carried out in Leicester, not to mention the general advance in the knowledge and treatment of infectious diseases; and if we look for an explanation of this remarkable fact, the thought suggests itself that probably sewer air had something to do with it.

In the first period undoubtedly sewer air or sewer gas would find its way into the interior of the houses; in the second period it escaped largely through the open covers at street level, hence the numerous complaints; and in the third period it is possible that with the closing of these open covers, sewer air gradually found its way back again into the interior of the houses.

In connection herewith it is interesting to observe that the medical officer of health, as has previously been stated, reports that in 1893, out of all typhoid-infected houses, 31·25 per cent. had defective drains, as shown through the smoke test, and that in 1894 this percentage had increased to 45·18. In passing, it might be remarked that the smoke test is not altogether reliable in cases of underground leakage.

The author is of course perfectly well aware that a variety of causes are at work in the propagation of infectious disease, and that the three periods under review are not very long ones; but whatever our opinions may be on this point, the fact remains that, in spite of a large expenditure on sanitary works, the typhoid rate has not decreased since the commencement of the closing of the open covers at street level, but has, on the contrary, slightly increased, and this fact alone is, he thinks, of sufficient importance to be noted down very carefully by all those who give these questions their anxious consideration.

CHAPTER III.

Concluding Remarks.

When the history of the sanitary progress during the present century, which is now fast sinking into its grave, comes to be written, a very important place will have to be assigned to what has been termed the sewer-gas theory, as it has exerted a most powerful influence for good in the matter of house and general sanitation; indeed, it has been stated that the results which the conviction that sewer air or sewer gas is dangerous to health has brought about surpass in brightness, excellence, and importance the results achieved by any other sanitary doctrine.

If we enquire into the causes which were capable of producing such weighty effects, we shall probably find that they are largely due to the very great interest the general public has taken in this question, as is evidenced by the controversy to which it gave rise in the public Press and elsewhere. That during the same the most divergent opinions should have been expressed cannot be surprising.

On the one hand, it was asserted that the influence which sewer gas exerts on health was practically unlimited and almost mysterious, and, on the other hand, sewer gas was said to be practically harmless. In the author's opinion the truth lies probably in the middle between these extremes, and whilst considering the chances of sewer air acting directly infective, or in other words, of sewer air, *per se*, producing typhoid fever somewhat remote, he is clearly of opinion that apart from its direct or mephitic action, which is admitted by everyone, sewer air or sewer gas (synonymous terms) has the power of predisposing the constitution to typhoid (and probably also to other) infection, so that if the typhoid bacillus is introduced into the system in some way or other after exposure to sewer gas, it finds there a favourable soil for committing its ravages. How large the dose of sewer gas must be before this predisposing influence is felt depends probably on a variety of circumstances, which in the present state of our knowledge we have no means of ascertaining correctly.

If, in his endeavour to survey the whole question, the author appears to have been too detailed in some places, he hopes he may be excused, as the subject is a most important one, and it was his wish to give the fullest information possible concerning it.

It is greatly to be regretted that we are not yet able to assign for every specific effect a specific cause, and there is good reason to fear that it may yet be a long while before this ideal state is reached; but this must not prevent us in matters of public and private health to carefully obey those preventive rules and laws which we have been able up to the present time, even though it were but imperfectly, to discern.

We probably only stand to-day on the threshold of the knowledge of health and disease, of life and death, and before us lies a vast tract of unknown land which has only been explored on its circumference, but into which no solitary traveller has yet penetrated. Therefore it behoves all those who interest themselves with matters of public and private health, always to fully bear in mind that health is the greatest blessing we enjoy, and that when once it has escaped our grasp it may probably never return to it. Hence it is far better to prevent an illness than to cure a disease.

What the protective forces within our system are, whether or no they are represented by the leucocytes, we do not know, but the aim and end of every true sanitation must be to carefully nurse, build up, and strengthen them and then protect them from injury, so that they stand us in good stead in the hour of our greatest need, when we are assailed by swarms of hostile germs, and gain a splendid victory in the life and death struggle that then ensues.

This then is the direction in which true sanitation must proceed, and if the author has succeeded in shedding further light upon this goal and the way that leads to it, all his labours will have been well repaid.

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Summary of Literature referred to:

84	English works,	papers,	etc.	
74	German	,,	,,	,,
20	French	,,	,,	,,
2	Italian	,,	,,	,,
180	works, etc., in all.			

APPENDIX II.

TABLE I.—Composition of Sewer Air.

Number.	Author.	Locality of Sewer.	Number of Analyses.	Gases in 10,000 Volumes of Air.					Vols. of Oxygen to oxidise the Organic Matter in 1,000,000 Vols. of Air.	Micro-organisms (per litre).		
				Carbonic Acid (CO_2).	Ammonia (NH_3).	Sulphuretted Hydrogen (H_2S).	Oxygen.	Nitrogen.		Moulds.	Bacteria.	Total.
1	Claubry (G. de)	Paris, choked ...		201		299	1379	8121				
2	,,	,, old, 1829..		340		125						
3	,,	,, ,, ...	19	230		81						
4	Lévy and Miquel	,, 1891-93....		4·8	1·2							3·63
5	Letheby	London, 1857-58		53·2	good deal	traces	1951	7996				
6	Miller	,, 1867	18	10·6	clean and well-ventilated sewer.							
7	,,	,, ...	6	30·7	tide-locked and ill-ventilated sewer.							
8	Russel	Paddington		51			2070	7880				
9	R. Nichols	Boston, January	31	8·65								
10	,,	,, Feb. ...	44	8·16								
11	,,	,, March...	47	11·53								
12	,,	,, April ...	12	10·75								
13	,,	,, June....	8	27·52								
14	,,	,, July	8	21·92								
15	,,	,, August.	8	23·95								
16	Beetz	Munich, soil-pipes to cesspits	6	42·37	·0004	traces						
17	,,	Munich, sewers..	8	31·4	2·2							
18	Haldane	Dundee, Westminster, and Bristol	32	7·5					7·2			8·9
19	,,	Bristol, Clifton outlet	2	20·2								2·0
20	,,	,, second outlet	2	11·6								8·5
21	Smith	Sydney	20									225
22	,,	cremating-shaft (before gas)	4									30
23	,,	,, (after gas)	2									25
24	Laws	London, normal.	8	8·95						5·04	1·06	6·10
25	,,	,, splashing...	3	12·87						2·04	1·15	3·19
26	,,	,, disinfecting	8	9·88						0·10	0·65	0·75
27	,,	Pimlico (vent) ...	5	16·36						0·60	1·59	2·15
28	,,	Experimental small sewer	9							1 90	1·46	3·36
29	,,	Stagnant sewer..	6	11·24						3·46	1·59	5 05
30	,,	Fulham-road	3	69·28						0·10	1·15	1 25
31	,,	,, ,, ...	1	93·10								
32	Average composition of atmospheric air			3·00			2090	7910				15

Table II.—Sewer Gases (W. H. Collins).

Gases Dissolved in Raw Sewage.

The Results are stated in C.C. per Litre. Averages 100 Samples.

No.	Carbon Dioxide.	Carbu-retted Hydrogen.	Nitrogen.	Sulphu-retted Hydrogen.	Oxygen.	Ammonia.
1	2·69	5·01	16·2	0·60	1·21	0·004
2	11·04	3·27	19·4	1·37	3·06	0·006
3	7·32	1·56	15·8	4·02	2·51	0·006
4	4·06	6·72	17·9	2·49	1·04	0·004
5	17·49	2·04	20·6	3·06	3·23	0·004

Table III.—Analysis of Mephitic Vapours (W. H. Collins).

From Disused and Unventilated Cellar Dwellings.

Results are stated in Volumes per cent.

No.	Oxygen.	Carbon Dioxide.	Ammonia.	Ammonia Albu-menised.	Sulphu-retted Hydro-gen.	Nitro-gen.	Marsh Gas.
1	20·83	0·58	0·086	0·142	0·26		0·313
2	20·85	0·64	0·088	0·139	1·02		0·206
3	20·73	0·59	0·084	0·144	0·56		0·564
4	20·71	0·49	0·087	0·153	0·64		0·606
5	20·65	0·92	0·085	0·136	0·72		0·217
6	20·62	0·95	0·084	0·146	1·13		0·393

See also A-21, Appendix I., for Tables II. and III.

APPENDIX III.

Micro-organisms in Sewer Air.—Experimental Results.

1. *Micro-organisms in the Air of the Paris Sewers* (see also page 26 of C-1 and also C-4, 5, 6, and 7, App. I.).

Analyses of the air in the Paris sewers are regularly made by Messrs. Albert Lévy and Dr. Miquel, who have charge of the municipal observatory of Montsouris. For this purpose an observing station has been established in the intercepting sewer "Sebastopol," not far from the point where it crosses under the rue Rambuteau, which is provided with the necessary instruments.

These examinations, which were commenced in 1891 and have since been regularly continued, have so far given the following results. The air of the Paris sewers contains on an average a little more carbonic acid than street air, from three to four times as much ammoniacal nitrogen, but only half the number of germs. The actual figures are as follows:

	Sewer Air.	Street Air.	
Carbonic acid	4·8	3·0	in 10,000 vols. of air.
Ammoniacal nitrogen	1·2	0·3	,, ,,
Bacteria	3·630	6·760	per litre.

It might not be uninteresting to mention here that there exists in the sewers of Paris another observing station, which has been established since 1893, in the intercepting sewer "Rivoli," and where the temperature, the humidity of the air, the evaporation, and the temperature of the sewage are recorded. These observations have led to the following results:

a. The variations of the temperature of the air and sewage are less perceptible in the sewers than in outside air ; and

b. The humidity in the sewers is great, and practically constant.

2. *Micro-organisms in the Air of the Berlin Sewers* (see also page 159 of B-30, App. I.).

Petri found that the air of the Berlin sewers contained only a very small number of micro-organisms.

3. *Uffelmann's Observations* (see also page 159 of B-30, App. I., and B-60, 61, and 62 of App. I.).

Uffelmann examined the air in house drains and public sewers, and reports that in house drains he could not find more than from 0 to 0·5 germs in one litter. He endeavoured to classify the various micro-organisms found, and distinguished the following kinds: bacillus subtilis, bacillus butyricus, bacillus proteus vulgaris, bacillus candicans, bacillus liquefaciens viridis lacteus, and staphylococcus pyogenes aureus. The latter germ produces suppuration, and is a pathogenic micro-organism. It is important to bear this in mind (see page 159 of B-30, App. I.).

4. *Micro-organisms in the Sydney Sewers* (see also page 32 of A-57, App. I.).

Smith examined the air of the Sydney sewers, and found on an average of 20 determinations 225 germs per litre, comprising bacilli, micrococci, torulæ, sarcinæ, streptococci, and mould fungi, some colonies liquefying gelatine. He distinguished the following kinds: bacillus fluorescens, micrococcus rosaceus, yellow bacterium, yellow sarcina, mycoides, orange sarcina, micrococcus cinnabareus, pink torula. The maximum number of germs found in 1 litre of sewer air was 2,260, and the minimum 7.

Concerning the slimy skin frequently found in badly-ventilated sewers, Smith remarks:

> "As noted in diary, cultivations from the slime on the top and sides of sewer proved in every case to be a compact mass of micro-organisms. When recently flushed there was less slime, and when dry the roof was in places covered with mould fungi."

See page 32 of A-57, App. I.

5. *Carnelley and Haldane's Observations* (see also page 12 of A-30, App. I.).

Haldane and Carnelley experimented on the sewers of Dundee, Westminster, and Bristol, and the conclusions they arrived at may be summarised as follows:

a. The number of germs in sewer air is on an average very small. It amounted on an average of all experiments to only 8·9 germs per litre.

b. Sewer air is, as far as germs are concerned, purer than outside air. The latter contained on an average 15·9 germs per litre.

c. The bursting of bubbles in a sewer will disseminate germs. Sir Edward Frankland arrived at the same conclusion from his experiments on bubbles bursting in a lithia solution (A-28).

d. With an increase in carbonic acid, the number of germs decreases.

This, expressed in other words, means that the fouler the sewer, the less is the number of germs.

e. As the draught in a sewer decreases, so also decreases the number of germs.

f. A decrease in the number of micro-organisms in fresh air is followed by a decrease of micro-organisms in the sewer air.

g. The germs in sewer air are as a rule derived from the outside air, and not from those contained in sewage.

Their experiments on the air of the Bristol sewers are particularly interesting, as these sewers are not ventilated at all and only accessible in two places, but, generally speaking, the results obtained are in keeping with those obtained at Dundee and Westminster. As far as I know, no attempt was made to classify and distinguish the different micro-organisms found.

6. *Laws and Andrewes' Experiments for the London County Council* (see also A-38 and 39, App. I.).

Perhaps the most recent, and, so far as the English language is concerned, the most careful and elaborate experiments on sewer air were made for the London County Council by J. Parry Laws, his first report being dated May, 1892, and his second 7th December, 1893. After these two reports had appeared, the London County Council further instructed him to make, in conjunction with F. W. Andrewes, investigations into the micro-organisms of sewage. Their joint report, which is dated 13th December, 1894, is divided into two parts: the first dealing with the micro-organisms of sewage and their relation to those in sewer air, and the second with the bacillus of typhoid fewer and its relation to sewage.

As these experiments have been freely discussed in scientific papers and periodicals and have given rise to many expressions of opinions, some of which cannot be said to be in any way derived from them, I will deal with them here more fully, and consider the conclusions at which Messrs. Laws and Andrewes have arrived.

In his first report on sewer air, Mr. P. Laws arrives at the following results:

a. Sewer air contains a smaller number of bacteria than outside air, but from two to ten times as much carbonic acid. No sulphuretted hydrogen was found.

b. "The micro-organisms in the sewer air are related to the micro-organisms in the air outside, and not to the micro-organisms of the sewage."

c. "In the air both within and without the sewer, the forms of micro-organisms present are almost exclusively moulds and micrococci; on the contrary, the micro-organisms of sewage are for the most part bacilli. Of the latter sometimes as many as 25 per cent. very rapidly liquefy the gelatine on which they grow, whereas in the whole course of my experiments with fresh air and sewer air I only met with one colony, and that a micrococcus rapidly liquefying gelatine."

d. "Moderate splashing carried out so as to imitate the inflow of a lateral drain or house sewer produces no variation in the sewer air even within such a short radius as 4ft. from the disturbance."

e. The mixing of deodorants with sewage or their distribution in sewer air produces no effect on the latter "beyond the removal of, in most cases, the disagreeable smell. In some instances, however, the deodorants when added to the sewage had a marked effect upon the sewage itself, reducing very considerably the number of bacteria present." Of all the chemicals experimented on with a view to ascertaining their deodorising powers, manganate of soda and sulphuric acid and carbolic acid were the most efficient; and setting aside the question of relative cost, the former is decidedly preferable for the reason stated above.

From his second report on sewer air, Mr. Laws draws the following conclusions:

f. A considerable increase in the velocity of the current in a sewer does not produce a concomitant increase in the number of micro-organisms.

g. The conditions in large sewers, so far as the micro-organisms in sewer air are concerned, appear to be the same as in small sewers, in which the sewage is intermittent and the velocity of the air current variable.

h. Stagnant and highly putrescent sewage has no influence upon the number of micro-organisms in sewer air.

i. The results of further investigations strengthen the conclusion arrived at from previous experiments (see conclusion *b* above), that the micro-organisms in the sewer air are related to the micro-organisms in the air outside, and not to the micro-organisms of the sewage.

Mr. Laws has gone to the trouble to classify some of the germs found in fresh air and sewer air, and his results are given in the following statement:

A.—Micro-organisms in Fresh Air.

1. *Micrococci.*
   Sarcina lutea.
   Micrococcus aurantiacus.
   Micrococcus candicans.

Diplococcus citreus conglomeratus.
Diplococcus roseus.
Sarcina rosea.
Pediococcus acidi lactici.
Micrococcus acidi lactici.
Micrococcus flavus desidens.
Diplococcus flavus liquefaciens tardus.

2. *Moulds.*
   Pencillium glaucum.
   Aspergillus glaucus.
   Aspergillus albus.
   Aspergillus repens.
   Aspergillus nigrescens.
   Aspergillus nidulans.
   Brown mould.

3. *Bacilli.*
   Bacillus subtilis.
   Bacillus fluorsecens liquefaciens.
   Bacillus ochraceus.
   Bacillus mesentericus fuscus.
   Bacillus arborescens.

4. *Torulæ.*
   Pink torula.
   Black torula.
   White torula.

5. *Cladothrices.*
   Cladothrix dichotoma.
   Cladothrix rubra.

B.—Micro-organisms in Sewer Air.

1. *Micrococci.*
   Sarcina lutea.
   Sarcina aurantiaca.
   Micrococcus candicans.

Diplococcus citreus conglomeratus.
Pediococcus cerevisiæ.
Staphylococcus cereus albus.
Micrococcus cremoides.
Staphylococcus cereus flavus.

2. *Moulds.*
Pencillium glaucum.
Aspergillus glaucus.
Aspergillus albus.
Aspergillus repens.
Aspergillus nigrescens.
Aspergillus nidulans.
Brown mould.

3. *Bacilli.*
Bacillus subtilis.
Bacillus aureus.
Bacillus arborescens.
Bacillus acidi lactici.
Bacillus helvolus.
Bacillus nigrescens.

4. *Torulæ.*
None.

5. *Cladothrices.*
Cladothrix dichotoma.

The second report concludes as follows:

"Although one is led almost irresistibly to the conclusion that the organisms found in sewer air probably do not constitute any source of danger, it is impossible to ignore the evidence, though it be only circumstantial, that sewer air in some instances has had some causal relation to zymotic disease. It is quite conceivable, though at present no evidence is forthcoming, that the danger of sewer air causing disease is an indirect one; it may contain some highly poisonous chemical substance—possibly of an alkaloidal nature—which, though present in but minute quantities, may nevertheless produce, in conjunction with the large excess of carbonic acid, a profound effect upon the general vitality."

In the first portion of the third, or joint report, Messrs. Laws and Andrewes deal with the micro-organisms contained in the sewage itself, with a view to comparing them with those in sewer air, and thus to elucidate this subject still further. It will not be necessary, however, to follow them into the details; it will suffice to say that they found on an average from about one million to five million colonies in 1 ccm. of sewage, of which they were able to classify only a very small number, given in the following statement:

BACTERIA FOUND IN LONDON SEWAGE.

1. *Moulds* (only 0·4 per cent. of the colonies examined were moulds).
   Pencillium glaucum.
   A mould of a dark-brown colour and identical with the species found in sewer air.
2. *Torulæ.*
   A white torula allied to common yeast (S. cerevisiæ).
   A pink torula liquefying gelatine.
3. *Micrococci.*
   Small streptococcus, in large numbers.
   Micrococcus ochroleucus.
   Micrococcus luteus.
   Micrococcus flavus liquefaciens.
   Micrococcus aurora.
   A citron-coloured micrococcus.

Pediococcus albus (doubtful).

Sarcina colonies of yellow colour, amongst them being:

Sarcina flava, in large numbers.

Sarcina aurantiaca.

Staphylococcus cereus albus.

Staphylococcus pyogenes citreus, in large numbers.

Staphylococcus pyogenes aureus, pathogenic.

A yellow staphylococcus.

Diplococcus albicans tardissimus, in large numbers.

Diplococcus roseus.

4. *Bacilli.*

Bacillus coli communis, in large numbers.

A bacillus very much like the bac. coli communis, in large numbers.

Bacillus typhosus (twice), pathogenic.

Bacillus fluorescens liquefaciens, in large numbers.

Bacillus fluorescens stercoralis, in large numbers.

Bacillus mesentericus ruber.

Bacillus aureus.

Bacillus janthinus, a brilliant violet species.

Bacillus albus putidus, in large numbers.

Bacillus subflavus (doubtful).

Bacillus fluorescens aureus (doubtful).

Bacillus mycoides, in large numbers.

Bacillus cloacæ fluorescens, in large numbers.

A dark-orange brown bacillus.

A bacillus resembling bacillus aquatilis sulcatus.

A bacillus resembling diphtheria bacillus.

Proteus Zenkeri, in large number.

Proteus cloacinus, in large numbers.

5. *Cladothrices.*

Cladothrix dichotoma.

For convenience of reference, I will give here the list of bacteria found by Jordan in the Lawrence sewage (see report of the Massachusetts State Board of Health, 1890, page 821):

Bacillus ubiquitus.
Bacillus circulans.
Bacillus cyanogenus.
Bacillus superficialis.
Bacillus reticularis.
Bacillus rubescens.
Bacillus hyalinus.
Bacillus cloacæ.
Bacillus delicatulus.
Bacillus violaceus laurentius.
Proteus Zenkeri.
Bacillus janthinus.

Messrs. Laws and Andrewes then contrast the micro-organisms which they found in the air of some of the London sewers with those found by them in the metropolitan sewage, and call attention to the following main points of difference:

A. Moulds.

Whereas moulds abound in sewer air, they are practically absent from sewage. In sewer air 64·33 per cent. of the total colonies found were moulds; in sewage, on the contrary, only 0·4 per cent. of all the colonies examined were moulds, the actual number found being seven, of which only one colony was allied to the common species existing in sewer air.

B. Micrococci and Bacilli.

The bacterial flora of sewer air consists mainly of micrococci, bacilli forming but a small proportion of the total species found. In sewage, on the contrary, bacilli preponderate over micrococci probably in actual numbers, certainly in the number of species present.

C. Bacillus Coli Communis.

Although bacillus coli communis (from 20,000 to 200,000 germs per cubic centimetre) and its allied species abound in sewage, they were never found in sewer air.

D. Sarcinæ.

Although enormous numbers of sarcina—in one case over 300,000 germs per cubic centimetre—were found in sewage, not one single colony of Sarcina lutea, so common in sewer air and fresh air, was ever discovered in it.

E.—Bacteria Liquefying Gelatine.

In sewer air, organisms rapidly liquefying gelatine were found to be practically absent, whereas in sewage these kinds of bacteria form so large a proportion as to make gelatine an impossible medium to employ in estimating their numbers.

F.—The Number of Micro-organisms in Sewer Air is Dependent on the Number of Micro-organisms in Fresh Air.

"The number of micro-organisms existing in sewer air appears to be entirely dependent upon the number of micro-organisms existing in the fresh air at the same time and in the same vicinity. With the advance of the colder weather, and consequent rapid decrease in the number of micro-organisms in fresh air, we find a corresponding decrease in the number of the micro-organisms of sewer air, although the temperature of the sewer air and sewage suffers but a comparatively slight variation."

The concluding sentences of Part I. are as follows:

"If the organisms existing in sewer air were derived from those existing in sewage, then the flora of sewer air should bear a very close resemblance to the flora of sewage. When, however, we compare the organisms which have hitherto been isolated from sewer air with those species which we have found to be predominant in sewage, it is at once evident that they bear no resemblance whatever to one another—indeed, we may go even further, and state that, so far as we are aware, not a single colony of any of those species which we have found predominant in sewage has been isolated from sewer air. We consider, therefore, that the study of the sewage bacteria on which we have been engaged fully confirms the conclusion previously arrived at from the study of the micro-organisms of sewer air—viz., that there is no relationship between the organisms of sewer air and sewage."

"It is possible that some of the ill-effects which have been erroneously ascribed to sewer air may be due to subsoil air derived from soil polluted by constant infiltration of excremental matter through a leaky drain. It is a well-recognised fact that subsoil air does at times gain access to our dwellings, either through the pressure of the wind on the surface of the ground or from currents induced by wide differences between the exterior and interior temperatures. Under such conditions it is possible that sewage may gradually extend through a permeable soil until its outer margin becomes sufficiently dry to give off micro-organisms to the subsoil air. Whatever the danger arising from this cause may be, it would in all probability be strictly limited in its effect."

Part II. of the third or joint report is devoted to an investigation of the bacillus of typhoid fever and its relation to sewage.

After stating that the micro-organisms contained in the London sewage are derived from the water used for drinking purposes, from the air, from the superficial layers of the soil, from the organic matter in the soil, and, lastly, from putrescible organic matters, Messrs. Laws and Andrewes dwell on the changes which the micro-organic life in sewage undergoes in the sewers. Various causes are here at work :

a. The sewage is a favourable medium for some germs, whilst others quickly perish in it.

b. Through the activity of the microbial life, chemical changes are brought about in the sewers which favour some species and destroy others.

c. In the struggle for existence, the healthier and stronger forms survive, the weaker ones perish.

Thus it is brought about that the sewage flora of the Barking and Crossness outfalls is very different from that of fresh sewage originally delivered into the house drains, etc. This being so, it is of the utmost importance to ascertain the fate of the pathogenic germs in the sewers.

Amongst the diseases which have been attributed to the contamination of drinking water with sewage, two stand very prominently in the foreground—viz., cholera asiatica and typhoid fever. Some observers have also held sewer air responsible for diphtheria, but it would appear that but a small part in the dissemination of this disease can be played by this cause.

As cholera asiatica was absent from London at the time of these experiments, Messrs. Laws and Andrewes were not able to discover Koch's comma bacillus in the

London sewage. They were, further, unable to find the diphtheria bacillus in it, though a careful look-out was kept for this organism.

Concerning typhoid fever, Messrs. Laws and Andrewes state there is no question that the specific poison of the "disease believed on very good grounds to be the bacillus typhosus of Eberth and Gaffky passes from the body with the fæces, and that the excreta of typhoid patients constitute the main channel of infection in this disease." They, therefore, searched for it very carefully in the ordinary sewage of London, taken at various places, but were never able to find it. They then came to the conclusion that the mathematical chances of ever detecting it in the ordinary London sewage were but extremely remote, as from an estimate of the reported cases of typhoid fever at the time of the experiments the sewage from the typhoid-fever patients could not form more than 1-250,000th part of the whole sewage.

In consequence of this they determined to analyse the sewage from the Eastern Hospital at Homerton, where there were at the time 40 cases of typhoid fever, many being acute cases suffering from diarrhœa. Here the drains are accessible at various places through manholes and inspection chambers, and the sewage, after its disinfection had ceased for two days, was taken at a manhole before it leaves the hospital. One would have expected that numerous colonies of bacillus typhosus were found in this sewage; but after very careful and most elaborate investigations, Messrs. Laws and Andrewes only found two solitary colonies. This is very remarkable, as undoubtedly there must have been a vast number of typhoid bacilli in the sewage when taken. In connection with this, it is stated in the report: "So far as we are aware, this important fact (that in the sewage from a typhoid block the typhoid bacillus can be found) has never previously been demonstrated."

After this result had been obtained, Messrs. Laws and Andrewes took a sample of sewage a quarter of a mile below the Eastern Hospital at Homerton, but were unable to find a single colony of bacillus typhosus in it. We must, therefore, conclude, that even in sewage, where according to our notions a great number of typhoid bacilli must exist, their detection is a matter of the extremest difficulty.

After making various experiments with a view to ascertaining the vitality of the bacillus typhosus in sewage, the authors conclude as follows:

"These preliminary experiments are necessarily very incomplete, and afford only an indication of the probable fate of typhoid bacilli which gain access in a living condition to sewage. It seems, however, clear that the sewage does not form a medium in which much, if any, growth is possible for them under natural conditions, and their death is probably only a matter of a few days, or at most one or two weeks. But this degree of resistance may, nevertheless, be sufficient to allow of their being carried in the sewage to remote distances, and of their being able to reproduce disastrous results should they gain access to any water supply. As our knowledge accumulates, it becomes more and more evident that water supply and, as an incidental result, our milk supply constitute the chief channels of infection by which typhoid fever is communicated, and this is true also of cholera, and possibly of other infectious diseases. It is, therefore, of the first importance to determine in an exhaustive manner how far sewage is a possible soil for the growth of these and other disease germs which admittedly gain access to it, and also to determine what precise influence their non-pathogenic companions may exert on them."

"In the conclusions to Part I. of this report we endeavoured to show that sewer air has no power of taking up bacteria from the sewage with which it is in contact. A strong argument in favour of this view is the fact that the very organisms which are most abundant in sewage are precisely those which are absent from sewer air. In the course of previous experiments on sewer air, the nature of the organisms in some 1,200 litres of sewer air was carefully determined. Not once was bacillus coli communis or any of the predominant organisms of sewage found, though we have shown above that the former is present in sewage in numbers varying from 20,000 to 200,000 per cubic centimetre. If this be so, how infinitely improbable becomes the existence of the typhoid bacillus in the air of our sewers. That sewage is a common medium for the dissemination of typhoid is certain; that sewage-polluted soil may give up germs to subsoil air is possible; but that the air of sewers themselves should play any part in the conveyance of typhoid fever appears to us, as the results of our investigations, in the highest degree unlikely."

APPENDIX IV.

Experimental Researches into the Causal Relations of Sewer Gas and Typhoid Fever.

1. *Experiment by Dr. T. H. Barker* (see also A-6 and A-50, App. I.).

The late Dr. Parkes reports in his "Manual of Practical Hygiene" an experiment made by Dr. H. Barker, as follows:

"Dr. Herbert Barker has attempted to submit this question to experiment by conducting the air of a cesspool into a box where animals were confined. The analysis of the air showed the presence of CO_2, hydrogen sulphide, and ammonium sulphide. The reaction of the gas was usually neutral—sometimes alkaline. The gas was sometimes offensive, so that organic vapours were probably present; but no analysis appears to have been made on this point. Three dogs and a mouse were experimented on; the latter was let down over the cesspit and died on the fifth day. The three dogs were confined in the box; they all suffered from vomiting, purging, and a febrile condition, which, Dr. Barker says, 'resembled the milder forms of continued fever common to the dirty and ill-ventilated homes of the lower classes of the community.' But the effects required some time and much gas for their production. Dr. Barker attributes the results, not to the organic matter, but to the mixture of the three gases, and specially to the latter two."

2. *Researches of Dr. G. Alessi* (see also A-4 and D-2, App. I.).

Perhaps the most careful investigations which have ever been made into the causal relations between putrid gases, including sewer air, and typhoid fever, are those conducted by Dr. Alessi in the Hygienic Institute of the University of Rome, and reported by him in the *Annals* of this institute for the year 1894. As I consider them of great importance, I had them translated, and the Sanitary Institute, sharing my views, was good enough to publish them in the *Journal* for 1895. I can in this place only give the outlines of these researches, but all those who wish to consult them more carefully can do so in the *Journal* just mentioned.

Alessi states at the commencement of his investigations:

"The fact (which with English sanitarians is a dogma of practical hygiene) that infectious diseases, and especially typhoid fever, are connected with bad exhalations is most important. The English hygienists, therefore, consider as injurious to health and life the emanations which may escape into houses through defective construction of sewers and closets, from accidental flaws in waste-pipes, or from any other imperfections in the system of the pipes for carrying away the refuse. And it is precisely this idea which has brought about the good hygienic arrangement in houses in England, to which also sanitary legislation has contributed, and the diffusion in a popular form of the rules necessary to protect houses from any putrid exhalations. This idea of the English hygienists having been carried out, has given the most magnificent results; therefore it is useful to see if it has any experimental scientific basis, and this is what forms the subject of this paper."

The plan on which Dr. Alessi conducted his experiments was as follows:

He took rats, guinea-pigs, and rabbits, exposed a certain number of them to the influence of putrid gases, including sewer gas; whereas the rest, as a control experiment, he kept under normal conditions, and after a while inoculated all of them with the bacillus of typhoid fever and the bacterium coli commune (called by some bacillus coli communis). He then most carefully observed and recorded the different results which this inoculation produced in both sets of animals, made sections of them as soon as possible after death, and besides instituting a very careful examination of the organs to reveal the macroscopic changes, he made cultures of them on gelatine plates, and took out anatomical pieces for the microscopic research of the bacilli.

After having thus completed the first part of his researches, he started a second set of experiments with a view to ascertain "whether the chemical substances which are commonly given out in a state of gas from putrid fermentations can also exercise separately a similar influence on the animal organism."

Concerning the way in which Dr. Alessi exposed the animals to the putrid gases it might be stated that the rats were placed in a box, the wire bottom of which closed the aperture of an untrapped water-closet; they were, therefore, exposed to the direct influence of sewer gas. The guinea-pigs and the rabbits were placed in a box, the wire bottom of which rested on a vessel containing excrementitious substances.

It is not stated whether these excrementitious matters were in a dry or liquid state, so that it is not possible to form an opinion whether in his experiments with rats Dr. Alessi wished to imitate the conditions prevailing in the water-carriage system of fæcal matters, and in his experiments with guinea-pigs and rabbits the conditions existing in conservancy systems; but be that as it may, no distinction is made between these two kinds of putrid gases in the report, and, indeed, the results obtained would not have warranted such a course.

The experiments throughout were conducted with the greatest care and precaution, and cannot fail to carry conviction to all those who read them; certainly, Dr. Alessi appears to have spared no pains to arrive at reliable conclusions.

For the inoculation with typhoid bacilli, he used two cultures, which he called A and B; culture A being derived from the laboratory of Prof. Koch, of Berlin, since 1889, and culture B coming from the collection of the Institute of Rome, where it was cultivated since 1887.

It would lead too far to follow Dr. Alessi into the details of his elaborate researches; suffice it to say that in his experiments with rats he used the A culture alone, of which he says its virulence might be considered almost nil, and that in his experiments with guinea-pigs and rabbits he used both typhoid cultures A and B. With bacterium coli cultures of attenuated virulence, he inoculated only guinea-pigs.

Looking at the whole of the experiments, it may be said that the virulence of the cultures and the doses used for inoculation were small.

It might not be out of place to mention here that the bacterium coli commune (called by some bacillus coli communis) is always found in sewage in large numbers, and is a common inhabitant of the bowels of human beings. It has frequently been mistaken for the typhoid bacillus, but is now generally considered harmless.

Dr. Alessi gives 14 tables in his report, from which I have compiled Tables I. to V., given at the end of this appendix on pages 127 to 130.

Table I.[1] gives the number of animals experimented on, and the results of the inoculation. For convenience of reference, I have in Table III.[2] summarised the mortality returns of all animals. On reference to these tables, it will be seen that from 75 to 100 per cent. of all the animals exposed to the putrid gases died after the inoculation, and that of all the animals not exposed to sewer gas, only 7 per cent. of the rats succumbed after this process. The figures are highly significant, and speak for themselves. It is further interesting to observe that rabbits appear to be less able to withstand the combined effects of sewer gas and inoculation than guinea-pigs and rats.

In the second table[3] I have given the time which has elapsed before the animals experimented on lost their natural immunity to typhoid infection and acquired the predisposition. From the facts there enumerated it would appear that again rabbits have a smaller resisting power than guinea-pigs and rats. Dr. Alessi observes:

> "It appears that generally the animals acquire the predisposition to infection more easily during the first two weeks than after that time. In fact, 90 per cent. of the animals inoculated in the first two weeks died, and only 76 per cent. of those inoculated in the following weeks."

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[1] Page 127. [2] Page 128. [3] Page 128.

"This fact may, in a certain degree, explain how it is that some individuals who habitually breathe air from sewers, or in whatever way corrupted, end by becoming habituated to it and are no longer attacked by intestinal infections."

Table IV.[1] gives the time that has elapsed between the inoculation and the death of the animals which had been exposed to putrid gases. No special order can be observed here, except, perhaps, that the rats after once they had lost their natural immunity to typhoid fell quickest a prey to the poison.

Table V.[2] contains the second set of experiments which Dr. Alessi made—after having studied the predisposing action of putrid gases taken in their entirety—with a view to ascertain whether the chemical substances which are commonly given out in a state of gas from putrid fermentations can also exercise separately a similar influence on the animal organism.

"It is known that 18 cubic metres of excremental matter can give out in 24 hours about 18 cubic metres of gas, of which 10 cubic metres are of fatty acids and hydro-carbons; from 5 to 6 cubic metres are of carbonic acid; from 2 to 3 are of ammonia; 20 litres of sulphuretted hydrogen."

"These gases, considered separately, constitute for man and animals the most poisonous substances, and their combination produces very rapid deleterious effects. It interested me to study their action on the animal organism in very small doses—certainly smaller than the minimum fatal dose—having reference to the possible conditions of air-pollution of houses, through gases arising from badly-constructed closets, filth, and other causes where the doses can only be found weakened, as

[1] Page 129. [2] Page 130.

even in such surroundings natural ventilation is constantly diluting these gaseous productions."

The substances used for these experiments were:

Retilindol (this is a very strong-smelling product of the putrefaction of albuminous substances, and can easily be found in the intestines);
Ammonia;
Sulphuretted hydrogen;
Methyl sulphide;
Carbonic acid;
Carbonic oxide; and
Ammonium sulphide.

These substances were put with the animals inside a large bell-glass, which was closed in such a manner as to make change of air impossible. After a certain time the animals were inoculated with typhoid bacilli in the same way as in the preceding experiments.

Dr. Alessi continues:

"Therefore the above-mentioned gases or vapours, taken separately, do not predispose animals to typhoid infection. In fact, in all the experiments only three animals died, and those from other causes which it was impossible for me to define. And not only did the gases taken separately have no predisposing effect, but even some of them when mixed; for which reason I may be allowed to suppose that both the exhalations arising from fæcal matter, and the exhalations arising from organic matter in putrefaction, are not composed of simple mixtures, but are much more complicated than might be believed. And the predisposing cause might also have its seat in those fetid substances of neutral character, which it is impossible either to understand or determine, whether from their small quantity, the insufficiency of analytical methods, or from the imperfection of those which we already have. In any case, from my experiments can be drawn this useful lesson: that the above-mentioned gases or vapours can be breathed in small doses without their predisposing to typhoid infection."

The conclusions at which Dr. Alessi arrived are stated by him as follows:

"From my researches, taken altogether, I think I am authorised to conclude that:

1. The inspiration of putrid gases predisposes the animals (rabbits, guinea-pigs, rats) to the pathogenic action of even attenuated typhoid bacilli, and of bacterium coli.
2. This predisposition is due to the combination of gases given out by putrid fermentations, and not to any one separately.
3. It is probable that this experimental predisposition is diminished by prolonged breathing of the said gases.

These conclusions, then, serve to confirm what some authors had epidemiologically foreseen, and social hygiene had practically and painfully confirmed."

TABLE I.—Dr. Alessi's Researches.
First Set of Experiments.
Influence of Putrid Gases upon the Animals experimented with.

First Set of Experiments. Experimental Series.	Animals Exposed to Putrid Gases.												Animals Not Exposed to Putrid Gases.											
	Rats.				Guinea-pigs.				Rabbits.				Rats.				Guinea-pigs.				Rabbits.			
	Inoculated.	Died.	Survived.	Percentage of Dead.	Inoculated.	Died.	Survived.	Percentage of Dead.	Inoculated.	Died.	Survived.	Percentage of Dead.	Inoculated.	Died.	Survived.	Percentage of Dead.	Inoculated.	Died.	Survived.	Percentage of Dead.	Inoculated.	Died.	Survived.	Percentage of Dead.
a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*k.*	*l.*	*m*	*n.*	*o.*	*p.*	*q.*	*r.*	*s.*	*t.*	*u.*	*v.*	*w.*	*x.*	*y.*	*z.*
First Series.—Inoculation with typhoid bacillus. Culture A	49	37	12	75·51	72	57	15	79·16	11	11	0	100·00	41	3	38	7·31	50	0	50	0·00	7	0	7	0·00
Second Series.—Inoculation with typhoid bacillus. Culture B					27	21	6	77·78	8	7	1	87·50					19	0	19	0·00	6	0	6	0·00
Third Series.—Inoculation with bacterium coli commune..................................					12	10	2	83·33									10	0	10	0·00				

NOTE.—The term "putrid gases" includes the term "sewer gas." The rats were exposed to sewer gas by placing them in a box, the wire bottom of which closed the aperture of an untrapped water-closet. The guinea-pigs and rabbits were placed in a box, the wire bottom of which rested on a vessel which contained excrementitious matter.

TABLE II.—Dr. Alessi's Researches.

First Set of Experiments.

Time necessary for the Animals to Acquire the Predisposition.

Kind of Culture Used.	Animals Experimented with.	Time necessary for the Animals to Acquire Predisposition.		
		Minimum Time.	Average Time.	Maximum Time.
		Days.	Days.	Days.
First Series. — Typhoid bacilli. Culture A.	Rats	5	22	72
	Guinea-pigs ...	7	18	58
	Rabbits	3	5	18
Second Series. — Typhoid bacilli. Culture B.	Guinea-pigs ...	5	6	21
	Rabbits	0	3	6
Third Series. — Bacterium coli.	Guinea-pigs ...	3	6	12

TABLE III.—Dr. Alessi's Researches.

First Set of Experiments.

Mortality Returns of all Animals.

Kind of Culture Used.	Animals Experimented with.	Percentage Mortality of all Animals.	
		Animals Exposed to Sewer Gas.	Animals Kept as Control under Normal Conditions.
		Per cent.	Per cent.
First Series. — Typhoid bacilli. Culture A.	Rats	75·5	7·3
	Guinea-pigs ...	79·2	0·0
	Rabbits	100·0	0·0
Second Series. — Typhoid bacilli. Culture B.	Guinea-pigs ...	77·8	0·0
	Rabbits	87·5	0·0
Third Series. — Bacterium coli.	Guinea-pigs ...	83·3	0·0

Table IV.—Dr. Alessi's Researches.

First Set of Experiments.

Time Elapsed between the Inoculation with the Bacilli and the Death of the Animals.

Kind of Culture Used.	Number of Animals Exposed to Putrid Gases.		Time Elapsed between the Inoculation with the Bacilli and the Death of the Animals.
First Series.—Typhoid bacilli. Culture A.	Rats	9	12 to 24 hours
	,,	25	24 ,,
	,,	3	24 to 36 ,,
	Total	37	Average, 23 hours.
	Guinea-pigs	18	24 hours
	,,	6	3 days
	,,	6	4 ,,
	,,	3	5 ,,
	,,	8	9 ,,
	,,	8	10 ,,
	,,	3	13 ,,
	Total	52	Average, 5 days 3 hours.
	Rabbits	3	2 days
	,,	4	3 ,,
	,,	4	4 ,,
	Total	11	Average, 3 days 2 hours.
Second Series.—Typhoid bacilli. Culture B.	Guinea-pigs	15	18 to 24 hours
	,,	3	30 ,,
	,,	1	2 days
	,,	1	5 ,,
	,,	1	6 ,,
	Total	21	Average, 1 day 10 hours.
	Rabbits	1	24 hours
	,,	3	2 days
	,,	3	3 ,,
	Total	7	Average, 2 days 7 hours.
Third Series.—Bacterium coli.	Guinea-pigs	1	8 hours
	,,	3	20 ,,
	,,	2	24 ,,
	,,	1	2 days
	,,	3	3 ,,
	Total	10	Average, 24 hours.

TABLE V.—Dr. Alessi's Researches.

Second Set of Experiments.

Experiments with Various Gases.

Substance Experimented with.	Animals Experimented with.	Day on which the Experiment began.	Day on which Typhoid Inoculations were made.	Animals Exposed to Sewer Gas.		Animals Kept as Control under Normal Conditions.	
				Inoculated.	Died.	Inoculated.	Died.
Retilindol	Rats.	24th May	5th June	1	0	1	0
	,,	24th ,,	28th ,,	5	0	4	0
Ammoniacal vapours	,,	7th July	23rd July	4	0	4	0
	,,	7th ,,	30th ,,	4	0	4	0
Sulphuretted hydrogen	,,	28th ,,	11th Aug.	8	1	4	0
Methyl sulphide ...	,,	16th Aug.	25th ,,	8	0	5	0
Carbonic acid	,,	29th ,,	7th Sept.	5	0	3	0
Carbonic oxide......	Guinea-pigs	13th Sept.	21st ,,	4	1	3	0
Retilindol and methyl sulphide...	Rats.	21st ,,	2nd Oct.	4	0	3	0
Retilindol, methyl sulphide, and ammonia	,,	6th Oct.	15th ,,	5	0	3	0
Sulphide of ammonia	,,	21st Sept.	2nd ,,	4	1	3	0
Sulphide of ammonia and methyl sulphide	Guinea-pigs	6th Oct.	15th ,,	4	0	3	0

APPENDIX V.

Explosions in Sewers and Cesspits.

1. *Explosion in one of the London Sewers* (see also A-44, App. I.).

The *Medical Times* of July, 1861, reports a case which happened in one of the London sewers. It appears some thieves entered a sewer with a view to stealing the stearine which had run into it in consequence of a fire the previous night. When attempting to light a match, an explosion occurred which not only singed them, but also acted as a prompt warning to the police to find out the whereabouts of these ingenious burglars.

It is surmised that with the stearine together inflammable fatty gases entered the sewer, which exploded when a naked light was applied to them.

2. *Explosion in a Cesspit at Mayence* (see also B-13, App. I.).

The *Deutsche Bauzeitung* of the 27th February, 1895, mentions the following case:

A public-house in Clara-street, Mayence, had two closets on the ground floor, which were connected with an arched-over cesspit under the street. The entrance to the latter was closed with a cast-iron asphalted cover in the causeway, and it was ventilated by a 3in. pipe, which higher up joined the rain-water down-pipe. Altogether, a not very sanitary or satisfactory arrangement.

One evening in the middle of February, 1895, the owner lighted his cigar in the room where one of the water-closets is situated, and threw the lighted match into the closet basin; whereupon, immediately and without any warning, a serious explosion, accompanied by great noise, took place. The cover of the cesspit—which, no doubt, was frozen hard to the ground—was burst open and thrown high into the air, damaging in its ascent portions of the cornice and roof of the building. Its contents were forced out of the two closets, and the owner had a very narrow escape.

The two closets had had to be thawed up every morning — February, 1895, being an exceedingly cold month; and it is surmised that the rain-water ventilating pipe was frozen up at the time the explosion took place. At any rate, it would appear that the gases forming in the cesspit could not escape through it and were forced up into the house. What their mixture and composition was has, unfortunately, not been ascertained, but it would appear as if coal gas could have played no part in it, otherwise the smell would have betrayed it.

3. *Explosion in a New Sewer at Burton-on-Trent* (see also A-16a, App. I.).

In this case an explosion took place in a new sewer at Burton-on-Trent on the 11th day of November, 1896, which was caused by a bricklayer, doing some pointing in the same, lighting a match. The force of the explosion was so great that the iron top of every manhole in the street was uplifted, and three were displaced. Houses were shaken, and the frightened inhabitants rushed out thinking that an earthquake had occurred.

The following is the account of the accident as reported in the *Burton, Ashby, and Coalville Guardian* of 14th November, 1896:

"People living in the vicinity of Alfred-street were greatly alarmed at seven o'clock on Wednesday morning by a loud explosion of gas in the deep sewer recently laid in that thoroughfare. It appears that a bricklayer named John Parry, living in Albert-street, and employed by Mr. Hodges, had descended the sewer through a manhole for the purpose of seeing if any pointing was required. He crawled along until he came to one of the manholes, where there was a great accumulation of gas, which the man evidently did not detect. He lit a candle and held it up, but the moment the light came in contact with the gas there was a terrific explosion throughout the whole length of the street. The force was so great that the iron top of every manhole in the street was uplifted, and three were displaced. Houses were shaken, and the frightened inhabitants rushed out thinking that an earthquake had occurred. The unfortunate man in the sewer managed to creep back to the spot where he had gone down, and was there rescued. He was almost suffocated, and was at once taken to the Infirmary. He was severely burnt about the face and arms, and the back of his hair and his whiskers had entirely disappeared. After he had been attended to by Dr. Sparks, the house surgeon, he was sent home. A boy who had gone down with Parry had a very narrow escape, for although he was not touched by the flame, he was knocked down."

APPENDIX VI.

Health of Sewermen.

1. *General Remarks.*

The statistical information concerning the health of sewermen is generally very incomplete, as the facts and figures have frequently had to be collected years after, and that, too, in a somewhat haphazard manner. The results of such enquiries are, therefore, in most cases not based upon a proper system of notification and tabulation, and must be received with a certain amount of caution.

Further, the information generally only deals with the workmen whilst actually employed in the sewers, but gives no clue as to the health of the workmen after leaving this employment, which, of course, is of the greatest importance when considering the influence of sewer gas upon health.

The information in most cases also refers only to the days lost through sickness, but does not give any idea as to the state of the health of sewermen before actually becoming unfit for work.

As to the length of time sewermen are employed in sewers, Prausnitz's labours for Munich, for instance, indicate that, out of the total number of men so employed, 43 per cent. only remain on an average 20 months in the sewers. (B-43, Appendix I.).

2. *Opinion of the late Dr. E. A. Parkes* (see also A-50, App. I.)

The late Dr. E. A. Parkes states on page 139 of the sixth edition of his "Manual of Practical Hygiene":

"It does not appear, therefore, that at present the workmen connected with fairly ventilated sewers show any excess of disease; at the same time it must be allowed that the inquiry has not been very rigorously prosecuted, and that the length of time the men work in sewers, their average yearly mortality, discharge from sickness, loss of time from sickness, and the effect produced on their expectation of life, have not been perfectly determined."

Parkes further mentions that whereas Guy and Parent-Duchâtelet deny that typhoid fever is more common among sewermen than others, Murchison and Peacock state that this disease is not uncommon among sewermen.

3. *Cases reported by Gaultier de Claubry* (see also C-3, App. I.).

G. de Claubry mentions four cases of real asphyxia and 20 of threatening asphyxia in 10 workmen who had been taken to the hospital after having been at work in the sewers for only about six months. One workman had no less than four attacks.

4. *Observations of Hankel* (see also B-24, App. I. and 11, App. VII.).

Hankel reports that cases of light poisoning through sewer gas are very common amongst the Paris sewermen. They distinguish two kinds. The first kind they call "la mitte"—vapour. This can last for several days, but leaves no ill-effects behind. It consists in great irritation of the mucous membrane of the nose, with decreasing secretion of the same, severe pains in the sockets of the eyeballs reaching as far as the frontal cavity, swelling and inflammation of the conjunctiva, photophoby, leading sometimes to complete darkening of the eyesight. It is probably brought about by ammonia or sulphuretted hydrogen, or through a combination of both gases.

The second kind of poisoning is called "le plomb"—lead—and derives its name probably from the feeling of heaviness in the head and limbs. It is caused by sulphuretted hydrogen.

5. *Sewermen at Munich* (see also B-43, App. I.).

Prausnitz examined the health of the sewermen at Munich, and came to the conclusion that they did not suffer more from illness than other workmen. From the figures given by this observer the rather remarkable circumstance can be deduced, that out of a total number of 42 sewermen, 43 per cent. remained on an average only 20 months in the sewers. No reason for this is given in the report, although it would have been of the greatest importance to ascertain whether or no the cause of this short service in the sewers was in any way connected with the impaired health of the men.

6. *Sewermen at Wiesbaden* (see also B-9, App. I.).

It has not been observed at Wiesbaden that sewermen suffer to a larger degree than others from epidemic diseases, but they are more subject to rheumatic complaints than other men employed by the town authorities. It should be observed here that the Wiesbaden sewers are comparatively new, having only been in use a few years.

7. *Health of London Sewermen* (see also A-58, App. I.).

Stevens mentions that the London sewermen complain about sore throats and rheumatism. He was not able to discover that they suffered from typhoid fever, and only found one case of diphtheria amongst them. He is of opinion that the time lost through sickness by them is not greater than that lost by other workmen, that they are able to work long in the sewers, and that their majority dies at an advanced age.

APPENDIX VII.

Some Authentic Cases of Mephitic Poisoning through Sewer Gas.

1. *Poisoning Case at Clapham* (see also A-18 and 31, App. I.).

In a case at Clapham the emptying of a privy produced in 23 children violent vomiting and purging, headache, and great prostration and convulsive twitching of the muscles. Two died in 24 hours.

2. *Deaths of Four Men in a Sewer in the City of London* (see also A-43, App. I.).

The *Medical Times* of February, 1861, reports a case in which four men perished in a sewer in the neighbourhood of the Thames. The post-mortem examination revealed that three men were suffocated by carbonic acid gas; but the late Dr. Letheby, M.O.H. City of London, expressed at the coroner's inquest the opinion that three men were killed by sulphuretted hydrogen gas, and that the fourth was drowned.

3. *Case reported by Gaultier de Claubry* (see also C-3, App. I.).

Gaultier de Claubry mentions a case where 12 workmen who had entered a sewer uttered cries one after another, became unconscious and asphyxial. When they were removed from the sewer it was found that eight were only slightly affected, and the remaining four so much that they had to be sent to the hospital. One of the latter died, but the other three recovered consciousness after several hours, and could be discharged after six days.

4. *Case reported by Hallé.*

Hallé reports that three workmen in a cesspit were overcome by the gas and that two died before they could be rescued.

5. *Chevalier* (see C-2, App. I.), *Blumenstock* (see B-7, App. I.), *and Thierling* (see B-59, App. I.) *mention similar cases of Mephitic Poisoning.*

6. *Case reported by Caspar* (see also B-11, App. I.).

Caspar reports a case where 10 men, working in a tannery, bored a hole in a tank containing hides undergoing the process of maceration. Some of the liquid containing 13 vols. of sulphuretted hydrogen escaped, and the workman who endeavoured to ladle it out of the pit suddenly fell down dead. The others ran to his rescue, but six of them died on the spot, and the rest only recovered after having been ill for some time.

7. *See also item 4 under "Health of Sewermen" in App. VI.*

8. *Accident in the Paris Sewers.*

Four men lost their lives in the Paris sewers about the year 1880.

9. *Case reported by Finkelnburg* (see also B-20, App. I.).

Finkelnburg reports a case which shows how quick and how serious the action of sewer gas can be upon human beings.

The basement of a house of detention, which is 4ft. below the level of the courtyard, was flooded to the depth of several feet by the backing up of sewage from the sewer. Not far from the rooms thus flooded, prisoners were at work during the day making brushes, and of these, 13 became so seriously ill that they had to be taken to the hospital, whilst some of the others did not feel the effects of the sewer gas in so decided a manner. Most of the men fell ill on the day after the sewage had been pumped out, during which operation a pestilential smell pervaded the premises.

10. *Fatality in a* New Sewer *at East Ham, near London, 1st July*, 1895 (see also A-25, App. I.).

A very sad accident happened at East Ham, near London, on the 1st July, 1895, by which five men lost their lives in one manhole.

At the point where the main outfall—a new egg-shaped sewer, 4ft. 6in. by 3ft.—enters the pump well, screens have been put up with a view to catch the rough, floating matter. These screens are accessible by means of a shaft 27ft. deep, closed with a ventilated cover.

It appears that on Monday morning, 1st July, 1895, a man named Digby went down this shaft with a view to clean the screens, after the cover had been removed for about 15 minutes. When halfway down he said he felt faint and would return to the surface for a short time. However, on reaching nearly the top of the ladder, he collapsed and fell down the shaft into the sewage. King, the man on the surface of the ground in attendance on Digby, called at once for help, when three men—named Rutter, Mills, and Durrant—went down the shaft and disappeared clean. The last man to go to the rescue was Jones; but he, too, being overcome by the gas when reaching the bottom, fell against the grating, and remained with his head above the sewage perfectly still, in an apparently lifeless condition.

When the next man, Herbert Worman, descended, he too, had to return, owing to feeling ill from inhaling the gas. A bucket containing lighted coal was then lowered into the well, and as this seemed to burn all right, Worman descended again, and brought Jones to the surface, who was then still breathing. Efforts were at once made to revive animation, which proved so far successful that he was removed to the West Ham Hospital, where, however, he died on Tuesday morning.

When the other four bodies were brought up, it was found that life was quite extinct. One poor fellow's face and head were frightfully swollen, and various marks about the nostrils, mouth, and eyes showed that he had died from suffocation.

A post-mortem examination was made on the body of Durrant, and at the inquest Dr. Smith stated that, as the result of the autopsy, he was of opinion that Durrant had died from asphyxia resulting from drowning.

Concerning the man Jones who, as already mentioned, died after admission to the hospital, the following report of the inquest is taken from the *Times* of the 8th August, 1895:

"The adjourned inquest on the body of Frederick David Jones, age 28, who died in the West Ham Hospital on the morning of July 2nd, took place at the King's Head, Church-street, West Ham, yesterday evening. Jones was one of the five men who went down a manhole at the East Ham sewage works, and there became unconscious through meeting with foul gas. When they were extricated, four of the men were dead, having been drowned. Jones was unconscious when taken out, he having fallen on the top of a grating. Charles King, labourer in the employ of the East Ham District Council, was called, and the evidence he gave at the other enquiry was read over. He detailed how the men went down the manhole and disappeared. Dr. Stuart Ryall Blake, house surgeon at West Ham Hospital, deposed that after the deceased was brought to the hospital artificial respiration was resorted to for 2½ hours, while brandy was administered and the stomach-pump used. He never recovered consciousness, and died the next morning. Witness was of opinion that he died from poisoning by sulphuretted hydrogen. Mr. W. H. Savage, surveyor to the East Ham District Council, stated that since the accident a cradle had been obtained, and it was lowered with the men, so that they could be taken up at a moment's notice. In addition, acting on the advice of Dr. Haldane, a mouse or a bird had been lowered each time the men went down, and no foul gas had been discovered. The Council had also determined not to have any part of the manhole covered up, and had also provided a respirator which would enable men to go down amongst any noxious gas. The jury returned a verdict that death was due to suffocation by sewer gas."

The widow of the man W. T. Digby brought an action against the East Ham Urban District Council for damages for the loss of her husband. The following is the account of the second trial as taken from the *Standard* of 25th May, 1897 :

"*Digby v. East Ham Urban Council.*—In this case Mrs. Esther Martha Digby, the widow of the late W. T. Digby, sued the East Ham Urban Council to recover damages on behalf of herself and her children for the loss of her husband. The deceased was in the employment of the defendants, and in July, 1895, went down a manhole on their sewage works, when he was suffocated in consequence of an escape of noxious gas. The plaintiff's case was that his death was caused by the defective condition of the defendants' works, or through their negligence, or the negligence of those engaged by them in superintendence. The defendants denied the plaintiff's statements, and a good deal of scientific evidence was called on both sides. This was the second time the case had been tried, as Mr. Justice Cave non-suited the plaintiff, and the Court of Appeal granted a new trial. Altogether five men died from the gas, and this was a test case. Mr. Ruegg, Q.C., Mr. J. D. Crawford, and Mr. Edmond appeared for the plaintiff; and Mr. Dickens, Q.C., and Mr. W. Ellis Hill for the defendants. The jury found a verdict for the plaintiff for £225. Judgment accordingly."

11. *Observations by Dr. Hankel* (see also B-24, App. I.).

Hankel states that in human beings four different forms of poisoning by sewer gas can be distinguished—viz., the mild form, the fairly severe form, the severe form, and the chronic form.

A. *The Mild Form.*—In the mildest cases the feeling of a heavy load upon head and chest is experienced. This feeling is well known amongst sewermen. If the case becomes more severe, other symptoms, such as vomiting, severe pains in the abdomen, breaking of wind strongly smelling of sulphuretted hydrogen, and eructation, have been observed. The pulse becomes small, the breathing quick and laboured, the patient feels giddy and very weak, especially in the muscular parts.

B. *The Fairly Severe Form.*—In fairly severe cases the skin becomes cold and covered with cold perspiration. The patient begins to feel sick, and frequently complains of pains in the stomach and joints and of a feeling as if the throat was closing up. Delirium, convulsive twitchings of the muscles, fainting fits, singing and talking, have frequently been observed at this stage. The latter is so well known to the Paris sewermen that they call it "chanter le plomb," which might be rendered by "the lead song."

After this follows unconsciousness and convulsions, chiefly of a tetanic nature. The pupils of the eyes become enlarged and the lips and the face blue and cyanotic.

C. *The Severe Form.*—In cases of this kind the death of the workman is frequently instantaneous. He enters the sewer or cesspit and collapses there all at once as if he had been hit by a bullet. Sometimes it has also been observed that the workman has uttered a cry and then had severe convulsive fits, with vomiting and spontaneous secretion of fæces and urine; foam covered the mouth, and the patient either died at once or remained unconscious for a long time.

D. *The Chronic Form.*—This form has been observed in labourers employed in chemical works who had drank water containing sulphuretted hydrogen, and in miners employed in the coal mines at Auzain.

The symptoms were pronounced anæmia, pressure in the stomach with pains, and pulse sometimes quick, sometimes slow. The strength of the patient diminished, the pains in the stomach gradually ceased, the skin became yellow, and profound perspiration commenced. The stomach became blown, and the stools contained pus.

In the case of the miners frequently sudden death took place, whereas in the case of the labourers of the chemical works furuncle or similar diseases in the neck, face, and skin supervened.

12. *Case reported by Hankel* (see also B-24, App. I.).

A very interesting case is reported by Hankel, which happened at Glauchau, in the kingdom of Saxony, on the 18th January, 1895.

A plumber, 26 years old, and to all appearances in good health, had been sent by his master to a house to thaw up the water-closets on the ground floor which, owing to the severe frost, had become frozen. He was known to be a steady, sober fellow.

At 3.30 p.m., when someone had been speaking to him, he appeared all right, and made no complaint whatever, but at 5 p.m., when the coachman came to look after him, he found him dead in the room with his trousers half off. Although the coachman had left the door open, upon entering he felt giddy and faint, owing to the pungent and suffocating nature of the air in it, and when, after an hour, Hankel, the medical officer of health, examined the place, he reports the air in the room made him feel dazed, and caused eructation.

In the house in question, the water-closets drain into a cesspit, and it appears that the poor fellow had for some reason or other, after lighting a coal fire in the room, opened the cover of a 4in. pipe which is directly connected with the cesspit, and the only use of which appears to be for inspecting and cleansing purposes. Up this pipe the gases seemed to have found their way from the cesspit into the water-closet room, and it is surmised that the plumber began to feel sick and wanted to use the water-closet, but before he could do so he fainted and fell, unfortunately, so that h face was close to the 4in. pipe, up which the gases ascending from the cesspit entered his mouth and nose, and so caused eventually his death. The seat of the water-closet was covered with fresh excreta, and the clothes of the plumber were soiled with vomited matter, defæcation having taken place of its own accord. The face was not distorted after death, and there is no reason to assume that the poor fellow had convulsions.

Although efforts were at once made to restore life, and were continued for some considerable time, they proved in the end fruitless.

Hankel then gives full details of the post-mortem examination, which, as he says, he was able to carry out under very favourable circumstances, and comes to the conclusion that the cause of death was asphyxia resulting from the inhalation of sewer gas. The autopsy seems to have revealed very little characteristic for such a death.

13. *Death in London Sewers* (see also A-42, App. I.).

Mr. T. de Courcy Meade states that in the summer of 1894 two men lost their lives in the London sewers.

14. *Death of Three Men in a Sewer at Widnes, Lancashire* (A-67A, App. I.).

A very sad accident happened on the 27th day of January, 1896, at Muspratt's Chemical Works, Widnes, Lancashire, in which three men lost their lives.

It appears that Patrick Fahey and Luke Farrell were engaged in cleaning out a sewer, when they were overcome by sewer gas. Their dangerous position becoming known, Thomas Atherton pluckily descended the shaft to rescue them. He, however, was also soon overpowered by the gas, and before the three men could be got up they had perished by falling into the liquid.

At the inquest, the medical man who saw the bodies when they were brought up from the sewer stated it as his opinion that the gas from the effects of which they had died was sulphuretted hydrogen.

15. *Death of Five Men from Sulphuretted Hydrogen at the Tynemouth Gasworks* (A-65A, App. I.).

A very sad accident, in which five men perished, happened at the Tynemouth Gasworks, North Shields, on the 20th January, 1896. This fatality shows what a very powerful poison sulphuretted hydrogen is and how very quickly it acts.

In this case, it appears, the valve in front of the purifiers had been left open by a quarter of a turn, and when two men descended into the tank to remove the foul oxide of iron they were immediately and without any warning overcome by sulphuretted hydrogen and fell down, apparently in a fit. Three men at once went to their rescue, but they shared the same fate, and when removed out of the tank it was found that in every case life was extinct.

16. *Death of One Man in a Sewer at Harpurhey, near Manchester* (see also A-40A, App. I.).

In this case, a man named Charles Jones, aged 52, was, whilst working in one of the Manchester sewers, overcome by sewer gas, and when removed to the surface life was found to be extinct.

The following is the account of the inquest as reported in the *Manchester Guardian* of 24th September, 1896:

"Mr. Smelt, the city coroner, held an inquiry yesterday respecting the death of Charles Jones, 52, a miner, lately living in Higher Burton-street, Queen's-road, who was poisoned by gas whilst working in a sewer at Harpurhey on Tuesday morning. The evidence was to the effect that the deceased went down a shaft which had been sunk in Henhurst-street, Queen's-road, for the purpose of driving a heading to find an old sewer. Jones probed with a rod in the direction of the sewer, and an outrush of gas which came from it overpowered him. Patrick Devine, who was at the top of the shaft, raised an alarm, and some men who came up, at his request, lowered him down the shaft. Just as he reached Jones, he called out that he wanted to be pulled up. The request was responded to, but when he had been lifted five or six feet he fell upon his mate, being overcome by the gas. Another labourer named Higgins then volunteered, but he suffered in a like manner. Some buckets of water were thrown down the shaft, after which a man named Lewis went to the rescue of the three workmen. He succeeded in sending up Higgins and Devine, and Jones was brought to the surface by another. Jones and Devine were taken to the Royal Infirmary. The former died from the effects of the poisonous gas, and Devine is still an in-patient, but is recovering. The jury returned a verdict of accidental death. The coroner commended Higgins and the others for their bravery, and expressed a hope that the attention of the Corporation would be drawn to it. Mr. Miller, from the town clerk's office, watched the proceedings on behalf of the Corporation."

APPENDIX VIII.

Cases of Septic Poisoning through Sewer Gas.

1. *Case of Poisoning at Sutton Coldfield* (see also A-33, App. I.).

The medical officer for Sutton Coldfield, Warwickshire, Prof. Bostock Hill, reports in the August number of "Public Health" for 1895 a very interesting case, in which he comes to the conclusion that very probably the septic poison was introduced through sewer gas. It might not be out of place to give here a short description of the leading features of the case.

The proprietress of the Wylde Green Hotel, at Sutton Coldfield, had during Christmas, 1894, cooked a soup, and gratuitously distributed the same in the neighbourhood for the benefit of the poor. This soup was prepared from a large piece of salted beef, pearl barley, peaflour, and vegetables, to which the broth in which a rabbit had been boiled was added, the rabbit itself having been eaten at the hotel for dinner the previous day without any symptoms of poisoning.

The soup was boiled in a large iron boiler in an outhouse of the hotel on Friday afternoon, the 28th December, 1894, and left standing in the same, loosely covered, till the next day, Saturday morning, about 11 o'clock, or about 18 hours, when it was distributed.

On the 1st January the attention of Prof. Hill was called to an outbreak of poisoning in the neighbourhood of this hotel, which was locally attributed to the consumption of this soup, and which affected about 100 persons, all of them having partaken of it. He describes the symptoms of the illness as follows:

> "The chief symptoms were pain, swelling of the abdomen, and purging, followed in some cases by vomiting. The purging generally lasted a considerable time, in some instances many days, despite medical treatment. Great coldness, with pains in the limbs (said to be in the bones by the patients), were complained of in many instances, and in one case a child nine years old was unable to use his legs sufficiently to walk for many days after the onset of the first symptoms. I found that the symptoms in nearly all cases did not come on for many hours, in some cases as long as 30, after taking the soup, and this, in my opinion, contra-indicates the presence of any form of mineral poisoning."

Unfortunately, one patient died.

Dr. Hill, who is at the same time professor of hygiene and public health and lecturer on toxicology at the Mason College, Birmingham, examined the soup and its constituents to see whether it contained arsenic or another mineral irritant, but found no such poison in it. No suspicion could be attached to the water from which the soup was made, as this was taken from the mains of the company which supply the district, the sanitary arrangements of the hotel were good, and after a very careful consideration of all circumstances it appeared that the soup had become toxic independent of the meat from which it had been made, and that the outbreak of poisoning was due to the presence in the soup of ptomaines or other substances generated from animal matter.

The boiler, which was said to have been used for the boiling of clean water only, is fixed, as already mentioned, in an outhouse, which is under the same roof as a stable and separated from it by a wooden partition, in which there is a door. On the floor of the stable there is a drain grating, and at the end of the outhouse near the boiler runs up the ventilating pipe of the house drain, while about 20ft. away, and up the side of the hotel itself, there is a large ventilating shaft connected directly with the main road sewer.

Concerning the state of the public sewer in the neighbourhood of the hotel, Prof. Hill remarks:

"The sewer at Wylde Green has been for years notoriously a stinking one. To obviate the nuisance caused to residents and those travelling along the road, the crown ventilator at this part of it was stopped up, and by permission a large 6in. shaft was erected against the wall of the hotel. That gases of an offensive kind were given off from this, I know to be the case, because nuisance had been complained of by the proprietress of the hotel in one of the rooms close to where it was fixed; and to obviate this nuisance a register grate had been put in, so that the evil-smelling gas might be shut out from the room. . . . ."

"These facts may, I think, throw some light on the matter. It is quite likely that on the Friday night sewer gas was discharged from the sewer ventilators, and as this became colder it would become heavier, and therefore fall if not rapidly diffused. This being so, it is highly probable that some descended the chimney of the outhouse, and gained access to the soup in the boiler, and in this way started septic change. It is, of course, impossible definitely to say that this was the case, but bearing in mind that the symptoms point to the poison being septic, or of animal origin, I cannot at the present time discover a cause more likely to have produced the outbreak."

That the gases escaping at the top of a soil-pipe sometimes descend again is, I believe, an admitted fact, and I have repeatedly observed it when smoke-testing the drains of a house. In support of this, Prof. Hill quotes his experience on two occasions in the winter of 1895, when he observed in his own house smoke from another chimney descending and entering a room in which there was no fire. This happened each time in the evening, and although the cold chimney through which the smoke descended had a good draught when there was a fire in it.

Whilst the medical officer was engaged in these investigations one of the patients died, and in consequence a portion of the soup was forwarded to Dr. Klein for bacteriological examination. It is to be very greatly regretted that this course was not at once adopted after the outbreak, as the soup was nearly three weeks old before Dr. Klein could examine it; and although January was a cold month, it is clear from Dr. Klein's report that fermentative changes had taken place in it.

As this report is of considerable importance, I will give it here in full, as follows:

"On January 24th, I received a glass jar of fluid material, tied with a membrane. The material in the jar had, on opening, a sour smell, and gave a strong acid reaction. It was a thick film, containing various vegetables, fat, and bits of flesh. Under the microscope, besides these substances, there was seen a multitude of microbes; in fact, the whole material was crowded with them. Amongst these could be recognised various forms of bacilli, differing from one another in length, and numerous yeast cells. Cultivations were at once made, so as to isolate the microbe. These cultivations yielded the following microbes in colonies: (1) torula, or yeast, very copiously present; (2) a short non-mobile bacillus, not liquefying gelatine, fairly abundant; (3) a bacillus which proved on sub-culture to be closely related to the typical bacillus coli—this microbe is the normal inhabitant of man and animals, and is a prominent microbe in sewage: in the soup it was present in considerable numbers; (4) a bacillus which also proved on sub-culture to be closely related to the bacillus coli, but must be considered as a variety of the typical bacillus coli—it is also a normal inhabitant of sewage, and was present in enormous numbers in the soup. Experiments were made with the soup and with the cultivations obtained from it: (*a*) feeding mice with the soup produced no ill-effect; this result does not prove much, since the time that had elasped since the consumption by human beings at Wylde Green and the experiment made here was considerable, and as it is known that organic substances, poisonous at one time, lose their action when exposed to fermentative changes; (*b*) inoculations of guinea-pigs with cultures of the microbes (3) and (4) bacillus coli and variety proved these microbes to be virulent, particularly microbe (4), which is highly virulent; (*c*) inoculation of guinea-pigs with microbe (1) and (2) had no ill-effect; (*d*) microbe (4) multiplies extremely rapidly in beef-broth kept at a body temperature—that is, about 37deg. C.—which turned the broth very turbid in 24 hours, the broth being filled with microbes. In addition, there are present by this time numerous flocculi entirely made up of the bacilli. If the broth culture is subjected to filtration by which these bacilli are separated from the fluid, and this latter is injected in small quantities (0·5 c. c.) into guinea-pigs, it is found that they die in from six to eight hours under symptoms of acute poisoning. From this it is then clear that this microbe is capable of rapidly forming in the broth a poisonous chemical substance. In conclusion, from the foregoing observations the following conclusions can be drawn: (1) the soup contained microbes which were derived from sewage, and it is thereupon highly probable that the soup had been polluted with sewage. Amongst the microbes present in the soup, the bacillus mentioned as a variety of the bacillus coli is possessed of virulent properties on account of its extremely rapid multiplication at the body temperature, and the poisonous substance it elaborates. It is most probable that this microbe caused the consumers of the soup the ill-effects and the disease. This bacillus, it will be remembered from the foregoing paragraph, was present in the soup in enormous numbers."

After making further investigations into the possibility of the pollution of the soup with liquid sewage, either intentionally by some evil-disposed person or accidentally by leakage from some pipe or otherwise, Prof. Hill concludes:

"I have previously remarked that the night was a cold one, so that the sewer gas coming from the top of this shaft would become heavier as it cooled, and would thus tend to sink lower in the atmosphere; and my belief is that this sewer gas in question did gain access to the outhouse by way of the chimney, and that in this way the soup was contaminated with those micro-organisms which were found by Dr. Klein. I do not by any means lay this down dogmatically, but after a very careful consideration of all the local circumstances, I see no method more likely of contamination of the soup with the micro-organisms of sewage."

2. *Cases reported by Dr. Fenton* (see also A-26, App. I.).

In the discussion on Dr. B. Hill's paper, given above, Dr. Fenton, the medical officer of health for Coventry, related two cases of meat-poisoning which had occurred within his own knowledge.

In the first case, a piece of green salted pork had been exposed in a pantry over an untrapped drain, and had produced choleraic symptoms, although nothing could be found by Dr. Klein.

In the second case, beef exposed to sewer gas had produced severe alkaloidal poisoning in those who had partaken of it.

APPENDIX IX.

Cases where Outbreaks of Typhoid Fever have been Traced to Sewer Gas.

1. *Buchanan's Historical Cases* (see also A-13 to 16, App. I.).

It is not contended that the late Sir George Buchanan was the first to trace outbreaks of typhoid fever to emanations from the sewers, but it is perhaps correct to say that he was the first to systematically investigate several such outbreaks, and to attribute them to this cause as a result of his researches. It would lead too far to give particulars of his classical investigations, and such a course would be further hardly necessary, as they are well known. I will, therefore, only mention that in the epidemics of typhoid fever at Worthing in 1865 (Ninth Report Medical Officer of the Privy Council), and at Croydon in 1875 (Appendix to Report Medical Officer of the Privy Council and Local Government Board, New Series, No. VII.), Buchanan came to the conclusion that sewer gas had entered the interior of the houses and thus brought about the outbreak, whereas in the local epidemic of typhoid fever at Caius College, Cambridge, in 1874 (Report Medical Officer of Privy Council and Local Government Board, No. II., 1874), he was of opinion that sewer gas entered the water-supply pipes, and thus brought about its pollution. Concerning the Worthing epidemic, Buchanan remarks that, in his opinion, the absence of any attempt to ventilate the sewers, and the fact that sewer gas had been forced up into the houses through the water-traps of sinks and water-closets was the cause of the outbreak. As a positive demonstration of this he mentions the following facts :

> "The fever almost exclusively attacked well-to-do houses on the higher levels, where the water-closets were inside the houses, and almost entirely spared the houses, mostly of a much poorer sort, situated on lower levels, where the closet was put outside the house. It was not so in the times of cesspools; then these low-lying poor houses were far more attacked with fever than the others. Moreover, the fever subsided as soon as openings were made into the sewers, from certain houses where it before maintained itself for months." (Quoted by L. Parkes in "Is Sewer Air a Source of Disease?")

In reference to the epidemic in Croydon in 1875, Buchanan remarks (quoted by L. Parkes in the same place):

> "Where sewers are small and ill-ventilated they constitute perfectly sufficient means for the rapid distribution of fever infection; and places having such sewers may not only show fever rates maintained as high as before the sewers were made, but they may show as smart outbursts of fever as are witnessed where conveyance through water or milk is in question. Croydon itself, after it had made its sewers and before it attempted to ventilate them, had this experience. So in other instances that have come under my personal knowledge, fever has maintained itself after pipe sewers, ill-ventilated, had been made, as in Rugby, in Carlisle, in Chelmsford, in Penzance,

in Worthing; in the last two places breaking out in severe, sudden, and diffused epidemics, without there being any question of other distribution than by sewers."

2. *Cases reported by Dr. Blaxall* (see also A-9 to 11, App. I.).

An outbreak of enteric fever at Melton Mowbray in 1880 was traced by Dr. Blaxall to the occurrence of floods, which caused the backing up of sewage specifically infected by typhoid evacuations in the flat sewers, and thus forced the sewer air to enter the houses through untrapped drain inlets and dry water-closet traps.

The same observer reports an outbreak of enteric fever at Sherborne in 1882, which, in his opinion, was caused through the contamination of the water-mains by sewer air, the water-closets of houses being in direct communication with the water-supply pipes.

3. *Case reported by Dr. Airey* (see also A-3, App. I.).

An outbreak of enteric or typhoid fever at York in 1884 was traced by Dr. Airey, of the Local Government Board, to "the exhalations from the ill-ventilated sewers under the influence of a very dry and warm season."

4. *Great Number of Other Cases.*

A very large number of other cases could be quoted—in fact, it is not too much to say that every year fresh cases are reported by medical officers of health and general practitioners in which the cause of an outbreak of typhoid fever is attributed to sewer gas; but, although some of them have been investigated with great care, it would lead too far to mention them here separately. It must suffice to say that in this country it is almost a doctrine of practical faith that there exists a causal relation between sewer gas and typhoid fever, and that this doctrine is supported by strong evidence. Those who wish to study this question more in detail will find ample material in the reports of the medical inspectors of the Local Government Board and in the annual reports of the medical officers of health, not to mention the cases which are from time to time reported in the medical and other periodicals (*Lancet*, *British Medical Journal*, *Health*, etc.).

I will only quote two more cases, which have happened within the last few years.

5. *Enteric Fever at the Foundling Hospital*, 1891, *reported by Dr. John F. J. Sykes* (see also A-61, App. I.).

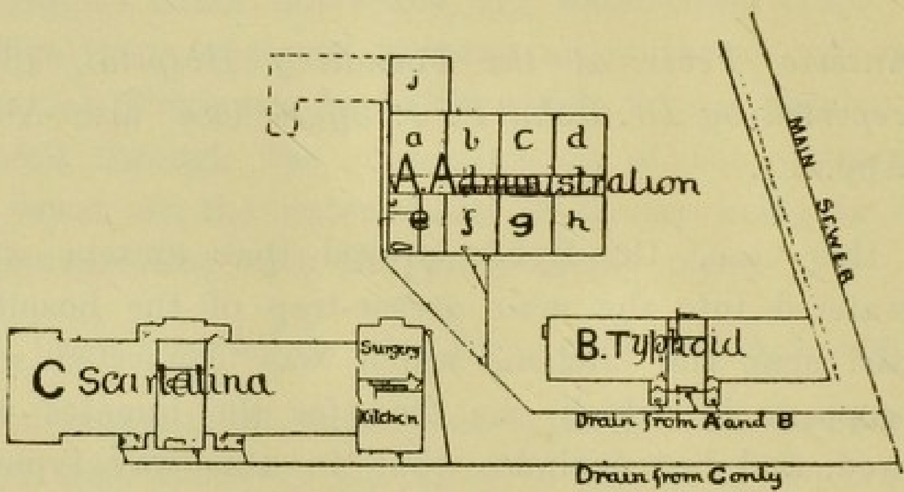
In this case, Dr. Sykes proved that excreta were backwatered into the main grease-trap of the hospital, situated near the kitchen, which was connected with the coppers in which the food for the inmates was prepared, and he concludes that in this way typhoid stools got into the grease-trap, which would undoubtedly form a very good incubation chamber, whence, borne by the sewer air, the typhoid germs found their way through the coppers into the kitchen and house. During cooking, the taps in the pipes leading from the coppers to the grease-trap would, of course, be closed, and the typhoid germs in the coppers destroyed through the heat necessary for this process. After the food had been served and consumed, the taps in the coppers would be opened for cleansing, and it was probably the sterilisation that saved the food supplies from infecting the whole of the residents in the institution.

The report contains many points of interest, and is well worth a careful study.

6. *Outbreak of Typhoid Fever at a Fever Hospital at Leeds* (see also A-17A, App. I.).

In the *Surveyor* of the 29th October, 1897, the medical officer of health for Leeds, Dr. J. Spottiswoode Cameron, reports the following case:

"The hospital buildings consisted of three blocks, roughly indicated on the diagram. Block A was a disused township workhouse, which, along with block B,



a one-storey building erected by the Guardians many years before for ordinary hospital purposes, was purchased by the Town Council for treatment of small-pox in 1872. When the outbreak was over, these buildings were used by the Corporation for the isolation of other diseases. Block A, the original workhouse, was utilised as an administration block, but occasionally typhoid patients were admitted, generally into the room on the first floor marked *a*, less frequently into that marked *b*, and even occasionally into *c* and *d* on the first floor. The motions of such patients, after disinfection, were passed down the basin of a recently-constructed long hopper water-closet on the first floor, built off a passage which intersected the house north and south. Room *e* on the first floor was occupied by a nurse, *f* was a linen-closet, *g* a nurses' bedroom, and *h* the matron's bedroom; all these on the first floor. On the ground floor under *e* was a bathroom, adjacent to which, and immediately under the one on the first floor, was a water-closet opening off the passage. The rooms under *f* and *g* were kitchens, *h* was the matron's sitting-room. The remaining rooms were only used for storage. There was ample cellerage, chiefly under *f* and *g*. The bathroom wastes and kitchen wastes were disconnected from the drains, but the keeping cellar under *f* had a trap in the floor. In B, the sink in the nurses' kitchen was disconnected outside over a gully in the ordinary way; the two water-closets in B each had a second trap; they were then connected with the drain coming from the one-storey washhouse, *j*, and taking also the drainage from the two water-closets, the disconnected bath wastes, the disconnected kitchen wastes, and the undisconnected waste from the cellar; all from the building A. The Corporation erected a new and separate pavilion, C, which was opened in 1881. The drainage of this building was conducted by an entirely separate drain to the main sewer in the street. The water-closets in this building were entered each through a separate cross-ventilated ante-room from the ward; each closet soil-pipe was doubly trapped; the bathroom wastes were disconnected outside, as were also the waste from the kitchen and surgery. At the time the limited outbreak of typhoid occurred, block B was used for typhoid patients, block A only for administration, block C entirely for scarlet fever.

Within a few days of one another (I am now speaking from recollection) two nurses attending typhoid patients in B, and sleeping in A, but not in any way engaged in C, two children who had gone home from C convalescent, and who had never been in B, and a day or two later one or two other children patients in C, sickened, evidently with typhoid. The husband of the matron, resident as caretaker of the establishment but living entirely in A, had also a feverish attack, but not very well defined. The only food common to all these patients was milk, some of the children in C having had at the time of the attack no other food than milk, and all the other patients having had milk, the caretaker least. The first thing done was to direct that the milk brought to the hospital should be taken to each separate block. Before it had all been taken to A, where it was kept in the cellar, *f*. This precautionary measure was adopted before the diagnosis was quite certain. We then obtained from the milkman a list of all the farms from which he got any milk. We found no evidence of fever at any of them or among any persons working there. Moreover, the persons among whom the same milk dealer distributed his milk elsewhere in the town were not specially attacked by typhoid fever, which existed, but to no very marked degree, in the borough, and not more among this man's customers than among those of other dealers. It would thus seem that if the milk were the cause of the typhoid, it had received the infection after it reached the hospital. No new case of typhoid occurred which could have received the infection after the date when the milk was delivered directly to the separate blocks. It seemed, therefore, probable that the milk received the infection in the cellar. I am not able to say whether there was any water in the trap connecting the small grate in the cellar floor with the drain. There was no trap in the cellar, and it is not impossible that the trap may have been dry. My own reading of the case was that through this trap the milk had been infected by typhoid poison from the drain. It was found afterwards that the soil-pipe from the block A had been badly connected with the drain, and that fæcal matter had collected at the base. Three conditions seemed to have conspired to infect the milk: (1) the actual typhoid germ; (2) the culture medium of filth; and (3) the opportunity for sewer gases to pass into the milk. I use the words 'sewer gases' as Mr. Roechling does—to signify not only gases but solids carried by them. The trap was in the cellar floor. The stone table on which the milk was kept was some 3ft. higher. If my supposition be correct, the bacteria must have travelled for a considerable distance *through the air* in order to reach the milk. The evidence that it was the infection of the milk that caused the outbreak rested principally upon the fact that some children whose only food was milk, and who were entirely separated from the nurses (who also drank milk, but who did not enter the block in which these children were), developed the disease at about the same time as these nurses, and that no fresh case received the infection after the milk ceased to be placed in the cellar."

7. *Case reported by H. Alfred Roechling* (see also A-52D., App. I.).

Mr. Roechling reports a case of typhoid fever in a house with faulty drainage in the *Journal* of the Sanitary Institute for 1897, Vol. XVIII. The case was carefully examined by him, and is in many respects interesting; it is accompanied by a plan of the premises.

8. *Cases reported on the Continent.*

A number of cases in which sewer gas is said to have led to an outbreak of typhoid fever are reported by German writers, and Dr. Uffelmann, who was a prominent sanitarian and a very careful observer, maintained that it was an established fact, that houses into which sewer gas entered periodically were frequently visited by diphtheria, malaria, and typhoid fever. At the meeting of the German Association of Public Health in 1895, Dr. Goepel (see B-23, App. I.) reported an interesting case from Frankfurt-on-the-Oder, where a house was never without a typhoid-fever case until the drainage was seen to and improved.

Further particulars will also be found in the very interesting investigations of Dr. Lissauer (B-36, App. I.) at Danzig, concerning the entrance of sewage gas into houses.

APPENDIX IXa.

Other Effects of Sewer and Cesspit Gas not previously referred to.

1. *Case of Blood-Poisoning through Sewer Gas* (see also A-21A, App. I.).

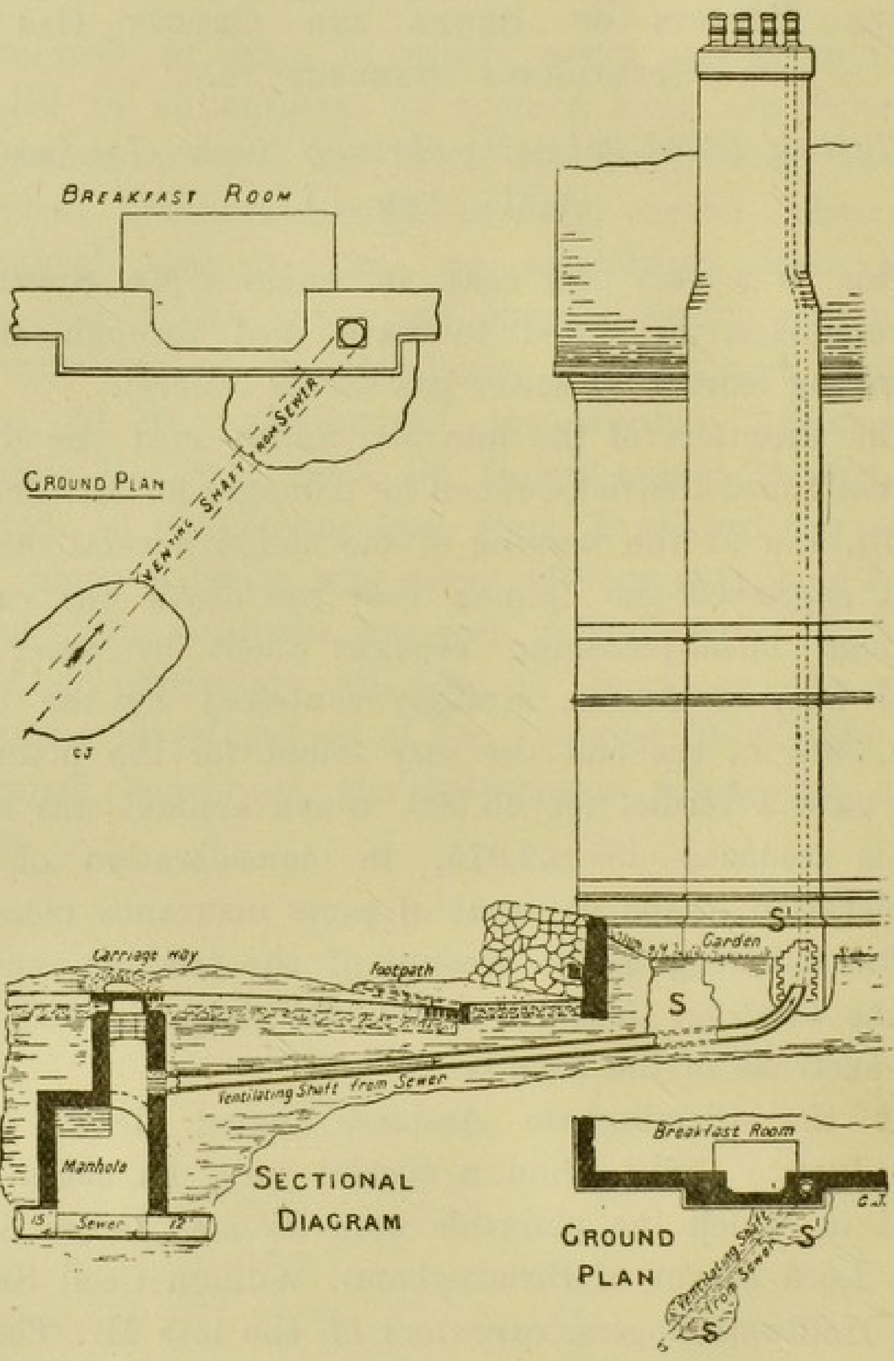
This is a very sad case, in which a Mr. Smith, of Birmingham, is stated to have died through blood-poisoning caused by sewer gas (*cause célèbre*).

The executors of the late Mr. Smith sued the King's Norton Rural District Council for damages for Mr. Smith's death, and at the hearing of the action several medical men expressed the opinion that the death was caused through blood-poisoning brought about by sewer gas. This was, of course, strongly contested by the other side, but in the end the jury found for the plaintiffs, and gave a verdict for £3,500, which amount was afterwards reduced to £2,875, in consideration of the acceleration of the payment of some insurance money.

The following is the account of the trial as reported in the *Contract Journal* of the 12th August, 1896, with the sketches of the locality:

At the Birmingham Assizes, August, 1896, before Mr. Justice Collins and a special jury, an action was tried in which the plaintiffs were Messrs. James Smith (the Lord Mayor of Birmingham), William Cecil Smith, and Halliwell Rogers, executors of the late Mr. Thomas Henry Smith, and the defendants the King's Norton Rural District Council. The action was brought in the interest of the widow and six children of the deceased gentleman to recover damages for negligence.

The deceased gentleman had lived at Daylesford, Wake Green-road, Moseley, and it was alleged on behalf of the plaintiffs that he died from illness caused by the



defendants wrongfully breaking, and entering, and putting, and continuing to maintain, a ventilating shaft from a sewer into a chimney of Daylesford, or alternatively that the defendants constructed the work in a negligent manner, or allowed the same to get into bad order, whereby sewer gas, in or about January last, escaped into the house, and caused the illness and death.

The defendants denied that damage had been suffered through their negligence; that they had been guilty of negligence; that they carried a ventilating shaft from the manhole into the chimney; or that any sewer gas escaped.

Mr. Murphy, Q.C., and Mr. Hugo Young (instructed by Messrs. Ryland and Co.) appeared for the plaintiffs; and Mr. Jelf, Q.C., Mr. Alfred Young, and Mr. Pritchett (instructed by Mr. Edwin Docker) for the defendants.

In opening the case, Mr. Murphy said the enquiry would be of an important character to both parties, important to the executors, who claimed compensation for the loss of a valuable life in which they were interested, and to the defendants, because if the plaintiffs' case was well founded there had been very great neglect, for which they ought to be made responsible. The late Mr. Smith had been the tenant since 1890 of Daylesford, which fronted Wake Green-road and School-road, Moseley. On January 9 last he disclosed symptoms of blood-poisoning, and on April 28 he died. A post-mortem examination showed that the view of the doctors was correct, and that it was a case of blood-poisoning caused by sewer gas. The defendants were the King's Norton Rural District Council, and by the terms of a recent Act of Parliament the responsibilities and liabilities of the former sewer authority became vested in them. In the month of December Mr. Smith suffered from sore throat, which might or might not have been connected with the sewer gas. On January 6, Mr. Augustus Clay was called in. He prescribed, and his attention was drawn to the possibility of the illness occurring from the state of the drains. Upon enquiry it was found that the drains had been examined in 1889, and everything that was then known to be necessary was done. At a subsequent date Dr. Carter was called in, and afterwards, in February, Sir Willoughby Wade, who came to the conclusion that the illness was consistent with an escape of sewer gas. The family were alarmed, and one of the present plaintiffs, Mr. James Smith, applied for the assistance of the sanitary inspector of the Corporation of Birmingham to assist in finding out what was the matter. On February 28 he communicated with Mr. Houghton, the sanitary inspector of Moseley, and an examination was made. In the cellar was discovered an escape of some deleterious gas, which, however, was not sufficient to account for the condition of the deceased. Subsequently a more exhaustive inspection was made, and as the defendants would give them no information, the parties acting for the plaintiffs made a trench round the house, and found a pipe running from a manhole at the corner of School-road and Wake Green-road, which pipe was continued up the flue of the house chimney. In its course it passed the library in which Mr. Smith passed his evenings and the bedroom in which he slept. The occupants of the house knew nothing about that shaft, but Mr. Godfrey, the chief surveyor of the defendants, knew, for the flue was constructed to his knowledge and under his superintendence in 1885. On discovery of that, a smoke test was applied, and it was found that smoke put into the drain at the manhole ascended into the library and the bedroom, and when put in at the other end came out at the manhole. The shaft was constructed in a most negligent and slovenly manner. The joints did not fit, and in one place there was a complete aperture. There was an imperfect obstruction at the manhole, consisting of brickwork with the mortar still wet. Mr. Murphy went on to say that in 1884 the land was vacant, and permission was given to the local authority to run up a ventilating shaft by the side of a tree. In 1885 Mr. Gough wanted to build a house on the land, and he submitted plans. He complained of the ventilating shaft against the tree, and asked for its removal. Mr. Godfrey claimed the right to keep it there, or to get some exchange for it, and he pressed Mr. Gough to give him a ventilating shaft to run up the chimney of the house, and permission was given. Mr. Murphy then indicated the extent of the deceased's business and the pecuniary loss which his family had suffered.

The medical evidence was first taken.

Mr. Augustus Clay, surgeon, Moseley, said he attended the late Mr. Smith during his illness, being first called in on December 23. He had a sore throat and slight febrile symptoms. The next day he went to his office for a few hours. Witness did not see him again until January 7, when he had a sore throat, fever, and bronchial catarrh. Witness suspected some form of blood-poisoning. On January 11 Dr. Carter was called in in consultation, and on February 17 there was a marked change in deceased's condition. He then had pneumonia of the right lung, which continued until his death. On discovering the pneumonia, there was another consultation with Dr. Carter; and on February 27 Sir Willoughby Wade was called in. He entirely agreed that deceased was suffering from blood-poisoning in some form. On March 2 deceased was removed to witness's house. Sir Willoughby Wade said the drains about Daylesford must be examined. As time progressed the patient became weaker, and on April 23 he died very suddenly from blood-poisoning. A post-mortem examination was made. The blood-poisoning was such as he should expect to find in a man who had been exposed to sewer gas.

By Mr. Jelf: From his enquiries he found that the deceased gentleman had had pneumonia about five years ago, and was then dangerously ill. About the end of the second week in January witness formed the opinion that deceased was suffering from blood-poisoning. Witness was assured by the relatives that the drains were all right. Besides deceased, there lived in the house Mrs. Smith, several children, and servants. Assuming the drains at Daylesford, apart from the ventilating shaft, were defective, he should not think that would be sufficient to set up the blood-poisoning; but assuming there was pent-up sewer gas in the drains, of course it would be very dangerous. He did not know that the whole state of the drainage was very defective, had been condemned, and had had to be reconstructed. He should say deceased, who was 51 years of age, was ordinarily a very healthy man.

Dr. Carter spoke to seeing the late Mr. Smith five years ago, when he was ill from pneumonia. He was then living at Daylesford. In the last illness, witness was called in on January 11. He found deceased in a very weak and prostrate condition, without anything of an obvious character to account for it. Witness formed the opinion that the cause of the illness was exposure to insanitary influences, and he made enquiries. He agreed with the symptoms described by Mr. Clay. In his judgment death was due to blood-poisoning, which was such as would be caused by exposure to sewer gas.

By Mr. Jelf : Blood-poisoning might arise quite independently of insanitary conditions. Supposing it turned out that Daylesford was in a shockingly insanitary condition, that might be amply sufficient to account for all he found.

By Mr. Murphy: Whatever mischief there might be locally, the connection with the sewer would aggravate it.

Sir Willoughby Wade said he was called in first on February 27, and then, from the state of the patient's throat and from the history of the case, he formed the opinion that he was suffering from blood-poisoning. Sewer-gas poisoning most frequently attacking the throat, he formed the opinion that the illness had arisen from a cause of that kind. His subsequent visits to the deceased confirmed his first impression.

Mr. Hugo Young: Supposing other people in the house suffered from carbuncles and boils, to what would you attribute them? Sir Willoughby Wade: They might arise from sewer gas.—That would be a symptom of blood-poisoning from gas from a sewer? It might be so.

Cross-examined: Sewer emanations of any kind might produce infectious disease in the absence of any ventilating pipe from the main sewer. At his suggestion the drainage about the house was examined.

Mr. Arthur Knight, son-in-law of the deceased, said that in April, 1895, he stayed at Daylesford for some time, and after he had been there a few weeks he suffered from carbuncles and boils. He had never suffered from them before. In 1896 he was at Daylesford again, and again had another attack of carbuncles and boils.

Cross-examined: He never noticed that the cellar, the closets, or the bathroom were insanitary.

Miss Jessie Smith, daughter of the deceased, stated that in November, 1894, she suffered from an abscess, and afterwards from a succession of boils. She went away from home and soon recovered.

Dr. Melson was called to speak to an illness of deceased about five years ago, and, in reply to Mr. Jelf, he said the question of the condition of the drains never came up. Mr. Smith completely recovered from that illness, and witness considered him a strong man.

Miss Dora Smith, another daughter of deceased, also spoke to suffering from a number of carbuncles and boils in April, 1895. In July, last year, her mother suffered from very much the same thing. Up to 1894 none of them suffered from carbuncles or boils.

Dr. Ratcliffe gave evidence to attending Miss Jessie Smith in her illness. He enquired as to whether the drains were right, because he could find no other cause for the abscess or boils.

Mr. J. Parker, inspector of nuisances to the Birmingham Corporation, said that on February 28 he went to Daylesford, with an assistant named Keasey, and made an inspection. He found defects, but not then sufficient to account for the illness. On a subsequent occasion he tested the ventilating shaft and other pipes, and found them very defective. The fumes from a ventilating shaft in the chimney found their way into the library and bedroom. It was absolutely wrong to turn a ventilating shaft into a chimney, as was done in this case.

By Mr. Jelf: In the cellar, immediately beneath the library, there was a gully stopped up. In it there was a quantity of what appeared to be decomposed urine. There were three ventilating spaces in the cellar. The walls of the cellar were damp. He did not go on the inspection in any official capacity. He went at the request of the Mayor, and at his expense.

Mr. Jelf: Is it usual for the officers of these different bodies to go out and take part in matters against local authorities in the neighbourhood around ?

Mr. Parker : It is not unusual.—You are the inspector of nuisances for the city.

Mr. George Robinson, builder's agent, having given evidence,

Mr. W. Martin, architect and surveyor, stated that on March 7 he made an inspection of the house. The smoke test was applied downwards from the shaft to the manhole, and they saw it coming through the "patch," covering what had been an outlet from the drain to the manhole. The mortar was wet. The upward test filled the library and the bedroom with smoke. The jointing of the ventilating shaft was defective. On March 19 he saw Mr. Godfrey, who was very indignant, saying that the covering from the drain to the manhole had been interfered with. The hammering from the inside by a rod pushed down the drains would probably displace the brickwork.

By Mr. Jelf: The house was built by a Mr. Gough, now deceased.—Mr. Jelf: Is he a jerry builder? Witness: He was what is known as a respectable jerry builder. He was one of the best of his class in Birmingham.— Not a sort of man you would entrust with any important drainage? He was a man who would think of himself. Witness added that he had never before heard of a ventilating sewer in connection with a flue.—Mr. Jelf: Do you say it is never done, when you want to ventilate the upper part of a sewer, to take the sewage gas by a pipe up by the side of the house? Mr. Martin: No.— Assuming it had been taken up in a pipe outside the stack of chimneys, and not inside, you would not say that was anything improper or unusual? If it is taken high enough above the windows.—Supposing it is taken in a proper pipe inside a separate flue, you would say it is the same thing? I should want it carried to a great height above the top of the chimney. Witness explained that if the pipe were not carried well above the chimney pipe, the fumes, in the event of several chimney flues standing together, would be apt to ascend one flue and descend another.

Mr. F. W. Martin, son of the last witness, corroborated his father's evidence.

Other witnesses were then examined.

Mr. James Smith, Lord Mayor of Birmingham, and brother of the late Mr. T. H. Smith, said the latter was a very strong man. When at home his brother chiefly used the library. His business was that of wholesale stationer. He was in partnership with his father. By an agreement made in 1885 deceased was entitled to two-thirds of the profits of the business. Deceased managed the business, his father having retired. In order to carry on the business since his brother's death, they had had to incur expenses to the amount of £339 a year. The average profits for the last three years had been £1,672 per year. He estimated the decrease in the future earnings owing to his brother's death at 25 per cent.—£418 per year—reducing the total to £1,254. From that he deducted also £339, money paid for extra assistance, leaving the widow's two-thirds share at £610, as against £1,115, or a loss of £505. Taking the life of the deceased at 51, and capitalising it upon a 3 per cent. table, gave £7,035. Deceased was insured for £2,500, and the premiums were £88. 15s. per annum. He had passed as a first-class life since his previous illness.

This completed the case for the plaintiffs.

Mr. Jelf, in opening the case for the defendant authority, expressed their deep regret at the termination of so valuable a life. He maintained that there was no liability whatever, on any theory, on the part of the defendants for anything that had happened. He described the history of the property, and said that in 1891 Mr. Essex, the architect, asked that the exit in the manhole should be closed up. That was the vent-hole over which they had got to fight out the battle. Was the opening from the manhole stopped up or not? That was the real battle-ground. He should call Mr. Godfrey and Mr. Essex, and the jury would hear the arrangements that were made with them. He would also call the bricklayer who was employed to put in the barrier, and which was done in cement, and by which the shaft was effectively shut off. Since then several people had seen the manhole, and the aperture had always been closed. Mr. Jelf complained strongly that the manhole and sewers were overhauled in the absence of anyone representing the defendants, and said that amongst so many people there was no difficulty in imagining that someone, thinking he was doing a very clever thing, pulled out some of the brickwork and put in other. When they were pounding away with a rod to try and find an exit, that would naturally shake the bricks, and might even produce dislocations. When people went down into the manhole once and could not find anything, and when, three days afterwards, a beautiful patch appeared, it looked uncommonly as if something had been done. Mr. Murphy was going to try and put it on to his (Mr. Jelf's) clients, but they would tell them that they knew nothing about it. Naturally, when Mr. Godfrey, the defendants' surveyor, discovered what had been done, he was very angry. Which was the side that had acted perfectly above board? When there were investigations, the plaintiffs' agents took care that no one else was present, whereas the defendants always invited the other side to their inspections. In the correspondence which had taken place the defendants had called attention to certain acts of trespass and damage by reason of the manhole having been entered, but no answer was made to this charge. He described it as a dirty and unhandsome thing for the plaintiffs' agents to go to the premises unknown to the defendants. If he was right in saying that the opening into the manhole was bricked up in 1891, what did it matter whether the pipe was taken up or not? If the bricking was effectual, as he should show it was, then there was no case. Speaking of how the deceased gentlemen met his death, Mr. Jelf said he did not think there was much doubt that it was due to something in the nature of a septic affection in the throat—that it was something which exhibited signs of some specific disease. A specific disease of that kind was not contracted by being taken direct from sewer gas. It was a thing which was apt to come from all kinds of causes, only it was most likely to attack those who had been predisposed to it. It was a vicious complaint which flourished best on the soil which was best prepared for it. In the constitution of a person exposed to insanitary conditions, it was very likely to have very injurious effects. If the house was in a bad sanitary condition in regard to its own drains—supposing it were bad enough—that would be amply sufficient to account for the preparation of the body for the disease which came to Mr. Smith without anything coming from the shaft. Mr. Jelf laid stress upon the unhealthy condition of the cellar, where, he said, there was a gully absolutely stopped, and where decomposed urine lay. This was directly under the library, and not far from the bedroom. The boards over the cellar and forming the library floor were so far apart that one could see through them. The fire would be eminently calculated to draw up exhalations from the place below. He did not think they need go | any further than that. Deceased's illness, which might have been caught anywhere, was aggravated by the conditions of the house.

Mr. Godfrey (examined by Mr. Jelf) said that he remembered Mr. Essex, the architect, calling and stating that he was preparing plans for the erection of certain houses. Witness, on being asked about the shaft, said that he had no objection to the shaft being removed from the tree if Mr. Essex would give a new shaft up the house. Ultimately it was decided to have the shaft in the chimney. By arrangement with Mr. Essex he laid tapering pipes from the sewer to the boundary of the house, Mr. Essex undertaking, on behalf of his client, to carry the shaft up the property. The sanitary authority had nothing to do with the ventilating shaft. In February, 1891, he was asked by Mr. Essex to brick up the opening from the manhole into the shaft, and he promised to do so. Up to 1895, when the new authority came into power, the roads were in the hands of the surveyor of highways. From 1891 until 1895, the road was repaired and raised from time to time, with the result that the manhole became gradually covered. In 1895 he became surveyor of the roads, and having occasion to find the manhole he found that someone had interfered with the brickwork, and that mortar had been removed.

Mr. Oliver Essex, the architect, also gave evidence as to the negotiations. He said that he did not understand

Mr. Godfrey to insist on the right to maintain the tree shaft or have a *quid pro quo*. Mr. Godfrey suggested the alternative.

By Mr. Murphy: He should not like such an arrangement in his own house.

Charles Brown, sewer foreman, deposed that in February, 1891, he received orders from Mr. Godfrey to brick up the connection between the manhole and the shaft, and he accordingly gave instructions to Sawyer. Witness superintended the work, which was done with brindled bricks and Portland cement. The work was properly done, and the cement must have set in 20 hours. In 1895 witness saw the manhole in the same condition as when he built it up in 1891, the bricks and cement being in good order. In February, 1896, he examined the drainage of the house from the outside. The syphon to the cellar was choked and full of solids, the result, in his opinion, being that the water from the lavatory went back into the cellar. Up to that time he had no idea that there was a cellar drain. The water falling from a height under such conditions would tend to go both ways—into the cellar and into the sewers. The lavatory pipe, however, was cut off when it joined the cellar drain. Such a condition of things would render the house unhealthy. There was also a defective soil-pipe, and altogether the house, on account of the state of its own drainage, was an insanitary dwelling. On March 19, under the direction of Mr. Godfrey, he examined the manhole. At one place he found green soft mortar. He and Mr. Webb took the whole of the bricks out, leaving the opening as it was early in 1891, only a little smaller. He saw something like whitening trickling out, and also found some at the back of the bricks. Mr. Lowcock and Dr. Hollinshead went down. The opening was left open for about a fortnight, and was then bricked up again. When he met Mr. Parker and others at the house, witness had a plan of the house, which was laid out on the kitchen dresser so that all present could see it. The plan was not kept back from anybody.

Re-examined by Mr. Jelf, Q.C.: The state of the house drains would fully account for all the bad smells. He had never tried whether a rod of the kind produced either with or without a heavy ball at the end would displace a piece of 4½in. brickwork.

William Henry Blundell, labourer, examined by Mr. A. Young, stated that under the direction of Mr. Godfrey he took part in fixing the brickwork. He went down the manhole in 1895, and found the brickwork all right.

A workman named Marshall gave similar evidence as to the state of the brickwork in 1895. If there had been anything wrong with it, he would have seen it.

By Mr. Murphy: He did not know anything at the time about the ventilating shaft.

Charles Harry Webb, assistant surveyor, examined by Mr. Pritchett, said that when the manhole was examined on March 19 he found that the joints of the brickwork had been raked out with a knife or something of the kind. The whitening had just oozed through, but was not trickling down the sides of the manhole. The bricks had been disturbed, and were set in green mortar. The old cement, quite hard, was still adhering to the brickwork. That was his first knowledge of the existence of the shaft. He had never heard of anyone connected with the authority interfering with the brickwork, and he did not know anything previously of the existence of the shaft.

John Houghton, assistant inspector of nuisances, who took part in the examination of the manhole, examined by Mr. A. Young, stated that there was not the slightest sign of percolation through the brickwork. He did not know of any tampering with the brickwork on the part of the defendants. No objection was made, as far as witness was aware, to anyone seeing the plans.

By Mr. Murphy: He knew nothing about the ventilating shaft previously. This was surveyor's work, and he was inspector of nuisances. He was a party to the report made by Mr. Brown which referred to some "serious defect which at present we cannot localise." That report was made on February 28, but the inspection of the house drains was not completed until March 3. A defect in the junction between the iron pipe and the earthenware pipe was discovered on February 29. This was outside the house, but it would account for the "serious defect," the discovery of which the report had anticipated.

Mr. Sydney Richard Lowcock, of 35, Waterloo-street, Birmingham, Associate of the Institute of Civil Engineers, declared the house to have been extremely insanitary, quite apart from the question of the ventilating shaft. The drain in the cellar, which was not shown on the authorised plan, was quite enough to account for any illness that had arisen. There ought not to be a drain in the cellar at all, because such a drain was likely to get dry, and so unsealed. On any defect arising in the connections, there was a danger of refuse and bad smells backing up into the cellar. There were other defects in the drainage. The emanations from defective house drains were likely to be a great deal worse than those from a well-built sewer. The connection of rainwater-pipes directly with the drains was universally acknowledged to be a source of danger. A gentleman sitting up late with a fire in his room would be very likely to breathe the foul gases from the cellar. On March 14, attention having been called to the existence of a ventilating shaft, he went down the manhole. He found that the vertical joints of the brickwork had been opened to such an extent that Dr. Fosbrooke, who went down with him, could push a wooden foot rule right through. If the rod produced were pushed down the pipe, it would be quite sufficient to displace 4½in. brickwork.

By Mr. Murphy: It would be quite possible, even if the bricks were found all right in 1895. If a great pressure could not be brought to bear with such rods they would not do for clearing out drains, which was what they were made for. Accumulations of soapsuds and bath waste generally would cause emanations quite as injurious as those from any other source. The lavatory must have sent deleterious matter into the drain in question.

W. Wright, formerly a clerk in the employ of the authority, produced a wages-sheet showing that a man was paid in 1891 for blocking up the foot of the ventilating pipe.

Dr. Saundby expressed the opinion that the state of things disclosed as to the house drains was sufficient to account for Mr. Smith's illness and death. Even supposing there were an influx of gas from the public sewer, that was not likely to be more than a predisposing cause of such disease.

Dr. George Fosbrooke, medical officer of health for Worcestershire, deposed to visiting the house on March 19, and expressed agreement with the opinions of Dr. Saundby as to the cause of Mr. Smith's illness.

By Mr. Murphy: You would rather expose a patient to a good blast of sewer gas than to what has been described as existing in this house? I think that the gases emanating from the drain would be worse than those from the sewer.—You would prefer the sewer? Yes.—Would you like to have a shaft from the sewer in your chimney? Not unless it were tight.—In a jerry-built house? Not unless it were perfectly tight.—You would be afraid of it? Yes.—You would not like to have your children in the house? No.

Dr. Francis Hollinshead, medical officer of health to the defendant authority, also declared that the state of the house drains fully accounted for the illness.

By Mr. Murphy: You agree with the opinions expressed by the other doctors? Well, not quite. There is a question in my mind as to whether it was true septicœmia or not. It is very difficult to say where ordinary sore throat ends and septicœmia comes in.

By Mr. Jelf: Don't you think that the gentlemen who saw this patient would be quite as good judges as to the symptoms as those who did not, if not better? Possibly.

This closed the case for the defence; and counsel on each side having addressed the Court,

His Lordship, in summing up, said that the questions to be decided by the jury were, Was Mr. Smith's death caused by the escape from the sewer ventilator, and, if so, what damages should be given? Many points arising in the case had been agreed upon. The case for the plaintiff was a straightforward one. There could be no doubt that Mr. Smith, immediately before these symptoms appeared, was in robust health, and it was no longer in dispute that death was caused by blood-poisoning. Neither was it disputed that the presence of sewer gas would be a sufficient cause of blood-poisoning which might result in death. If the jury found that sewer gas got into the house through the ventilator, they were confronted with another problem—namely, the alternative raised by the defence: that the more probable cause of the symptoms was the condition of the drains, as to which a considerable amount of evidence had been tendered by the defence.

The jury retired shortly before five o'clock. They several times called for their custodian, but only to ask for refreshment and to state that there was no prospect of them agreeing. Ultimately the judge was sent for, arriving at a quarter to eight.

The Foreman informed his Lordship that the jury were unanimous as to the death being due to an escape of sewer gas from the ventilator, and that eleven of them were agreed as to the question of damages.

His Lordship asked the jury if he could help them in any way. He thought it would be a pity if a special jury in the city of Birmingham could not decide a question which was settled almost every day by a sheriff's jury.

The dissentient juryman said that he thought the damages agreed upon by his colleagues most excessive.

His Lordship said that in assessing damages in such a case they should take into account the time of life at which the man died, how long he might have lived, and what he might have made for his family. From that they would have to deduct his personal expenses; but, on the other hand, they must take into account the provision of a person in his stead to manage his affairs.

A further consultation having proved unavailing, his Lordship advised the jury to look at the matter in the spirit of compromise. It would be a public scandal if, after two days of assize, they failed to agree on the question of damages. He must ask them to address themselves to the question again.

After another little talk the Foreman stated that one man seemed to have made up his mind. Practically there was no hope of agreement unless the eleven gave way to the one.

"The one" informed his Lordship that he had already met his colleagues by £1,000.

The Foreman: It is only a question of years of life that we cannot agree upon, and there is only a difference of two years between us.

The jury, after another short dispute, agreed upon a verdict for £3,500.

On Thursday morning, 6th August, 1896, his Lordship heard the defendants, represented by Mr. J. R. Jelf, Q.C., Mr. Alfred Young, and Mr. Pritchett, on the questions of law. Mr. Hugo Young appeared for the plaintiff.

In the first place, Mr. Jelf applied for a reduction of the damages in respect to the insurance, pointing out that, whereas the jury had assessed the loss at £3,500 capitalised, the family would receive, with the insurance, £6,000, which passed absolutely into their own hands. It was submitted that an allowance should be made in respect to the accelerated payment of the premiums, 14 years being mentioned.

Mr. Hugo Young claimed that 8½ years, as the presumed basis of the jury's finding, should guide his Lordship. He further contended that the policy was an investment, capable of treatment like unto that of the rest of his property.

Mr. Jelf applied that judgment should be entered for defendants. The jury had only found on one single fact out of all the facts involved. They had found that sewer gas from the shaft was a cause of death.

The Judge: *The* cause.

Mr. Jelf submitted not. He held there was nothing to show that what came from the shaft was not assisted in producing death by other causes.

Eventually the Judge allowed a reduction in the damages of £625 for the acceleration of the payment of the insurance money. He entered judgment for £2,875 as against the District Council, and stayed execution for 21 days.—*Birmingham Post*, 5th, 6th and 7th August, 1896.

2. *Case of Diphtheria attributed to Cesspit Gas. Damages Awarded* £50.

The following account is taken from the *Journal of State Medicine* for August, 1897:

"*Deaths from Diphtheria—Action for Damages.*—An action has just been tried before Mr. Justice Wills against the owner of certain cottages at Bexley Heath for negligence in allowing a cesspool to become a nuisance. The plaintiff lost three children through an attack of diphtheria, which it was alleged was caused by the effluvium from the defective cesspool, and sued for damages. Mr. Justice Wills held that the defendant was liable, and gave judgment for £50 damages and costs.

APPENDIX X.

Influence of Sanitary Works upon the Mortality from Typhoid Fever.

1. *Investigations of the late Sir George Buchanan* (see also A-14, App. I.).

On page 35 of the annual report of the Medical Officer to the Privy Council for the year 1866, the late Sir George Buchanan gives the following classical table, which clearly illustrates the influence of sanitary works upon the health of towns at that time:

Table I.—Mortality from Typhoid Fever in Various English Towns before and after the execution of Sanitary Works.

Buchanan's Table.

Population 1861.	Towns.	Periods of Comparison before the Construction of Sanitary Works.	Periods of Comparison after the Construction of Sanitary Works.	Mortality from Typhoid Fever per 10,000 Inhabitants. before the Construction of Sanitary Works.	Mortality from Typhoid Fever per 10,000 Inhabitants. after the Construction of Sanitary Works.
160,714	Bristol	1847-1851	1862-1865	10·00	6·50
68,056	Leicester	1845-1851	1862-1864	14·60	7·75
52,778	Merthyr Tydfil ...	1845-1855	1862-1865	21·33	8·66
39,693	Cheltenham	1845-1857	1860-1865	8·00	4·66
32,954	Cardiff	1847-1854	1859-1866	17·33	10·50
30,229	Croydon	1845-1850	1857-1864	15·00	5·50
29,417	Carlisle	1845-1853	1858-1864	10·00	9·75
27,475	Macclesfield.........	1845-1852	1857-1864	14·25	8·50
24,756	Newport	1845-1849	1860-1865	16·33	10·33
23,108	Dover	1843-1853	1857-1865	14·00	9·00
10,570	Warwick	1845-1855	1859-1864	19·00	9·00
10,238	Banbury	1845-1853	1857-1846	16·00	8·33
9,414	Penzance	1843 1850	1856-1865	7·50	8·00
9,030	Salisbury	1844-1852	1857-1864	7·50	1·75
8,664	Chelmsford	1843-1852	1855-1864	12·00	12·66
7,847	Ely.....................	1845-1852	1859-1864	10·40	4·50
7,818	Rugby	1845-1851	1855-1864	10·00	9·00
7,189	Penrith	1845-1852	1856-1864	10·00	4·50
6,823	Stratford-on-Avon	1845-1853	1860-1864	12·50	4·00
6,494	Alnwick	1845-1851	1856-1864	13·50	8·66
6,334	Brynmawr	1843-1852	1856-1865	23·50	10·25
5,805	Worthing	1843-1852	1857-1865	7·50	9·25
4,490	Morpeth	1845-1852	1856-1864	16·50	10·00
3,840	Ashby-de-la-Zouch	1845-1851	1855-1864	13·50	5·75

2. *Cases quoted by Soyka* (see also B-55, App. I.).

In his paper at the Vienna Congress of the German Association of Public Health, in September, 1881, Soyka quotes a number of German towns in which, after the introduction of a proper system of sewerage, the typhoid mortality has considerably decreased. Concerning Munich, he gives the following interesting table:

TABLE II.—Typhoid Mortality in Munich.

Periods.	Year.	Sanitary Progress.	Number of Deaths from Typhoid Fever per 10,000 Living.
1	1852-1859	No means whatever for preventing the pollution of the subsoil and air.	24·20
2	1860-1865	Commencement of reforms—making of cesspits watertight etc.	16·80
3	1866-1873	Sewerage in parts of the town.	13·30
4	1874-1880	Continuation of the sewerage ..	8·90
5	1881-1885	Sewerage of town still further improved.	1·75

In the first period it may well be assumed that all the cesspits were utterly neglected, and no supervision whatever exercised. No doubt, cesspit or sewer gas freely circulated in the interior of the houses without let or hindrance. Of those days it has been said that the smell of cesspits was ever present in the taste of man, and houses were little better than ammonia works on a small scale.

In the second period, cesspits were more systematically constructed and emptied. Probably, too, the question of the disposal of other refuse matters was more carefully looked into, and, generally speaking, in this period the noxious gases from the decomposition of organic matters were more methodically treated and avoided.

In the third period, no doubt all these questions were still further examined, with the result that the town was partially sewered, and although the sewers were originally not intended to convey away fæcal matters, it is recorded that the overflow from the cesspits in many cases was connected with them. At any rate, there is no doubt but what the gases from decomposing fæcal matters were more and more excluded from the interior of the houses. In the fourth and fifth periods, the sanitary arrangements of the town were still further improved.

The successive improvements in the death-rate from typhoid fever can be clearly traced in this table.

At the present time all fæcal matters are passed direct into the sewers, and without the intervention of cesspits.

3. *Investigations by P. Baron* (see also B-2, App. I.).

P. Baron examined this question for a very large number of German towns with and without drainage, and found that in Berlin, Danzig, and Hamburg the typhoid mortality had considerably decreased since the introduction of the water-carriage system.

He then compared the average typhoid mortality for nine years in 37 towns without drainage with the mortality in 46 towns with good drainage, and arrived at the following conclusions:

1. The heaviest typhoid mortality occurred in towns without drainage.
2. Average rates occurred more frequently in non-seweraged than in seweraged towns; and
3. The lowest typhoid rates were by far more frequently observed in seweraged towns.

Baron further then subdivided the towns into those with the highest and those with the lowest typhoid rates, and found:

4. Out of 70 towns with the highest yearly rates, 51, or 73 per cent., were not drained; and
5. Out of 51 towns with the lowest yearly rates, 36, or 70 per cent., were drained.

Summarising these results, he concludes his investigations by saying:

"The lowest yearly typhoid rates occurred in 36, or 78 per cent., of the 46 seweraged towns, and only in 15, or 40 per cent., of the 37 towns without drainage.

4. *Typhoid Fever at Berlin* (see also B-68, App. I.).

It might not be out of place to make a few remarks here on the prevalence of typhoid fever (typhus abdominalis) in Berlin before and after the systematic sewering of the town, as the statistical material at our disposal appears to have been collected with the greatest care.

In Table III., on the next page, I have given the number of deaths from all causes and from typhoid fever between the years 1854 and 1890, and with a view to illustrate the movement of these death-rates I have prepared Diagrams No. I. and II., on which I have also noted the years in which various of the sanitary improvements have been commenced or carried out.

On reference to the table and to Diagram I., which shows the typhoid rates, it will be seen that there has been a very steady decline in the typhoid mortality since 1856, when the waterworks were opened, but that this decline has become considerably more rapid since the commencement of the drainage works in 1875. In Diagram II., which, together with Diagram I., is taken

TABLE III.—City of Berlin.

Mortality from all Causes and from Typhoid Fever between 1854 and 1890.

Year.	Population.	Mortality from all Causes.		Mortality from Typhoid Fever.	
		Actual Number of Deaths.	Deaths per 1,000 Inhabitants.	Actual Number of Deaths.	Deaths in 1,000 Deaths from all Causes.
1854	429,390	10,305	25·60	342	34·6
1855	432,685	12,328	29·99	483	42·2
*1856	442,040	10,889	26·30	397	38·2
1857	449,610	12,664	30·16	536	44·1
1858	458,637	11,854	28·03	426	37·3
1859	474,790	12,163	27·78	490	41·1
1860	493,400	10,988	24·34	371	34·5
1861	547,571	14,201	28·18	440	33·4
1862	567,560	14,044	26·94	467	39·0
1863	596,390	16,473	30·21	488	31·8
1864	633,279	17,848	30·99	459	27·3
1865	657,690	20,609	33·80	693	35·7
1866	665,710	26,305	41·62	599	24·9
1867	702,437	18,668	28·96	485	27·5
1868	728,590	23,531	34·69	725	31·9
1869	762,450	20,193	26·48	518	25·2
1870	760,000	22,984	30·24	596	25·9
1871	825,937	30,756	37·24	732	23·8
1872	864,300	26,635	30·82	1,208	45·4
1873	900,620	26,427	29·34	859	32·4
1874	932,760	27,423	29·39	691	25·0
†1875	966,858	31,225	32·29	805	25·8
1876	995,470	29,185	29·32	623	21·3
1877	1,010,946	29,988	29·66	612	21·0
1878	1,039,447	30,629	29·47	326	10·6
1879	1,069,782	29,545	27·62	296	10·0
1880	1,122,330	32,823	29·25	506	15·4
1881	1,138,784	31,055	27·27	340	10·9
1882	1,175,278	30,465	25·92	355	11·7
1883	1,212,327	35,056	28·92	221	6·3
1884	1,250,895	32,932	26·33	241	7·3
1885	1,291,359	31,483	24·38	214	6·7
1886	1,337,171	34,293	25·65	181	5·2
1887	1,386,562	30,333	21·88	193	6·3
1888	1,439,618	29,294	20·35	188	6·4
1889	1,495,151	29,545	19·76	290	6·4
1890	1,548,279	32,823	21·19	143	4·2

* 1856, opening of waterworks. † 1875, sewerage of town commenced.

PLATE I.

TO FACE PAGE 193.

Diagram Appendix X.

TYPHOID MORTALITY IN BERLIN, 1854-1890.

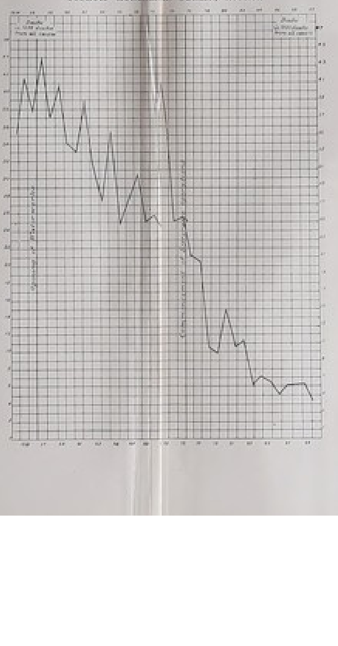


Diagram II.—Appendix X.

MORTALITY FROM ALL CAUSES IN BERLIN, 1840-1890.

from Dr. Weyl's book, quoted under B-68, App. I., is shown the rise and fall of the general death-rate between 1840 and 1890, and from this it would follow that whereas since the opening of the waterworks the general death-rate shows, if anything, a slight increase over previous years, it at once commences to fall with the starting of sewerage operations in the town, and has done so more or less regularly ever since. If we compare the results of these two diagrams, the thought forces itself upon one's mind, that of the two great sanitary works the sewerage has exercised the greater beneficial influence upon the public health of Berlin. It would be very interesting to investigate this apparent difference further, but for this I regret there is no time.

It is by no means contended that to this reduction in the death-rates only the water supply and drainage have contributed. On the contrary, no doubt, a great many other factors have added their quota, but I think we are perfectly entitled to say that amongst the beneficial influences at work, sewerage and water supply occupy a most prominent position.

Dr. Weyl mentions, concerning the reduction of the typhoid mortality in the years immediately preceding the commencement of the sewerage and since that, out of 1,000 annual deaths, there were on an average due to typhoid fever:

In the years 1871 to 1880, 23·05 cases.
" " 1881 to 1890, 7·13 "

This shows that in the 10 years since the partial completion of the sewerage works the typhoid rate per 1,000 deaths from all causes was less than one-third of what it was in the previous 10 years. The sewerage of the town might be said to have been commenced in 1875, and has been carried on ever since.

5. *Other Cases.*

Innumerable other instances might be quoted where, after the drainage of the place had been carried out, the mortality from typhoid fever has year after year decreased, but this would lead too far.

It will suffice to say that ever since Buchanan drew attention to this connection for the first time in his memorable report of 1866 (A-14, App. I.), such a reduction has in almost every case been observed, not only in this country, but also abroad, where a place has been systematically sewered, and that where it has not taken place, special and local reasons have been found to exist which prevented it. We, therefore, consider this reduction in the typhoid mortality consequent upon the systematic sewering of a town practically in the light of an axiom.

APPENDIX XI.

Notes on the Coincidence between Typhoid Fever and Faulty Drains as Demonstrated by the Smoke and Other Tests.

1. *Experience at Leicester.*

In Leicester, it has now become the rule with the sanitary authorities to test the drainage of a house with smoke as soon as a case of typhoid fever has been notified from it, and as this has been systematically carried out since the year 1893, it might not be out of place to give the results, as ascertained from the annual reports of the medical officer of health, in the following table.

Table I.—Typhoid - Infected Houses with Defective Drainage in Leicester.

Years.	Typhoid-Infected Houses.		
	Total Number of Infected Houses.	Number of Houses with Defective Drainage.	Percentage of Houses with Defective Drainage.
1893	96	30	31·25 per cent.
1894	197	89	45·18 per cent.

2. *Experience at Bristol.*

The medical officer of health for Bristol reports that during the five years, 1890-1894, 585 cases of enteric fever occurred in Bristol, of which 548 were single cases—*i.e.*, occurred in 548 houses—and the rest of 37 cases was distributed over 11 houses. Out of the 548 houses, 161 showed drainage defects on the application of the smoke test, so that for 29·38 per cent. of the 548 typhoid - infected houses, the possibility of the entrance of sewer gas has been proved.

3. *Experience at Hornsey.*

The medical officer of health for Hornsey states in his report for the year 1893, on pages 11 to 14, that nine typhoid-infected houses were examined with the smoke test between the 10th day of August and the 30th day of December, 1893, and that in every one of them defective drainage arrangements were discovered. The number of typhoid-infected houses with drainage defects was 19 in 1894.

4. *Experience at Leeds.*

The medical officer of Leeds, Dr. J. Spottiswoode Cameron, gives a very interesting paper in the *Journal* of the Sanitary Institute for 1897, Vol. XVIII. (see also A-17B, App. I.), on his experience with the smoke test. All in all, the drains of 1,121 houses, in which typhoid or diphtheritic disease was supposed to be present, were tested, with the result that 30·51 per cent. were found defective. The table of particulars and the summary are as follows:

TABLE II.—Showing Drain Test Findings in 1,121 Houses in which Typhoid or Diphtheritic Disease was supposed to be present.

—	Houses.	Percentage.	
		Found Faulty.	Result Negative.
The whole group	1 121	30·51	69·49
Wastes "severed"	529	16·26	83·74
Wastes not "severed" ...	592	43·24	56·76
Convenience outside	994	28·17	71·83
Wastes "severed"	442	11·54	88·46
Wastes not "severed" ...	552	41·49	58·51
Closet inside	127	48·82	51·18
Wastes "severed"	87	40·23	59·77
Wastes not "severed" ...	40	67·50	32·50

"Severed" means that every waste, other than the soil-pipe, comes through an outer wall and discharges in the open air outside the house.

Summary.

"So far as these figures go, it would appear that :—

1. Nearly one third of the 1,121 houses were in aërial communication with their drains.

2. This fault was more than twice as common where disconnection of wastes had not been carried out—namely, as 43 in the non-severed to 16 in those "cut off."

3. Neglecting disconnection, a water-closet *inside the dwelling* increased by four-sevenths the chances of the entrance of drain air, raising the faulty proportion from 28 to 49 per cent.

4. Where severance of other wastes was effected, the risk of direct aërial connection with the sewer increased from 12 per cent. in houses with closets *outside* the dwelling to 40 per cent. where they were *inside.*

5. Where, on the other hand, drain severance was incomplete, the risk was greater whatever kind of closet was in use, but rose from 41 per cent. in those *without*, to 68 per cent. in those *with* an inside convenience.

The table appended to the paper gives the following results :

Percentage of houses in aerial connection with their drains where:

Wastes were severed and closet outside...	11·5
Wastes not severed, but closet outside ...	41·5
Wastes severed, but closet inside	40·2
Wastes not severed, closets inside	67·5

These figures may perhaps warrant some of the following *conclusions*:

1. As even in houses free from the special dangers due to the presence of a water-closet within the dwelling, and further protected by the disconnection of all other

waste-pipes, drain testing revealed serious defects in nearly 12 per cent. of those tested, it is obvious that there should be a regular, systematic, and periodical testing of all house drains.

2. This periodical examination by tests should be three times as frequent where, though free from the special dangers attending the inside closet, the other waste-pipes are not "cut off" outside the house.

3. It should also be three times as frequent where, though all other wastes are disconnected, there is a water-closet within or beneath the dwelling.

4. It should be six times as frequent where there is the double danger of an inside water-closet and undisconnected house wastes."

5. *General Remarks on Smoke-Testing Drains.*

In connection with the testing of houses with smoke, it should be borne in mind that there are defects in the drainage arrangements, especially below ground-level, which are not very easily discovered by this test; and, in my own experience, I have had cases where, suspecting defects, I could not discover them with smoke, though I made repeated trials, and where I only succeeded in localising them after I had subjected the drains to the hydraulic test. It would, therefore, be incorrect to conclude that in all cases where the smoke test has shown no defects, sewer gas could not possibly find its way into the interior of the house, and in such a case the more reliable hydraulic test ought, in my opinion, never to be omitted.

APPENDIX XII.

Notes on the Typhoid Mortality and the Ventilation of the Sewers in Leicester.

It might not be out of place to record here some of the Leicester experiences in connection with the ventilation of the sewers and the mortality from typhoid fever.

Leicester is supposed to have led the way in the introduction of the notification of infectious diseases, as this came in force in the borough on the 13th September, 1879, after Parliament had given its sanction to this step in a private Act.

Leicester may further be said to have been amongst the first towns to carry out a systematic drainage scheme, as this was commenced under the late Mr. Wicksteed in 1852. Owing to the rapid increase of the town, however, the main sewers soon became too small for their work, and ever since 1870 proposals have been made to improve them. However, it was not until 1886 that the late Mr. Gordon's scheme was accepted by the Town Council, and this has now practically been completed at a cost, up to the 31st day of March, 1895, of £191,197. 10s. 4d. Besides this amount, the town of Leicester has also spent since 1885 £69,867. 6s. 6d. for a new sewage pumping station and £68,496. 10s. 5d. on the new sewage farm.

Mr. Wicksteed's sewers were practically not ventilated at all, and in 1881 the Town Council decided to open them up and thoroughly cleanse and ventilate them by open covers at street - level. These operations were continued up to 1886, when, owing to numerous complaints from the inhabitants about obnoxious smells, the Sanitary Committee decided to close the ventilating covers where objected to, and to erect in their places cast-iron pipes up the sides of houses wherever the necessary permission of the house-owners could be obtained. In some cases, also, the sewers were connected with factory chimneys. This policy has since been adhered to. From a report of the present surveyor, it would appear that in September, 1894, the following was the number of open and closed covers in the borough:

Table I. — Open and Closed Manhole and Lamphole Covers, September, 1894.

Description of Sewers.	Manholes.			Lampholes.		
	Open.	Closed.	Total.	Open.	Closed.	Total.
Foul sewers	470	980	1,450	508	1,103	1,611
Storm-water sewers	280	245	525	305	232	537
Totals	750	1,225	1,975	813	1,335	2,148

From this statement the following figures follow:

Total number of open manhole and lamphole covers	1,563
Total number of closed manhole and lamphole covers	2,560
Grand total.....	4,123

The borough surveyor also reports that up to September, 1894, 255 (6in. by 4in.) ventilating pipes had been put up on 125¼ miles of foul sewers, and 52 factory chimneys had been connected with them, mostly by 6in. pipes. Besides the foul sewers, there were at that time in Leicester 36¾ miles of surface and storm-water sewers, and nearly four miles of storm outfall sewers—making a total of about 166 miles of all kinds of sewers.

Bearing the above-mentioned facts in mind, three periods can be distinguished:

1. The period before 1881, when the sewers were very foul and not ventilated.
2. The period from 1881 to 1886, in which a great length of the old sewers was cleaned out and ventilated by open covers at street-level; and,
3. The period since 1886, in which practically two-thirds of the open covers at street-level were closed, about 300 ventilating shafts erected, and the old main sewers replaced by larger and better constructed ones.

In 1887, when the complaints of objectionable smells from the sewers became louder and louder, the author was instructed by his chief to investigate the question What influence the ventilation of the sewers, if any, had exercised on the death-rates of the town? and his results were given in a diagram, a copy of which is attached to this appendix (see Diagram I.). Since then, as has already been stated, the open covers have largely been closed again, so that in September, 1894, out of the total number of manhole and lamphole covers, 62 per cent. were closed and only 38 per cent. were open covers.

With a view to comparing the typhoid rates after 1886 with those before that year, the author has prepared Table I.[1] and Diagram II. in this appendix, in which he has also given the number of certificates received. In passing, it might be mentioned that the number of certificates received represent the number of infected houses only, and that the number of infected persons is probably somewhat higher.

On comparing Table II.[2] with Diagrams I. and II. on Plates II. and III., the following facts can be observed:

[1] See page 200. [2] See page 202.

TABLE II.—Borough of Leicester.

Mortality from Typhoid Fever and Number of Certificates for 22 Years—1875 to 1894.

Year.	Population.	Deaths from Typhoid Fever. Actual Numbers.	Deaths from Typhoid Fever per 100,000 Living.	Average Death Rates from Typhoid Fever for certain Periods.	Number of Typhoid Certificates received. Actual Numbers.	Number of Certificates received per 100,000 Living.	Average Number of Certificates per 100,000 Inhabitants in certain Periods.
1875	110,000	64	58				
1876	113,581	43	38				
1877	117,462	20	17				
1878	119,845	31	26	32·2 (1875–1880)			
1879	117,610	21	18				
1880	120,325	46	38		245	204	
1881	123,120	29	23		179	145	
1882	126,275	19	15		110	87	
1883	129,483	10	8		85	66	
1884	132,773	16	12	16·3 (1881–1886)	55	41	100 (1881–1886)
1885	136,147	36	26		216	159	
1886	139,606	19	14		141	101	
1887	143,153	31	22		222	155	
1888	146,790	32	22		266	181	
1889	150,520	22	14		147	98	
1890	154,344	24	16		165	107	
1891	177,353	29	16		178	113	
*1892	180,066	17	9	17·9 (1887–1896)	116	64	131 (1887–1896)
1893	184,547	47	26		392	212	
1894	189,136	27	14		215	114	
1895	193,839	38	20		248	128	
1896	198,659	40	20		283	142	

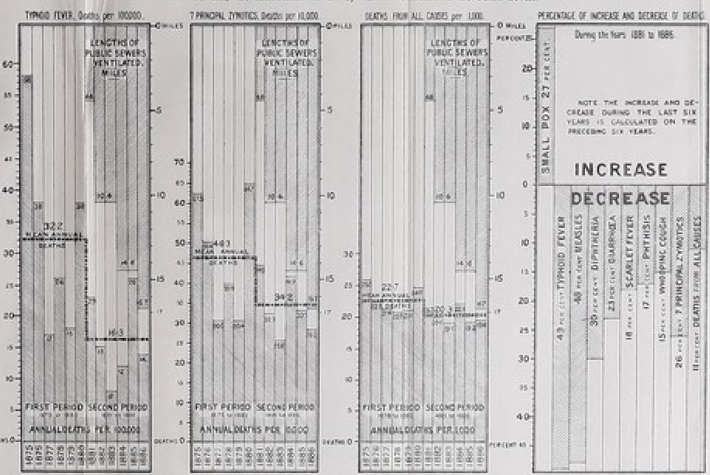
* Enlarged borough, 1st April, 1892.

NOTE.—The systematic ventilation of the sewers was commenced in the year 1881, and the closing of the manhole covers, owing to complaints, dates from the year 1887. The number of certificates received represents the number of infected houses, the number of infected persons being somewhat higher. The registration of infectious disease came into force on the 13th September, 1879. The reconstruction of the main drainage of Leicester was commenced by the late J. Gordon in 1886, and has cost up to the 31st March, 1895, the sum of £191,197. 10s. 4d. (capital expenditure only). The sums spent upon main sewers, pumping station, and sewage farm (capital expenditure only, J. Gordon's scheme) amounted up to 31st March, 1897, to £332,687. 7s. 3d.

Diagram I.—Appendix XII.

SANITARY STATE OF LEICESTER DURING THE YEARS 1875 TO 1886.

Before and after the Introduction of the Systematic Ventilation of the Public Sewers.



The systematic ventilation of the Leicester public sewers was introduced in 1881. The lengths of public sewers ventilated at the end of each year are taken from the medical officer's reports. Saving of life annually, 323.

Leicester, January, 1888.

H. Alfred Roechling.

The Year 1887.

Since preparing this diagram, the returns for the last year (subject to further revision) have been obtained from the medical officer, and the following statement has been drawn up from them:

Percentage of Increase and Decrease of Deaths during the Seven Years from 1881 to 1887, in relation to the Six preceding Years.

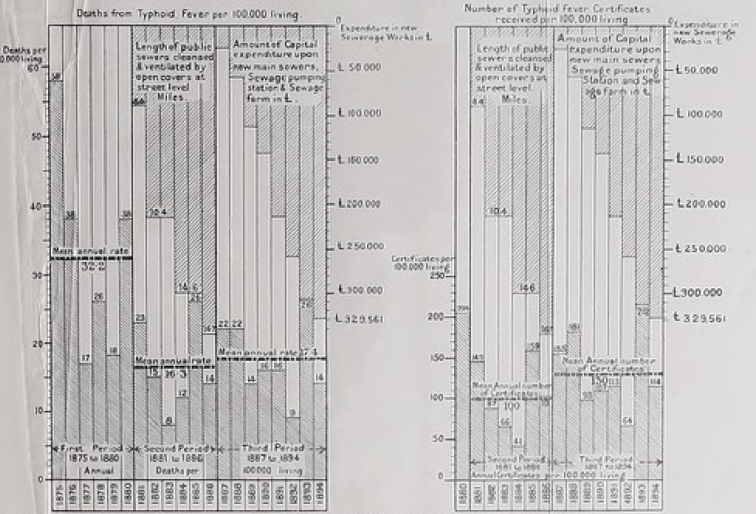
Increase.	Per cent.	Decrease.	Per cent.
Small-pox	7·4	Typhoid fever	46·19
		Measles	40·30
		Scarlet fever	30·26
		Diphtheria	25·29
		Diarrhœa	22·70
		Whooping cough	14·21
		7 principal zymotics	27·35
		All causes	11·52

In the first period, 1875 to 1880, there were only seven deaths from small-pox, and in the second period, 1881 to 1886, ten.

Diagram II.—Appendix XII.

TYPHOID FEVER IN LEICESTER FOR 20 YEARS, 1875 TO 1894.

Before and during the Ventilation of the Sewers at Street Level, and since the Closing of about Two-Thirds of the Open Covers.



The first period from 1875 to 1880.—In this period the sewers were very foul and practically not ventilated at all.

The second period from 1881 to 1886.—In this period the sewers were cleaned out and ventilated by open covers at street level.

The third period from 1886 to 1894.—In this period practically two-thirds of the open covers were closed, and about 300 ventilating shafts erected. In this period two new main sewers were laid down at a capital cost of £191,197. 10s. 4d. (31st March, 1895), a new sewage pumping station was erected at a capital cost of £69,867. 6s. 6d. (31st March, 1895), and a new sewage farm was laid out at a capital cost of £68,496. 10s. 5d. (31st March, 1895). Besides these works, numerous other sanitary improvements have been carried out.

The number of certificates received represents the number of infected houses; the number of infected persons being somewhat higher.

The notification of infectious diseases came in force on the 13th September, 1879.

If the years 1895 and 1896 are added to the third period, the mean annual death-rate from typhoid fever (per 100,000) for this period is increased to 17·9 instead of 17·4, as shown in the diagram, and the mean annual number of typhoid-fever certificates is increased to 131 instead of 130.

The total capital expenditure on new sewerage works, etc., amounted, up to 31st March, 1897, to £332,687.

January, 1896. H. Alfred Roechling, C.E.

1. In the first period, with badly-constructed, very foul, and ill-ventilated sewers, the typhoid death-rate was highest—viz., 32·2 per 100,000.
2. In the second period—of cleansing and ventilating the sewers—the typhoid death-rate suddenly went down very considerably, and was lowest—viz., 16·3 per 100,000.
3. In the third period, with new main sewers of good construction and nearly 66 per cent. of ventilating covers closed, the typhoid death-rate rose again, and was higher than in the preceding period—viz., 17·4 per 100,000, or 17·9 if the years 1895 and 1896 are added.
4. The increase in the prevalence of typhoid fever in the third period over the second period is still further illustrated by the number of certificates received, the average rate per 100,000 inhabitants for the second period being 100 per annum, and for the third period 130, or 131 if the years 1895 and 1896 are added. On the first day of April, 1892, the borough of Leicester was enlarged by taking in the outlying suburban districts which had sprung up close to the borders of the old borough. But as these were not so densely populated as the old borough, and as the prevalence of typhoid fever in them was on the whole not so great as in this, it is not unlikely that the typhoid and certificate rates have been favourably influenced by this step. No account has, however, been taken of this in foregoing remarks.

This increase in the typhoid rates since 1887 is all the more remarkable, as since that year the new main sewers (their cost, including pumping station and sewage farm, amounted up to 31st March, 1895, to £329,561. 7s. 3d.) and a large number of other sanitary improvements have been carried out in the town, not to mention the general advance in the knowledge and treatment of infectious diseases; and if we look for an explanation of this remarkable fact, the thought suggests itself that probably sewer gas had something to do with it.

In the first period, undoubtedly sewer gas did find its way freely into the interior of the houses, forcing the water seal of the traps, as it could not escape either through ventilated manhole covers or soil-pipes.

In the second period, the sewer gas, instead of being forced into the interior of the houses, was systematically allowed to escape through the ventilated manhole covers. That this actually did take place is sufficiently proved by the numerous complaints made. It must further be noted that the typhoid death-rates in this period decreased about 50 per cent. in spite, as it were, of the very foul accumulations which were removed from the sewers, and which have repeatedly been observed to cause local outbreaks of this infectious disease.

In the third period, the sewer gas was more and more prevented from escaping at the street-level by the closing of the open covers, and may have gradually, owing to insufficient ventilation, gained access again to the interior of the houses. In this connection, it is very interesting to observe that the medical officer of health reports that in 1893, out of all the typhoid-infected houses, 31·25 per cent. had defective drains, and that in 1894 this percentage rose to 45·18, the defects being discovered by the smoke test. When, therefore, practically for one-third and one-half of the typhoid-infected houses the possibility of the escape of sewer gas into them has been actually proved, it would be wrong to conclude that in the remaining cases sewer gas could not have got into the houses, as underground defects are not always brought to light by the smoke test. It must also be borne in mind that there are many other causes besides sewer gas which may and undoubtedly have been at work in bringing about the fluctuations in the typhoid rates.

Whatever our opinions on this point may be, the fact remains that in spite of the construction of the new main sewers, and in spite of numerous other sanitary improvements, the typhoid rate of Leicester has, since the commencement of the closing of the open covers at street-level, not gone down, but has, on the contrary, slightly increased, and this fact should not be overlooked by every thoughtful observer.

If sewer gas is dangerous at all, one might very properly conclude that its effects will be more seriously felt in confined spaces and rooms than in the open air of streets, where it is diluted at once.

In the present state of our knowledge it is quite impossible to assign for every specific effect a specific cause. It behoves, therefore, in the author's opinion, all those who occupy themselves with these questions to carefully note all the circumstances that contribute or appear to contribute to the rise and fall of death-rates, and to give them their most careful consideration before embarking upon measures the sanitary effects of which are, to say the least, very doubtful.

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