DOMINE DIRIGE NOS

REPORT

TO THE

HONORABLE COMMISSIONERS OF SEWERS
OF THE CITY OF LONDON,

ON

SEWAGE AND SEWER GASES,

AND ON THE

VENTILATION OF SEWERS.

BY

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At a Meeting of the Commissioners of Sewers of the City of London, held at the Guildhall, of the said City, on Tuesday, September 14th, 1858:—

The Medical Officer of Health laid before the Court the following Report, which was ordered to be Printed, and a Copy to be sent to every Member of this Court, and of the Court of Common Council.

JOSEPH DAW,

Principal Clerk.

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REPORT

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TO THE HON. THE COMMISSIONERS OF SEWERS OF THE CITY OF LONDON.

GENTLEMEN,

The subject of the present reference, like that of other important measures, which you have adopted for the improvement of the public health, shows that in providing for the sanitary wants of a community, it is not sufficient merely to procure and distribute an adequate supply of the things which are needful for life, but provision must also be made for the complete disposal of them after they have performed their duties and are no longer fit for the purposes of health. It is not enough, for example, to furnish an abundant supply of pure water, but there must likewise be the means for quickly removing it after it has become foul in the services of life and industry. The neglect of this, and of other such provisions, is among the principal causes of the unhealthiness of towns.

Even in this metropolis, where attention has been directed to the subject for a long series of years, and elaborate means have been provided for the removal of all offensive matters; where the public Sewers are unrivalled,* and the general arrangements for the disposal of the grosser filth are not to be surpassed, it is found that the liquid refuse undergoes decomposition before it can be discharged from the Sewers; and the putrid miasms which are thus generated, escape from the drains and gullies into the houses and public way, causing annoyance to the inhabitants and injury to their health. This indeed has become so serious a nuisance that you have called for a remedy.

I know that there is a disposition among those who are not well acquainted with the facts of

* The length of the City Sewers is about 48 miles, 45½ of which are large enough for men to enter, and some are 16 feet in diameter.—*Haywood.* Those of London are about 1,500 miles in length.—*Bazalgette;* while the Sewers of Paris are not above 50 miles in extent, and are for the most part mere drains. —*Tardieu.* Those of other cities can hardly be called Sewers.

medical science to underrate the importance of this subject, and to believe that the Sewer miasms are not injurious to health. Your own engineer, with whom I am associated in this inquiry, has declared his doubts, by asking, "What if it should be stated at a future day that great exaggeration, if not total misapprehension, exists upon the subject of the pernicious influence of the chance emanations from gullies. Has it yet been proved that they are to be feared when diluted to such an extent that they are no longer offensive to the sense of smell?"* and more recently in his evidence before a parliamentary committee, he has stated that although he has read much on the subject, yet medical men have failed to convince him that the effects of Sewer gases are so distinctly injurious as to be worth a remedy, at the price of a little more than fivepence a year to each of the inhabitants. This is doubtless the opinion of others, and it shows how necessary it is at the very outset of the inquiry, not only to inform the ignorant of facts, but to disabuse the learned of fallacies. So strongly am I impressed with this, that I consider it to be of prime importance to re-discuss a question which I had hoped was long since finally settled, viz., the question of the pernicious effects of Sewer miasms; and if I have gone

* Report upon the Ventilation of Sewers, March 16, 1858, p. 22.

a little beyond the record of your instructions, by seeking to ascertain the physical nature, and chemical composition, and physiological effects of the matters with which we have to deal, it is because I have endeavoured to place the subject on the secure basis of experiment and observation.

This may, perhaps, appear unnecessary; for it might be truly said, that public opinion, guided by the commonest observation, has long since decided that these miasms are injurious to health. It is, in fact, a popular, as well as a medical notion, that every kind of putrid pollution is hurtful to the human body; and this has been impressed upon the public mind, not by the fancies of the faculty, but by the terrible and unmistakeable facts of experience. The history of the old epidemics, and especially of those in the middle ages, has but too fully demonstrated how, little by little, the people, as well as the profession, have come to know that the neglected filth of their houses and cities has fed the plague, and spread the pestilence. When there were no sanitary regulations beyond the merciful regulations of heaven, which now and then sent torrents of rain to wash away the heaps of ancient filth from their old resting places in the public streets; when every house incorporated its own stink, and treasured up its own putridity; when earth, and air, and water, were alike polluted with the foul products of decomposition, then the pestilence knew its power, and walked forth in all its strength to devastate the cities of Europe. Then it was that the average mortality of a healthy season was greater than it now is in the worst times of cholera; and the slaughter from typhus in a wet autumn was more terrible than the ravages of an invading army. Those times have happily passed away; and although we have largely profited by the lesson from them, yet it is evident that we have still much to learn before we shall fully appreciate the laws of hygiene, and be able to dispel the ignorance which can tolerate so false a faith, as that there is no danger from putridity and filth when they are no longer offensive to the sense of smell.

THE NATURE OF SEWAGE.

The matters to be dealt with in the Public Sewers of every town and city are very complex, for they are composed not only of the solid and liquid ejecta of the population, but also of the fluid refuse of every branch of industry. They consist of the filth of kitchens, laundries, and dye-houses; the drainings from stables, slaughter-houses, and the public markets; the various liquid impurities of trade and manufactures; and the washings of the streets and alleys: all of which, with the ejecta of the inhabitants, and a large quantity of water, compose the Sewage of Towns. Each of these constituents, however, has its influence on the composition of the general mass, and on the putrefaction to which it is liable. Every part of a city, therefore, has its own peculiar quality of Sewage—the quality being affected by the density of the population; the habits of the people, as to their diet, cleanliness, and trade pursuits; by the season of the year; the day of the week; the hour of the day; and even the state of the weather. This makes it difficult to obtain precise information of the nature and composition of Sewage. Nevertheless, there are two ways by which a knowledge of the subject may be approached, viz., by the sythetical method of ascertaining the average amount of solid and liquid matter contributed by each of the inhabitants; and secondly, by the analytical process of examining the Sewage at different places, and at different times and seasons. Both of these plans of research are, no doubt, open to objection, but still they give results which are sufficiently accurate for our present purpose.

The first method of inquiry has been pursued by Mr. Lawes *, and by Professor Way †; and

* *Journal of the Society of Arts.*—March 9th, 1855.

† On the use of Town Sewage as Manure.—*Journal of the Royal Agric. Soc. of England.*—No. XXXIII., 1854, p. 135.

the results of their investigations are that from 2 to $2\frac{1}{4}$ ounces of dry solid matter are contained in the excrements, per diem, of each member of the population. In the moist state as they are discharged from the body, they amount to about forty ounces per diem. These give a daily total of 152·6 tons of dry matter, or 2993·6 of moist, for the excrements of the whole population of London at the present time.* But, while on the one hand the ejecta are not entirely discharged into the Sewers, so on the other, the numbers take no account of the contributions from trade, or of the washings from streets. I am not acquainted with any data for the estimation of the first of these, but the second may be ascertained approximatively from the analytical results of Professor Way. He has found that the rain-water which runs from the streets into the gullies after a heavy shower of rain, contains about 262·6 grains of solid matter per gallon, of which 113·34 are in solution, and 149·26 in suspension. In the case of the granite roads, where the traffic is very large, the total amount of solid matter is 813·33 grains per gallon, of which 276·23 are dissolved, and 537·1 suspended; and in that of the wood pavements with the same kind of traffic, the amount is only 39 grains per gallon, of which 34 are dissolved, and 5

* See Table I. in the Appendix for particulars.

suspended.* It will be manifest from this, that a large quantity of solid matter is carried from the streets into the public Sewers during heavy rains. Altogether, it may be said, that the ejecta of the inhabitants of this Metropolis, and the washings of the streets daily furnish about 233 tons of solid matter to the Sewage; and these, with the trade refuse, are diluted with about $84\frac{3}{4}$ million gallons of water.†

The second mode of estimating the composition of Sewage is founded on the analytical results of its examination at different times and places. These results are given in the Tables III. to VII. in the Appendix. They show that the Sewage which is discharged by day from the City Sewers, contains about 94 grains of solid matter per gallon, of which 38 are suspended, and 56 dissolved: of the suspended, 17 are organic, and 21 mineral; and of the dissolved, 15 are organic and 41 mineral.‡ The night sewage is not so rich in solid ele-

* See Table II. in the Appendix for the particulars of these results. They are taken from the *Journ. Agric. Soc.*, No. xxxiii., p. 149.

† The calculation is on the assumption that the water supply is about 5 cubic feet, or 31·15 gallons per head of the population, and that the population, in the middle of the year 1858, is 2,721,000.

‡ See Table III. in the Appendix.

ments, for it contains only about 79 grains of solid matter per gallon; of which 14 are suspended, and 65 dissolved; and of these 15 are organic, and 64 mineral, the organic being distributed very evenly between the soluble and insoluble constituents.*

The Sewage of the Tower Dock Sewer contains by far the largest proportion of solid matter. A gallon of it furnishes about 921 grains of solid impurity; of which about 890 grains are in solution. The chief constituent is common salt,— a trade refuse of the neighbouring fishmongers. That which has the least impurity is the Sewage which flows into the Whitefriars Dock, for it contains only about 41 grains of solid matter per gallon; of which 14·5 are suspended, and 26·5 dissolved.

Branch Sewers, and those which are nearly stagnant, are generally very foul; for the Sewage of them contains from 150 to 500 grains of solid impurity per gallon; of which from 90 to 250 are suspended. The organic matter ranges from 20 to 120 grains in the soluble part, and from 20 to 176 in the insoluble.†

* See Table IV. in the Appendix.

† See Table VII. in the Appendix, (Sewers of Swan Street, Wormwood Street, &c.)

Taking the average of all the results obtained in the examination of the Metropolitan Sewers, it may be concluded that the Sewage which flows into the Thames contains about 90¼ grains of solid matter in the gallon; of which about 29¾ are suspended, and 60½ dissolved: there being about 15 grains of organic matter in each of these constituents.*

As I have already said, a storm of rain does not diminish the proportion of solid matter; for although it has a tendency to dilute the Sewage, yet it washes away so large a quantity of filth from the streets, and disturbs so much of the sediment in the stagnant Sewers, that Sewage after a storm generally contains more than the average proportion of solid impurity. Taking 88 grains per gallon as the usual amount in some of the Sewers, it will, after a storm, be increased to 125 grains per gallon; of which 64 will be suspended, and 61 dissolved.† So that the quantity of filth removed by a heavy fall of rain is enormous.

As to the particular constituents of the solid matters, they are given in Table VII. of the Appendix; and I have added them, not so much for the purpose of illustrating the chemistry of the subject, as with the view of showing that there

* See Table V. in the Appendix.

† See Table VI. in the Appendix.

is but little expectation of profit in the manufacture of Sewage into manure; and this is further exhibited in Table VIII. of the appendix, where I have tabulated the composition and commercial value of human ejecta, as well as of the solid matters obtained from Sewage.

The mineral constituents of Sewer water are chiefly carbonate of lime and common salt, with small proportions of the alkaline sulphates and phosphates. They are derived from urine and from the water supply. The mineral part of the insoluble matter consists almost entirely of the debris of the streets, and the detritus of wheels and horse-shoes. These amount to about 15 grains per gallon; which, in the aggregate, is as nearly as possible 81 tons per day for the whole of the Metropolis, or 19 for the City. I am not able to apportion the several constituents of the 116·61 tons of solid matters daily discharged from the City Sewers;* for there is a difficulty in ascertaining the precise extent of the area drained, and the number of the population; but by taking the whole of the Metropolis, the difficulty disappears.

* The total amount of Sewage discharged per day in dry weather by the City Sewers is 3,255,840 cubic feet, or 20,316,442 gallons, (*Haywood, Report on the Gaugings of the City Sewers, April 28th*, 1857, p. 10), and these contain 90 grains of solid matter per gallon.

Then, of the total amount of 488·5 tons of solid matter contained in the Sewage of one day, about 152·60 tons are the ejecta of the inhabitants; 81·08 tons, the pulverized granite and iron from traffic on the roads; 102·04, the saline matter contained in the water supply; and the residue, 152·78 tons, is from trade and manufactures. The total amount of organic matter in all this is about 215·14 tons; of which half is in a state of solution, and the rest is suspended.

The physical properties of Sewage are peculiar, for when it is examined under the microscope, it is found that the clear supernatant part contains a large quantity of amorphous organic matter, with the filaments of various fungi. It swarms with animal life, as beaded *Spirulina*, *Vibriones*, and *Monads;* and soon after exposure to air the higher forms of infusoria appear, as, *Paramecium*, *Vorticella*, *Rotifera*, &c. Besides which, it contains small particles of animal and vegetable tissues, as the fibres of cotton, wool, &c.*

The sediment, which is black and glutinous, consists of the remains of undigested food, as muscular fibre, husk and hair of wheat, the cells and starch of potatoe, and the tissues of cabbage, and other vegetables. It also contains the products of some of the

* See Plates I. and II., Figs. 1.

secretions, as yellow biliary matter, intestinal mucous, and the crystals of uric acid and triple phosphate from urine. As in the last case, the living animal forms are numerous; and the vegetable growths are *Oscillatoria*, *Conferva*, *Vegetable spores*, and numerous *Fungi*. The mineral part is composed of the *débris* of the streets, as particles of granite, flint, and carbonate of lime, with a large quantity of black sulphuret of iron.* When the Sewage has a very unpleasant odour, and is charged with sulphuretted hydrogen, it never exhibits much sign of animal or vegetable life, notwithstanding that it contains an abundance of decaying organic matter. This is the case with the foul contents of the nearly stagnant Sewers.† But when it is diluted with water, and exposed freely to the air, the bad odour soon disappears, and the higher forms of infusoria are rapidly developed.‡ This is proof of the salutary influence of air and water in promoting the less hurtful kinds of decay. I have noticed the same fact on many occasions, when too large a quantity of Sewage has been discharged into a running stream. The insoluble matters settle, and do not obtain a sufficient supply of air or fresh water, to check the putrefactive decomposition, which goes on with great activity: an abundance of foul gas is thus

* See Plates I., II., and III. † See Plate III., Fig. 2.
‡ See Plate III., Fig. 1.

generated, and little or no organic life appears. This happens to the black muddy water on the banks of the Thames, where the only living things are *Monads*, *Vibriones*, and *Fungi*. But in the middle of the stream the air and water have so completely destroyed the foul gases, that the highest species of infusoria abound; and the same thing may be observed in every river that receives the sullage of a large town. At first, when the Sewage enters the stream, it contains nothing of vegetable life but the simplest fungi, then come higher forms of vegetation, as *Conferva*, *Calothrix nivea*, *Vaucheria*, &c., the last being known by its dirty brown color and short hair-like structure. Soon after this, as the process of oxydation goes on, and the excess of organic matter is destroyed, higher and higher forms of vegetation appear, and at last the *Anacharis*, *Nasturtium*, *Veronica*, and other aquatic plants abound; and when these are clean and healthy, the Sewage is no longer injurious to animal life, for fish will thrive in it.

THE PUTREFACTIVE DECOMPOSITION OF SEWAGE.

Looking at the enormous quantity of organic matter contained in Sewage, it is not surprising that its decomposition is attended with the evolution of a large amount of noxious gas; and when we consider that it is composed of organic materials which have just lost their vitality, and are exceedingly prone to decay; that the solid constituents of it are in a finely divided state, and are therefore in the best form for chemical change; that the proportion of water is just sufficient to hold them in a state of suspension; that the temperature of the Sewers is exactly suited for putrefaction*; and above all, that the complex mixture is brought into contact with matter already in a state of active decomposition, it is not remarkable that it should at once take on the putrefactive change, and begin to evolve foul gases directly it enters the Sewers. Under ordinary circumstances the solid excrements do not ferment in less than three or four days, but here the catalytic influences are so strong that putrefaction begins at once, and it is always of the same kind as that already in progress in the old Sewer matter. This tendency to accelerate and direct the decomposition is very remarkable. Its power lasts for weeks after the Sewage has ceased to ferment, and it operates immediately on all kinds of organic substances. Blood, sugar, fæces, urine, and other fermentable bodies, are rapidly changed by it; and they evolve compounds of a most offensive character. Common sugar, instead of being fermented into alcohol, is converted

* See Table IX. for temperature of the City Sewers at different times of the year.

into lactic acid, which smells like putrid pigs'-wash: then it passes into butyric acid, and gives off hydrogen and carbonic acid, with the odour of rancid butter and human perspiration.* The same thing occurs to other vegetable matters that are susceptible of change into sugar; and although they do not contain nitrogen, or sulphur, or phosphorus, which are the usual stink-producing elements, yet they evolve compounds that are in the highest degree offensive. Albuminous matters produce ammonia, carbonic acid, and sulphuretted hydrogen, all of which are found in the atmosphere of sewers. But besides these there are many intermediate products of decay which have not been fully investigated; and little is known of the part played by atmospheric air in the sewers beyond this, that when oxygen intervenes in the molecular movements, it gives birth to mineral products, as water, carbonic acid, the sulphates, phosphates, and nitrates, which are the final products of decay. Its influence, therefore, is most salutary, and

* Grape sugar ($C^{12}\ H^{12}\ O^{12}$) is changed by Sewage or Thames mud into Lactic Acid, ($C^{12}\ H^{12}\ O^{12}$) by the mere displacement or change of position of the elementary atoms; then it evolves hydrogen and carbonic acid, and the product is butyric acid, ($C^{8}\ H^{8}\ O^{4}$), this being the equation, $C^{12}\ H^{12}\ O^{12} = C^{8}\ H^{8}\ O^{4} + 4\ C\ O^{2} + 4\ H$. From the butyric acid thus obtained I have procured most excellent butyric ether or essence of pine apple; and this flavoring agent might be profitably manufactured from sugar and Sewage, or Thames mud.

ought not to be disregarded. Experiment has also shown that the oxydising power of the air is promoted by water, by porous substances, and by the fixed alkalies.

In seeking to know what part of the Sewage it is which undergoes decomposition, I have ascertained that it is not the liquid part which continues to ferment, but the solid; and, this keeps up the putrefactive action for months, evolving large quantities of ammonia, sulphuretted hydrogen, marsh gas, and carbonic acid. It is the sedimentary matter, therefore, which is the chief cause of the offensive effluvium, and to this I shall direct attention hereafter.

THE NATURE OF THE SEWER GASES.

This part of the inquiry is of great importance; for very little can be really done in the way of providing a remedy for the Sewer miasms, until something is definitely known of their nature and composition. Hitherto this subject has been treated quite empirically; and the suggestions which have been made from time to time for ventilating the Sewers, and destroying the foul gases, have had no foundation in a right knowledge of the things to be dealt with. The history, therefore, of these schemes is a history of unprofitable failures, and is of no practical value, beyond that of informing us what cannot be accomplished.

I have endeavoured to procure the knowledge which is wanted from three sets of investigations, viz.:—1st, from inquiries into the composition of the gases dissolved in sewage; 2nd, from an analysis of the gases evolved during its putrefaction; and 3rd, from an examination of the Sewer air itself. Each of these modes of investigation has furnished valuable results.

1st. If the clear liquor of Sewage is heated to the boiling point, it evolves all the gases which were in solution. They consist of carbonic acid, sulphuretted hydrogen, ammonia, marsh gas, and nitrogen. The quantity of them varies from about 32 to 76 cubic inches per gallon; and the proportion of carbonic acid varies from 36 to 72 per cent.; the sulphuretted hydrogen from 0·9 to 3·1.* Thames water, near to the shore at low tide, contains the same gases in nearly the same proportions.†

2nd. While the insoluble part of Sewage is fermenting, it gives off a large quantity of gas, the amount of which is influenced by the proportion of organic matter in the deposit. In the case of one

* See Table X. in the Appendix for details.

† *Ibid.*

of the worst of the City Sewers, where the Sewage contained 128·8 grains of organic matter per gallon, the quantity of gas evolved during the first week of putrefactive decomposition amounted to 3 cubic inches per hour. From that time to the end of the third week, it amounted to 1·56 cubic inches per hour; and so it gradually fell until the end of the ninth week, when the quantity was only 0·17 per hour. The average of the whole time was about 1·2 cubic inches per hour; and, as in the last case, the gases were composed of carbonic acid, carburetted hydrogen, ammonia, sulphuretted hydrogen, and azote—the proportions being about 72 per cent. of light carburetted hydrogen, 17·7 of carbonic acid, 10·2 of nitrogen, and 0·08 of sulphuretted hydrogen, with a notable proportion of ammonia.*

In my visits to the City Sewers, I have remarked that the same gases are abundantly evolved wherever the Sewage becomes stagnant or nearly so. The thick slushy matter in the Sewer of Catherine Wheel Alley, for example, furnished me with a large supply of gas. It was bubbling up from the deposit; and was so highly charged with light carburetted hydrogen that it could be ignited with ease; and in the act of burning, it would frequently set fire to the neighbouring bubbles, and produce

* See Table X. for particulars of the analytical results.

a sheet of flame that would extend for some distance along the surface of the Sewage. The gas contained 68 per cent. of inflammable air, 17·6 of carbonic acid, 14·1 of nitrogen, and 0·2 of sulphuretted hydrogen.*

Large quantities of gas are also generated in the Sewage deposit which has been deodorized with lime. This is noticed in the subsiding tanks of the works at Tottenham and Leicester; but, in this case, the gas is composed almost entirely of light carburetted hydrogen, there being but little carbonic acid, and not a trace of sulphuretted hydrogen.†

The amount of ammonia contained in the liquid is always considerable. It ranges from 3 to 15 grains in the gallon of ordinary Sewage, and from 15 to 41 in that of the nearly stagnant Sewers.‡

In addition to all these there are other volatile compounds which have not yet been isolated—compounds which give to the Sewage its peculiar odour, and perhaps also its poisonous action. One of them is evidently of an alkaline nature, and is nearly allied to ammonia. It is easily pro-

* See Table X. for particulars of the analytical results.

† *Ibid.*

‡ See Table VII. in the Appendix.

cured by distilling the liquid; and its properties are highly offensive. Dr. Odling has examined it, and has noticed that it contains a large amount of carbon.* My own analyses, like his, have given with the impure muriatic salt about 6·61 per cent. of carbon; and the platinum compound about 41·73 per cent. of metal. Dr Odling thinks it may be the conjugate body *ethylamine;* but it is rather premature to speculate on its nature, before there is some certain knowledge of its composition.

3rd. The analyses which I have made of the atmosphere of the City Sewers, show that the air is deficient in oxygen; and that it contains an excess of nitrogen, carbonic acid, and ammonia.† The proportion of sulphuretted hydrogen is rarely so large as to be discoverable in definite quantity; for although I have never failed to recognise its presence, yet the amount of it could not generally have been greater than 1 part in 60,000 of the air. Marsh gas is also present in minute quantity; and there are also organic compounds, which, as I have said, have not yet been isolated. Their existence is known by the formation of water and carbonic acid, when the air, completely deprived of these matters, is passed through an ignited tube filled with metallic

* On the Alkaline Emanations from Sewers and Cesspools, 1857.

† See Table XI. in the Appendix for analyses of Sewer air.

copper. The quantities of the products vary considerably, but they are never such as to indicate the same proportions of carbon and hydrogen as are found in marsh gas.*

By another mode of proceeding, I have been able to condense the organic vapour from the sewer atmosphere, and obtain it in a liquid form. A glass globe filled with ice, was suspended from the crown of a sewer, and the cold thus produced has, in the course of a few hours, caused the condensation of aqueous vapour, and with it the organic matter contained in the atmosphere. In this way, on three separate occasions, I have obtained from 1½ ounces to 4 ounces of liquid,† the properties of which were as follows. It had a turbid appearance, and contained minute flocculi of organic matter. Its odour was very disagreeable, like that of bad Sewage. Its re-action was alkaline; and it contained free ammonia, with a large quantity of sulphate of ammonia,—a compound derived from the oxydation of sulphuretted hydrogen. Nitrate of silver, and

* See Table XI. in the Appendix for illustrations of this.

† The liquids were obtained at the following places :—

No. 1. From Angel Street, St. Martin's-le-Grand, June 7, 4 ozs. were collected in 16 hours.

No. 2. From the Sewer in the South Place branch of the London Bridge Sewer, June 9th, 3 ozs. were collected in 8 hours.

No. 3. From the Sewer in Catherine Wheel Alley, Bishopsgate Street, June 12th, 1½ oz in 6 hours.

chloride of gold, were quickly reduced by it; and a drop of sulphuric acid added to the liquid and evaporated, gave a black organic residue. All these are proofs of its containing organic matter.

When the flocculi were examined under the microscope, they were found to be composed of amorphous organic debris, with myriads of *Vibriones* and *Monads*. There were also present the higher forms of infusoria, as *Spirulina*, *Vorticella*, *Paramecium*, &c., with the ovules of vegetables, and the filaments of *Fungi* and *Conferva*.*

Parent-Duchâtelet collected the condensed water from the Sewers of Paris, and he also found that the liquid had a peculiarly faint odour, and an alkaline re-action; and that on allowing it to stand, it quickly began to putrefy.

These results prove that the atmosphere of the Sewers is charged with decomposing organic matter, and with the germs of living organisms. It is also deficient of oxygen, and contains an undue proportion of carbonic acid, nitrogen, and ammonia, with a notable quantity of sulphuretted hydrogen. In the case of the City Sewers, these gases are not present in very large quantity; but they may accumulate to a dangerous extent, as

* See Plate IV., Figs. 1 and 2.

sometimes happens in the air of stagnant Sewers. When, for example, the Sewers of Amelot, De la Roquette, Saint Martin, and others of Paris, were cleansed in 1826, they were found to be highly charged with these foul gases, as with from 0·2 to 1·2 per cent. of sulphuretted hydrogen, and from 0·5 to 3·4 per cent. of carbonic acid; * and the fatal accidents which have occurred in the Sewers of this Metropolis are a sufficient proof of it.

PROPERTIES OF THE SEWER GASES, AND THEIR EFFECTS ON THE ANIMAL SYSTEM.

It is hardly possible to form a correct opinion of the injurious qualities of the Sewer miasms without a previous acquaintance with the properties of the individual constituents; and foremost in the rank of these is *Sulphuretted hydrogen.* This gas is constantly produced during the putrefactive decomposition of Sewage. It is known by its peculiar odour, which is sufficient to discover it, when it is diluted with 10,000 times its bulk of air. The gas is a little heavier than atmospheric air, in the proportion of 1179 to 1000; but its diffusive power is

* See Table XII. of the composition of the air of the Paris Sewers.

so great that the increase of weight has little or no influence in making it occupy a low level. In a pure state it is highly combustible, and burns with a pale blue flame; and the products of combustion have the odour of burning sulphur. When it is diffused through atmospheric air, it may form an explosive mixture; and if the proportion of air is less than 7½ times the bulk of the gas, the hydrogen only is burnt, and the sulphur is set free; but if there is a larger supply of air, as from 8 to 9 times its bulk, then it is completely consumed, and it forms aqueous vapour and sulphurous acid.

Water and the fixed alkalies absorb it freely; in fact the latter take it up in large quantity, and render it comparatively innocuous. Chlorine and chloride of lime destroy it by combining with the hydrogen and setting free the sulphur. Almost all the common metals are discolored by it; indeed, the salts of lead and silver are so quickly blackened, and are so sensitive of its action, that they indicate the presence of the gas when the atmosphere does not contain more than 1 part in about 100,000: these, therefore, are the tests for it.

Sulphuretted hydrogen is exceedingly poisonous; it will destroy life under all circumstances, whether the gas be inhaled, or absorbed through the skin, or injected into the cavities and tissues.* Dupuytren and Thenard have found that 1 part of the gas in 1500 of air will kill small birds immediately, and that 1 in 290 is fatal to rabbits and dogs in a few minutes. Horses are killed by an atmosphere containing 1 part of it in 250 of air † ; but much less is hurtful if it is breathed for any length of time.

Dr. Barker in his recent inquiries into the action of this gas on the animal system, has ascertained that 1 part of it in 1800 of air, is immediately fatal to birds, and that so small a quantity as 1 in 2112 of air will sometimes kill them in about a minute and a half. Larger animals are not so easily affected, although dogs are quickly killed by a mixture containing 1 part of the gas in 210 of air, and more slowly by 1 in 500. My own experiments are to the same effect, for I have found that 1 part of gas in 500 of air is soon fatal to rabbits; and I have no doubt from the energy of its action that such a proportion would be highly dangerous to all classes of animals. These facts make it difficult to understand the accounts given by Parent-Duchâtelet and others, of the thriving of rats

* Nysten, *Recherches Chemico-physiologiques*, p. 114 et seq., also Chaussier.—*Sedillot's Journ. de Méd.* xv., 28, 34.

† Dupuytren, Thenard et Barruel, *Recherches sur le Méphitisme des fosses d'aisances.—Journ. de Méd.* I., xi., p. 294.

and mice in Sewers, which have an atmosphere composed of from 1 to 2 per cent. of the gas; and I am inclined to think that the means which were at the disposal of his colleague, Gaultier de Claubry, who examined the air, were not sufficient to determine the actual proportion of the mephitic gas.

Observation has likewise shown that when the gas is diluted with very large quantities of atmospheric air, its action is slowly but surely deleterious. Of this there are many examples. When the men were engaged in cutting through the bed of the river, for the construction of the Thames Tunnel, they suffered severely from the effects of the gas, although the proportion of it in the air was hardly to be discovered by lead paper, and could not, therefore, have exceeded 1 part in 100,000. It is true that it sometimes came in gushes from the fissures of the mud, but the quantity was rarely sufficient to be recognisable by its odour. Strong and robust men were, however, reduced to a state of extreme exhaustion, by breathing it for a few months; and several of them died from it. The symptoms with which they were affected were giddiness, nausea, or actual sickness, and great debility. The men became emaciated, lost their appetites, and fell into a state of low fever, from which, in several instances, they did not recover. Chloride of lime, and other prophylactics, were used; but the evil did not entirely cease until the tunnel was opened from end to end, and free ventilation established.*

According to Dr. Taylor, another remarkable instance of the same kind of poisoning occurred last summer at Clayton Moor, near Whitehaven, where there is a row of small cottages built on the refuse slag of some neighbouring iron-furnaces. The houses are occupied by the workmen and their families, who, for some time, had been annoyed by a bad odour, which pervaded the lower rooms. Suddenly, however, in the month of June of last year, the smell became unusually offensive; and, in the course of two days, thirty of the inhabitants were made seriously ill by it. The attack was remarkably sudden, as if a poison had been at work. In one of the houses there was a family of seven persons, consisting of the husband and wife, and five children. They retired to rest in their usual health, but in the morning two of them were dead, and the others were in a state of profound insensibility. Before the day was over, another of them died, and in the course of the week a fourth. In a second case, a strong, healthy man came home from his night-work, and went to bed; but an hour had hardly elapsed, when he also was found dead. And in a sixth instance, a child was taken ill in the

* Taylor on Poisons, p. 810.

morning, and was a corpse at night. An inquiry was instituted for the purpose of discovering the cause of the mischief, and Dr. Taylor came to the conclusion that it was sulphuretted hydrogen, generated by the action of water on the refuse slag, upon which the houses were built. If so, it is a remarkable instance of the poisonous action of this gas; for those who examined the air of the rooms declare that the test of lead paper failed to show the presence of the poison, except in mere traces—that is, in quantities which could not have been greater than 1 part in 100,000 of air; for such a proportion would have been easily recognised if it had been present. It is unfortunate that an ultimate analysis of the air was not made, for that might have proved the existence of some other gas, perhaps carbonic oxide, which is largely produced in the furnaces, and which might have been wafted from them to the bed-rooms. Those who survived the action of the poison, declared that they were suddenly attacked with giddiness and insensibility; and this was followed by a death-like coma. In some cases there were nausea and vomiting, and in others there was a feeling of oppression and closeness in the air.

These experiments and observations show that sulphuretted hydrogen gas is a powerful narcotic poison; that in a concentrated state it kills immediately, as with the energy of prussic acid. In a more dilute form it causes death by lingering stupor; and when more diluted still, so as hardly to be discovered by its odour, it prostrates the vital powers, and produces a low fever which may end fatally. Dr. Barker, in his prize essay, has summed up his observations of the effects of the gas in these words:—"The symptoms arising from sulphuretted hydrogen are well marked, and may be considered specific. Vomiting and diarrhœa are the first and most prominent symptoms. The latter is painful; the vomiting is difficult and exhausting; and eventually there is insensibility and entire prostration. When the dose of the poison is at first very large, the prostration and insensibility are immediate. The pathology following such poisoning is also definite. If the death take place quickly, the pathological evidence is that of asphyxia. If the poison is long breathed in a diluted dose, the pathology is modified; the fibrine of the blood is separated, and the heart is slowly clogged up with fibrinous depositions."*

Carbonic acid is also produced by the decay of organic matters. It is found in the air of Sewers to the extent of 0·5 to 2·3 per cent.; and the gases evolved from the Sewage itself contain about 19 per cent. of it.

* On the Influence of Sewer Emanations.—*Sanitary Review*, No. XIII, April, 1858, p. 70.

This gas is not easily recognised by its sensible properties, for it has no distinct odour, unless it is breathed in a very concentrated state, and then it irritates the nose and throat in much the same way as the fumes of burning sulphur. It is heavier than air in the proportion of 1525 to 1000, and its diffusive power is very great. A taper will not burn in it, even when the gas is diluted with eight times its bulk of air. This, therefore, is generally the test of its presence; but it is not a good test, for a taper will burn in an atmosphere in which an animal cannot exist,—as, for example, in air containing about 10 per cent. of the gas.

As in the last case, the gas is a powerful narcotic, and will cause immediate asphyxia, if it be breathed in a somewhat pure condition. Even when it is diluted with four times its bulk of air, it destroys life in a few minutes; and with a much larger dilution it produces giddiness and headache, with a sense of weight and throbbing at the temples. This is sometimes followed by slight delirium, and then by an irresistible desire to sleep, the stupor of which passes slowly into coma. According to M. Varin, these effects are produced by the continued inhalation of air charged with about 2 per cent. of the gas; and MM. Peclet and Leblanc assert that animals are affected by an atmosphere containing only 1 per cent. of it. Even so little as

0·5 per cent. is said to be injurious, if it is breathed for a long time.

If the gas has been produced at the expense of the oxygen of the air, as happens in Sewers and crowded rooms, then the effects are more strongly marked; for under these circumstances as little as 3 per cent. will quickly destroy life. Expired air contains from 3 to 5 per cent. of the gas; and the tragedies of the black-hole at Calcutta, and the round-house of St. Martin's are examples of the terribly fatal power of such an atmosphere: even the proportion of from 1·5 to 2 per cent., will cause almost immediate distress, and a feeling of suffocation. These were the proportions found by Dr. Bence Jones in the dormitories of a metropolitan workhouse, where the effects of the vitiated air were remarkably unwholesome;* and, to quote another familiar case, in the atmosphere of the Wellington Barracks, where the sickly Household Troops are lodged, Dr. Roscoe ascertained that the quantity of carbonic at night ranged from 0·12 to 0·14 per cent.† In a crowded theatre it does not exceed 0·32 per cent.; and yet there are few persons who have not experienced the depressing influence of such an

* *Times*, February 27, 1856.

† Some Chemical facts respecting the Atmosphere of Dwelling-houses.—*Quart. Journ. Chem. Soc.*, No. XXXIX, Oct., 1857, p. 268.

atmosphere. What shall we say, therefore, of the Sewer gases, which contain from 0·5 to 2·3 per cent. of it?

Ammonia is another constituent of the Sewer air; and is a product of putrefaction. It is known by its peculiar odour, and alkaline reaction. It is lighter than the air in the proportion of 590 to 1000. The gas irritates the mucous membrane of the nose and eyes; and in some cases it is found in sufficient quantities to produce ophthalmia, and inflammation of the lungs. Parent-Duchâtelet speaks of the first of these as a common effect on the night-men of Paris, but we do not observe it in this country. When ammonia is inhaled in a concentrated state, it produces immediate asphyxia: when it is somewhat diluted with air, its action is chiefly on the lungs; and when it is more diluted still, and is breathed for a considerable time, it liquifies the corpuscles of the blood, and produces the symptoms of typhoid fever. Dr. Richardson has lately inquired into this matter, and he finds, from experiment, that the continued action of the gas, even when it is largely diluted with air, is peculiarly injurious to the animal economy, "the tongue becomes dry and dark; there is an involuntary action of the muscles, varying from a mere twitching to violent convulsions; there are insensibility, extreme sensitiveness to sound, obscurity of sight, and ultimately, if matters are pushed far enough, death by coma. The morbid anatomy is equally demonstrative. The blood is dark and fluid; the serous membranes show petechial spots, and the tissues are softened."*

Dr. Barker's experiments have confirmed these observations; and they prove that the continued inhalation of atmospheric air, charged with only a small quantity of ammonia is dangerous to health.

But there is another property of ammonia which is more dangerous still: it is that of conveying the less volatile products of putrefaction into the air. In all probability it is the purveyor of the miasms of infected districts, as it is known to be of the fætid compounds of animal and vegetable decomposition. It was the agent which gave volatility to the putridities of the Thames during the hot weather, and it is the medium by which the more offensive matters of coal gas are held in suspension. Nor is it less powerful in diffusing the sweet odours of plants, and the subtle constituents of many perfumes. It may therefore act for good as well as for evil.

The volatile compounds of ammonia, with carbonic acid, and sulphurated hydrogen are also injurious. The first act like the alkali itself, and the second

* Prize Essay on the Coagulation of the Blood, 1857, p. 345.

like sulphuretted hydrogen. I have found that one part of hydrosulphate of ammonia in 1000 of air will kill birds almost instantly; and one in 500 will kill rabbits. Dr. Barker has noticed that the symptoms produced by it, even in small quantity, are vomiting, diarrhœa, muscular debility, and quick respiration. The surface of the body becomes hot, and then cold; the tongue protrudes, and looks livid and dry; there is constant twitching of the muscles, and jerking of the limbs; the pulse is quick and feeble; and death follows within a short time, even if the animals are removed from the poisoned atmosphere, and placed in the open air. In an experiment by Dr. Richardson on a dog, the symptoms were those of low fever; and after death, he found the same kind of ulceration in the intestines as is noticed in the typhoid form of the malady.

Light carburetted hydrogen, or marsh gas is also found in the atmosphere of Sewers, but it rarely occurs in such proportion as to be dangerous; now and then, however, it accumulates, as it does in coal mines, and becomes explosive.

The gas is a product of putrefaction, and it is likewise formed by the action of organic carbon on the elements of water.* It escapes freely from the mud

* $2, C + 2\ H\ O = 1, C\ O^2$ and $1, C\ H^2$

of stagnant ditches, and, as I have already said, from the solid deposit of the sewers.* The gas has no odour, and therefore cannot be recognised by its sensible properties. It is about half as heavy as air, the specific gravity of it being 557·6; and it is very combustible, burning with a yellow flame. When it is largely diffused through the atmosphere it forms an explosive mixture, the violence of which is dependant on the proportions of the air and gas. If there is 1 volume of gas to about 9·5 of air, the explosion is most powerful; but the proportions on either side of this are not so violent; for the shock becomes gradually weaker and weaker until, with 1 of gas to 14 of air, or 4 of gas to 1 of air, the mixture does not explode at all. When the combustion is perfect, the products are carbonic acid and aqueous vapour, with the residual nitrogen of the air—the volume of carbonic acid being the same as that of the gas consumed. Such an atmosphere is therefore dangerous to life, not only because of its deficiency of oxygen, but also because of its containing so large a quantity of carbonic acid; and this is the thing to be feared after an explosion in a sewer or coal mine.

Marsh gas has but little action on the animal body, unless it is breathed in a pure form, and then it causes the general effects of anæsthesia.

* See Table X. in the Appendix.

Miners are often obliged to work in an atmosphere containing from 8 to 10 per cent. of the gas, but they experience no ill effects from it, until the proportion rises to about 20 per cent., and then they feel giddy, with a sense of weight upon the forehead.

Coal gas is likewise present in the Sewers: it is not formed there, but escapes from the street mains. The quantity which is let loose in this manner is enormous. Gas engineers say that from 12 to 35 per cent. of all the gas manufactured in London is lost.* Now supposing that of this, the leakage amounts to 5 per cent., which my friend Mr. Wright informs me is about the quantity; then as much as 386,400,000 cubic feet of gas escape into the public ways of this metropolis every year, or rather more than a million cubic feet every day; and in the city it amounts to about 25,000,000 cubic feet per annum, or nearly 70,000 cubic feet per day.† Most of this must find its way into the Sewers, and therefore is a matter of some importance.

* Evidence of the Metropolitan Gas Engineers before the Referees, in the matter of Croll and the Great Central Gas Company, 1857.

† The quantity of gas supplied to this Metropolis amounts to about 7,728,000,000 cubic feet per annum—*(Lowe)*, and that to the City to about 500,000,000 cubic feet—*(Croll)*.

The chief constituents of coal gas are hydrogen and light carburetted hydrogen. The former amounts to about 40 per cent. of the gas, and the latter to 45. The other constituents are about 7 per cent. of carbonic oxide, 2 of nitrogen, 1 of carbonic acid, and 5 of the condensable hydro-carbons. Besides which there are always traces of ammonia, bi-sulphuret of carbon, and coal tar.

The principal danger from this gas is, its inflammability, and its property of forming an explosive mixture with atmospheric air. Coal gas, of the composition just stated, will form the most dangerous mixture if it be diffused through about 6 times its volume of air; but, as coal gas varies in its composition, it has been found that different proportions of air are required to explode the gas of different companies. MM. Tourdes and Wurtz of Strasburg, found that the gas of that city required 7 times its volume of air to explode it;* and Dr. Arnott, in his report of the mischief done by an explosion of gas in Albany Street in 1848, stated that the gas required 10 times its bulk of air to fire it. The general results of my own experiments are that common gas explodes most violently, when it is mixed with from 6 to 6·5 times its bulk of air, and canal gas when it is mixed

* Ann. d'Hygiène, Jan., 1842.

with about 10 times its bulk. Every proportion greater or less than this, reduces the violence; and at last, with 4 or 5 volumes on either side of the scale, the explosive power ceases entirely.

Again; the force of the explosion varies with the mixture, and with the volume that is fired. Theoretically, it is known that marsh gas in exploding, exerts a pressure of 38 atmospheres, hydrogen 26·5, and carbonic oxide 22·6.* The force of the other hydro-carbons varies from 44 to 88 atmospheres. My experiments on this point have not been numerous, but they indicate an explosive power of about 30 atmospheres, for ordinary coal gas.

The physiological properties of coal gas are more marked than those of light carburetted hydrogen; for the condensable hydro-carbons are endowed with great activity as poisons. When, therefore, the gas is inhaled in a concentrated state, it quickly produces insensibility, which is followed by coma and death. An atmosphere containing from 7 to 12 per cent. of gas will kill rabbits and dogs in a very short time; and M. Tourdes found that even a thirtieth or fiftieth part of it in the air, would act injuriously on animals. This proportion causes in the human subject, nausea and headache, with great depression of the vital powers; and if the inhala-

* Bunsen's Gazometry, by Roscoe, 1857, p. 244.

tion is continued for a long time, it produces giddiness and insensibility. Dr. Taylor has collected the records of seven cases of death from the action of coal gas, and it is probable that the air was not charged with more than 8 or 9 per cent. of it in any of them.*

As to the properties and effects of the organic vapour which is contained in Sewer gases, I cannot speak with certainty, except that it is matter in a state of active decomposition; and experience has long since decided that matter in this condition has power to disturb the equilibrium of other organic molecules, and to propagate to them its own state of decay. When this occurs in the living animal body, it is productive of the most terrible consequences. Our ignorance of the nature of this organic vapour is not surprising, when we consider that we are equally uninformed of the composition of the subtle miasms and putridities which abound in the air of infected districts, and in the vapours of organic decomposition. Guntz tried to catch the volatile matters of putrid flesh, but he only obtained a stinking liquor that could not be analysed. Moscati condensed the miasm of the pestilential rice fields of Tuscany, but the liquid which he procured defied investigation, notwithstanding that it was so charged with organic matter, that it quickly

* Taylor on Poisons, p. 809.

putrefied.* Rigaud did the same with the atmosphere of the marshes of Lanquedoc,† and Boussingault with the air of some of the worst districts of Paris;‡ but their labours were fruitless. Even the wards of a hospital crowded with cholera patients,§ and the fœtid dormitories of our household troops,‖ and the no less unwholesome dens of the city poor,¶ have been vainly searched for the occult molecules, which are endowed with so much virulence. All that we know of them is that they will reduce the salts of silver and gold, and blacken sulphuric acid; that they contain the elements of organic matter in a state of active change; that they form a nidus for the growth of the lowest forms of animated beings; and that they have power to engender disease in higher animals.

Sometimes these miasms are odourless, but in the case of the Sewer gases, it is the organic vapour

* *Gilb.* 43, 12, and Gmelin's Handbook of Chemistry, vol. ii., p. 415.

† *Ibid*, vol. ii., p. 415.

‡ Boussingault—Mémoire sur la possibilité de constater la présence des miasmes, et sur la presence d'un principe hydrogéné dans l'air.—*Gaz. Med. de Paris*, 1834, p. 523.

§ Dr. Dundas Thomson, on the Air of the Cholera Wards of St. Thomas Hospital.—*Appendix to Report of the Commission for Scientific Inquiries in relation to the Cholera Epidemic of* 1854, p. 122.

‖ Roscoe. *Quart. Journ. Chem. Soc.*, No. XXXIX., p. 261.

¶ My Quarterly Report for March 28th, 1857, p. 13.

which gives them their peculiar smell; for when the sulphuretted hydrogen is entirely renewed, there are still the characteristic stinks, which have been so accurately described by Parent-Duchâtelet.

With this general account of the properties of the individual constituents of the Sewer gases, I proceed now to consider—

WHAT ARE THE DANGERS OF THE COMPLEX SEWER GASES THEMSELVES?

Experience has shown that they are of two kinds, namely; the dangers which are incidental to the poisonous action of the gases; and those which arise from their explosive property.*

As to the first of these, it must be evident, from what we know of the composition of the gases, and the properties of the individual constituents that the complex miasms must be exceedingly hurtful to the animal economy. Observation has confirmed this, by proving that they are among the most active poisons. One breath of the undiluted gases will destroy life immediately; and even when they are mixed with a rather large quantity of atmospheric air,

* See the List of Accidents from Sewer Gases, in Mr. Haywood's Report on the Ventilation of Sewers, Appendix A., p. 125; and also page 89, in the Appendix to this Report.

they quickly cause asphyxia or narcotism, and death. Those who are exposed to their influence are suddenly deprived of consciousness: they fall powerless, as if they were shot; the lips become livid; the face turgid; bloody froth oozes from the mouth; the surface of the body gets cold; the action of the heart tumultuous and irregular; the breathing difficult and spasmodic; and the sufferer dies in convulsions, or lingers for a short time in deep and irrecoverable coma. In smaller quantity the miasms are less active, but not less certainly injurious; for they produce nausea or actual sickness, vertigo, delirium, and gradual insensibility. The muscles of the face and chest are convulsed; and the action of the heart is feeble and fluttering: the skin acquires a death-like coldness; and the respiration is irregular and catching. In this state the danger is imminent, and if means are not promptly taken for recovery, the patient dies in a state of coma.* If the gases are still further diluted with atmospheric air, they produce a general prostration of the vital powers. The appetite fails;

* The writings of Portal, Gériel, Labouire, Parmentier, Alibert, Dupuytren, Cade de Vaux, Hallé, Geraud, Parent-Duchâtelet, Chevalier, D'Arcet, Orfila, Devergie, and others of the French, abound with instances of the fatal *mephitismes* caused by the gases from the *fosses d'aisances:* and the works of English Toxicologists contain many examples of a similar kind. See the list of authorities in the bibliography which I have given in the Appendix, p. 85.

the bowels become disturbed; diarrhœa of a chronic character sets in; and the sufferer is either worn out by exhaustion, or he falls into a state of low fever, from which it is difficult to raise him.

I need not weary you with examples of the acute forms of poisoning by these gases, for they are but too well known.* It is, however, necessary for my

* I may, however, remark that within the last twelve months, seven men have been suffocated by the gases in the Sewers of this Metropolis. One accident happened in the month of June last year, at the Green Bank Sewer at Wapping Wall. The workmen suspected the foulness of the Sewer, and before they went into it, tested it with a light, after it had been opened for some time for ventilation; but hardly had the men entered the Sewer when there came a flush of water which disturbed the mud and let loose the foul gases. The men were at once asphyxiated, and three of them died immediately, while the fourth lingered for nearly a week.

The second of these accidents occurred in the month of August following. An old Branch Sewer at Whitechapel was opened for the purpose of draining it into the main sewer; and after a hole had been made into it, the men left for breakfast. By the time of their return the gases had escaped into the pit where they were working; and on making a descent into the hole, five men were rendered insensible. They were carried to the London Hospital, but before they reached it three of them were dead, and the other two were in a dangerous condition; although with active treatment they slowly recovered.

Another example of the same kind of poisoning occurred at the Kennilworth Sewer at Pimlico, in October, 1849, whereby five men lost their lives; and so sudden and decisive were the effects of the gas that Dr. Ure and Mr. Lewis Thompson were of opinion that they were caused by cyanogen or prussic acid; but purpose that I should mention a few cases of chronic poisoning, in which the effects were produced by the inhalation of very small quantities of sewer miasms. One of the most remarkable instances of this is recorded by M. D'Arcet. He states that there was a small lodging in Paris, consisting of a bed-room and ante-room, which had been successively tenanted by three vigorous young men, each of whom died within a few months of his occupying the place. D'Arcet was requested to examine the rooms, and ascertain the cause of the evil. He found that a pipe from a privy in the upper floor ran down by the side of the wall near to the head of the bed where the inmates slept. The pipe was unsound, and the wall was damp from leakage of the soil into it; but there was no perceptible smell in the room when D'Arcet examined it: nevertheless he had no doubt that the deaths of the former occupants were referable to the emanations from the wall. The pipe was, therefore, repaired, and from that time the unwholesomeness of the place was cured.*

In August 1831, 22 boys living at a boarding

the investigations of Dr. Lyon Playfair, and Professor Miller proved that they were due to the ordinary Sewer gases.

And in August, 1848, a man was poisoned in a privy in Langley Court, Long Acre, by the gases evolved from a drain, into which oil of vitriol had been thrown.

* Ann. d' Hygiène, Juillet, 1836.

school at Clapham, were suddenly seized with alarming symptoms of irritation in the stomach and bowels, with twitchings of the muscles of the arms, and excessive prostration of strength, Another boy had been similarly attacked three days before, and he died in twenty-five hours: one of the others died in 23 hours. A suspicion of accidental poisoning naturally arose, and the various utensils, and and articles of food used by the family were examined, but nothing of a deleterious nature was found. The only circumstance which appeared to explain the accident was, that two days before the first child was taken ill, a foul cesspool had been opened, and the matter of it diffused over a garden adjoining to the children's play-ground. This was considered to be the cause of the disease; and the opinion was formed not only by the medical attendants, but also by Drs. Latham, Chambers, and Pearson, who personally examined the whole of the particulars.*

The third instance to which I shall refer is of more recent date, and has been a subject of considerable discussion. In the month of August 1852, an attempt was made to drain the town of Croydon by means of small stoneware pipes, which were not only of insufficient size but were imperfectly

* Christison on Poisons, p. 810., and Med. Gaz. 1831, pp. 375, 410, 448.

cemented together. The consequence was that a large quantity of the Sewage escaped into the earth, and drained away to the neighbouring ditches. This became a subject of great annoyance; and in a short time it produced an alarming outbreak of fever, diarrhœa, and dysentery. Out of a population of about 16,000 persons, 1800 were attacked with fever, and 60 of them died. The cases of diarrhœa and dysentery were also numerous, and of these 10 died. Dr. Arnott and Mr. Page were instructed by the Secretary of State to inquire into the matter, and they reported that the Sewer miasms which had been let loose by the imperfect system of drainage had been influential in producing the epidemic.* Dr. Carpenter, of Croydon, has informed me that even now he can tell where the pipes are stopped, by the occurrence of diarrhœa, or fever, in the houses through which the foul gases are forced.

Last summer a remarkable instance of the same kind occurred in Fleet Lane, while the Sewer was being made through it from the Old Bailey to Farringdon Street. The Sewer was open for about four months, namely from the 29th of June to the 30th of October, and during the whole of that time the inhabitants complained of the offensive

* Reports of an inquiry relative to the prevalence of disease at Croydon in 1853, by Dr. Arnott and Mr. Page.

smell; but soon after the Sewer was opened, diarrhœa began to appear, and then fever followed. These diseases prevailed to an alarming extent; so that of the 140 families that occupied the 50 houses in the Lane, hardly one escaped. Mr. Ross, who is the Medical Officer of the District, and who saw most of the cases, attributed them to the Sewer miasms. I made a personal inquiry into the matter at your request, and came to the same conclusion; for the outbreak was confined to the Lane and immediate neighbourhood; it appeared soon after the Sewer was opened, and it disappeared when the Sewer was closed.

In the report from the Poor Law Commissioners on the sanitary condition of the labouring population of Great Britain there are many examples of the morbific action of Sewer and cesspool gases. Cases are recorded where fever has periodically prevailed in the localities of bad drains; where it has attacked those, and those only who were exposed to the mephitic gases. Out of a row of houses, the disease has fixed upon those tenements which were badly drained, or were fouled by Sewage. There is one case which is remarkable for its significance. On the north side of a street in Derby there are 54 houses, all of the same description, and inhabited by the same class of persons. Six of these houses, in the very centre of the row, became the abodes of fever; and of 16 persons attacked with the disease, 5 died. The fever was nowhere else in the row; and on inquiry it was found that these, and these only, were exposed to the action of Sewer gases, and to the miasms from cesspool matter which had soaked into the soil.*

Dr. Duncan, in his report to the Commissioners on the sanitary condition of Liverpool, says:— "There is one court, Banastre Court, containing only 12 houses, in which during a single year, there were 63 cases of fever, caused by the oozings from a couple of cesspools."† And Mr. Thompson, of Clitheroe, relates that in the summer of 1839, some remarkable cases of fever appeared amongst the inhabitants of a cluster of small cottages, called Littlemoor, the situation of which is remarkably healthy and agreeable. The cottages were occupied by only 21 persons. In the course of the summer 15 cases of fever occurred, 9 of which were among the cottagers, and the rest among the nurses and friends who came to wait on the sick. The disease had its origin in Sewage matter which run along an open drain near to the houses; for directly that

* Report from the Poor Law Commissioners to the Secretary of State, on the Sanitary Condition of the Labouring Population of Great Britain, July, 1842, p. 26.

† *Ibid*, p. 31.

was removed and the drain covered in, the progress of the disease was arrested.*

To nearly the same effect is the report of Dr. Acland, of a recent outbreak of fever in a small village in Buckinghamshire.

And not less instructive is the report of an epidemic that in 1838 desolated the commune of Prades in the department of Ariège. Out of the 750 inhabitants of the commune, 310 or nearly half were attacked with a putrid disease, and 95 died. The cause of the epidemic was traced to a Sewer which was the receptacle of all the refuse water and filth of the district. The first persons attacked were the women employed in washing linen in this pestiferous pool, and the labourers at work in the neighbourhood of it. Three times the pestilence returned, and always when the wind was blowing over the infected water.†

Lastly, I may state that during the inquiry which was instituted by the Board of Health in 1854 into the circumstances of the terrible outbreak of cholera

* *Ibid*, p. 35. See also Dr. Pickford on Hygiene, article, Drainage, p. 197, for many such examples.

† Rapport de la Commission des Epidémies de l' Academie Royal de Medicine pour l'Année, 1839, et un partie d' 1840, par M. Brichetan, Secretarie Rapporteur, &c.

in the Golden Square district, there was abundant proof of the injurious effects of the mephitic gases from the street gullies and untrapped closets. In fact, it may be generally said that at every outbreak of epidemic disease, the badly drained districts, where there are neglected cesspools, stagnant Sewers, and untrapped gullies, are always the localities where the disease is most active. This is the experience, not of a few medical men, but of the whole profession; for there is not a person in it of any considerable share of practice, who has not frequently seen the morbific effects of Sewer miasms, and who does not know the significance of fever and diarrhœa.* It need not be, that to produce disease, these miasms should be so concentrated as to be unendurable. In many of the cases which I have quoted, the gases were in a highly diluted form, and yet their effects were un-

* As far back as the flourishing times of old Rome, there was a general belief that the emanations of Sewers were fruitful of disease, and the subject commanded so much attention as to be a matter of religious observance, as well as of domestic policy. The Sewers were placed under the protection of *Cloacina*, and her subordinates—*Sterquilinus* and *Mephitina;* and the general regulations for cleansing them were under the direction of the Prætor; though the actual management of the business was in the hands of the head scavengers—the *curatores cloacorum urbis.* It was their duty to see that the aqueducts and Sewers were always in a wholesome condition, for we are told that experience had shown that uncleansed and unrepaired Sewers threaten a pestilence, and are dangerous.—*Digesta Just. Lib.* 43, Tit. 23.

mistakeable. It is, therefore, a dangerous fallacy to maintain that Sewer gases are not hurtful when they are no longer offensive to the sense of smell; for, as I have more than once had to remark, there is no necessary connection between bad odours and zymotic poisons. The pestiferous matter that floats over the coast of Africa, the Sunderbunds of India, the plains of Algeria, the marshes of Europe, and the fens of England, is not offensive to the nose, though it is deadly enough to the body; and conversely there are many horrible stinks which are incapable of producing disease. The test of this, therefore, is experience; and experience has fully decided that the emanations from Sewers and foul drains are in the highest degree dangerous to animal life; in fact Dr. Barker has recently put this to experiment. He has conveyed the gases from a cesspool into a chamber where animals were confined, and in some cases, as with dogs, the effects were almost immediate; there were vomiting, diarrhœa, loathing of food, general emaciation, and great prostration of vital power. In other cases the effects were those of a mild continued fever, such as is often seen in the dirty and ill-ventilated houses of the poor.*

* Op. Cit.—Injurious, however, as are the Sewer gases to animal life, yet I have noticed in the well-ventilated Sewers of the City that the following creatures live and thrive. Rats, the common crustacean *Oniscus murarius;* several kinds of snails,

As to the other danger, namely that whicn arises from the inflammable and explosive properties of the Sewer gases, it may generally be guarded against; for it is almost always caused by the escape of coal gas, and this is easily known by the smell, long before the proportion is so large as to take fire. Now and then, however, there is danger from the accumulation of light carburetted hydrogen, or the marsh gas generated in the Sewer mud; but this happens only when a Sewer has been closed up for a long time, or is very foul and imperfectly ventilated.

THE REMEDY FOR THE SEWER MIASMS.

This is the great question which you have submitted to me for consideration, and the preceding facts show clearly enough that it is an important one. I am far from thinking with your engineer that the mischief occasioned by Sewer gases is not of such magnitude as to be worth a remedy that may cost 6d. a head to the population; nor do I believe that if you had temporized with the matter, and had yielded to the demand on the

as *Zonites cellarius*, *Physa fontinalis*, and *Planorbis vortex;* many species of spiders and winged insects; and in the mud which accumulates on the wall, above the water-line, there are often myriads of a small annelid—the blood-worm, which is also found in the Thames mud and is erroneously called a *Gordius:* it being a species of *Nais*. Besides which the walls are here and there encrusted with fungi, one of which, the *Polyporus sulphureum*, grows in great luxuriance.

part of the public, to close up the ventilating gratings, which are now so offensive, and had thus turned the foul gases into the house drains, the nuisance would have been regarded simply as a domestic evil, for which the cure was to be sought privately and individually by those who felt the annoyance: in fact, such a proceeding would have been unworthy of the trust which is reposed in you as the custodians of the public health, for it would have been a matter of life or death to the great bulk of the community. The question then is of the utmost importance, and must be dealt with in an earnest and independent manner. To aid you in its solution, I will describe what is known of the action of the several substances that have been proposed as correctives for the mischief.

At all times attempts have been made to destroy or neutralize the offensive products of decomposition; and the simplest way of doing it has been by the use of another scent—a perfume or volatile oil, which would cover or mask the offensive body. These were the correctives employed in religious worship. They entered into the composition of the ointments of the high-priest, and the incense of the altar; and to this day they have enjoyed a reputation and general popularity which they have not deserved; for their action is not on the putrid product, but merely on the sense of smell, which they blunt to the action of the offensive vapour. In the middle ages when the plague, the black-death, and sweating sickness, and pestilential fever desolated the cities of Europe, immense importance was attached to the use of perfumes: fumigations with costly spice and rich smelling oriental drugs were largely used in the houses of the rich, but with no good effect.* The ancients also knew the value

* The advice of the learned Dr. Caius, who wrote of the Sweating Sickness of 1552, was to "haue alwaies your handekercher for your nose and mouth, bothe within your house and without, either the perfume before saide, (namely, a mixture of spices) or vinegre rosate; and in your mouth a pece, either of setwel, or of the rote of *enula campana* wel steped before with vinegre rosate, a mace, or berie of juniper. In wante of suche perfumes as is beforesaide, take of mirrhe & drie rose leues, of eche a lyke quantite, with a little franke-encense, for the like purpose, and cast it vpon the coles; or burne juniper and their berries. And for so moche as clenelines is a great help to helthe, mine aduise is, that all your clothes be swete smellynge and clene, and that you wasshe your handes and face, not in warme water, but with rose water, and vinegre rosate colde, or elles with the faire water and vinegre, wherein the pilles of pomecitres and sorel is boiled . . . . . And in goyng abrode, haue in your hande either an handekercher, with vinegre and rose water, or a litle muske, balle of nutmegge, maces, cloues, saffrō, & cinamone, of eche the weight of ij. d., finely beatē; of mastike the weight of ij. d. ob., of storax v. d., of ladane x. d., of ambre-grise vi. graines, of muske iii. grains, dissolued in ryght muscadel: temper al together, & make a balle." A Boke of Counseill against the disease commonly called the Sweate, or Sweating Sickness, made by Jhon Caius, Doctuer in Phisicke, 1552.—*Hecker's Epidemics of the Middle Ages*, p. 370.

of fire as a disinfectant; and they also made use of the fumes of burning sulphur.

But the right knowledge of the action of disinfectants and deodorizers dates from a very recent period; for so late as the year 1773, Guyton Morveau one of the best chemists of France, thought that the vapours of muriatic acid were the most powerful of disinfectants; and later still—in the year 1803, Dr. Carmichael Smith obtained a grant of £5,000 from Parliament for a suggestion which is nearly valueless, namely, the employment of the fumes of nitrous acid. Chlorine gas was discovered by Scheele in 1774, and soon afterwards its disinfecting properties were noticed by Berthollet; but its use cannot be dated farther back than the beginning of the present century, when Guyton Morveau and Dupuytren first pointed out the great value of it as a disinfectant; and even then it was not generally employed: in fact, its present popularity dates only from the time that chloride of lime has been largely manufactured for bleaching purposes. Within the last twenty years almost all the refuse products of the arts, and a great number of special compounds have been recommended for the deodorization of sewage,* &c. They all act in one of two ways: they either give stability to the organic mat-

* See Table VII., in Appendix, for a list of the substances proposed for the deodorization of Sewage.

ter, and so check its tendency to decay, or they operate on the putrid vapours, and destroy their offensive properties. This they do either by fixing the effluvium, and forming compounds which are inert, or by breaking up the putrid molecule, and changing its nature, or by expediting the process of decay, and hurrying it on to the last stage of oxydation.

Those substances which give stability to organic matter are properly called *Anti-septics* or *Anti-putrescents.* They have always been more popular than any of the second class of deodorizers, because of their importance in the arts. Salt, sugar, vinegar, creosote, and the empyreumatic oils of wood, peat, coal, &c., are examples of this class; so also are chloride of zinc, sulphate of copper, and corrosive sublimate—substances which have been respectively patented by Sir William Burnett, Mr. Margary, and Mr. Kyan. Alum, and the astringent matter of many vegetables have likewise been used for ages as the means of preserving gelatinous tissues, in the form of leather. None of these however, except the chloride of zinc, is applicable to the case before us ; and that operates more as a deodorizer than an anti-putrescent. In fact, as I have already stated, the matters of Sewage are always in a high state of decomposition, and cannot therefore be treated with much advantage, unless the anti-septics are applied to them, before they enter the

Sewers; and this, I need not say, is altogether impracticable. Even in Paris, where there are special contrivances for such a purpose, it fails because of its utter impracticability.

Of the second class of substances, namely, the *Deodorizers* and *Disinfectants*, there are many which deserve notice.

A.—Those which combine with the putrid gases, and fix them in an involatile form, are the metallic oxides, and their salts, as chloride and sulphate of zinc, acetate and nitrate of lead, sulphate, muriate and pyrolignate of iron, impure muriate of manganese—the refuse of bleaching works, common alum, the fixed alkalies, and the salts of lime and magnesia. Most of these compounds unite with the sulphuretted hydrogen and ammonia of sewage; and so far, therefore, they remove the unpleasant smell of it, but they do not touch the organic vapours. Besides which, they are difficult to apply, and are very costly. In fact, putting aside all the working expenses that would attend their use, the mere cost of the deodorizers alone would range from about £2837 to upwards of £10,000,000 per annum for the City Sewage; and from £11,838 sterling to £48,000,000 for the Sewage of the whole of London.* This, together with the insufficiency of their

* See Table XIII. in the Appendix for the power and cost of the most approved deodorizers.

power, as deodorizers, and the difficulty of applying them while the Sewage is within the Sewers, deprives them of all practical utility. That power which they do possess—namely, the power of coagulating a great part of the soluble matter of Sewage, and favouring the precipitation of the insoluble, can only be applied, with any chance of success, after the Sewage has left the Sewers; and even then there are but two of them,—namely, lime and the superphosphate of lime with magnesia, that can be used with advantage. In Tables XIV. and XV. of the Appendix, I have given the results of the action of lime on the night and day Sewage of the City. These results show that, in addition to the whole of the insoluble part of the Sewage, the lime throws down about one-fourth of the soluble organic matter, leaving about 11 grains of it still in solution in every gallon of day Sewage, and about half that quantity in the Sewage which is discharged by night.

B.—Of the second class of disinfectants, those which act chemically on the volatile matters and break them up, so as to form new compounds, which are inert, the most important are, chlorine, chloride of lime, hypochlorous acid, sulphurous acid, and nitrous acid. The first three of these,—namely, chlorine and its oxy-compounds,—operate by abstracting hydrogen from the putrid vapours, and perhaps also by decomposing water, and setting the oxygen free to destroy the miasms. Their power is remarkably great, as may be seen by the action of chlorine or chloride of lime on ordinary Sewage,* —8 grains of chloride of lime, or less than an ounce of a solution of chlorine will completely deodorize a gallon of Sewage, and the diffusion of a little chlorine through the worst kind of Sewer gases is sufficient instantly to deprive them of their offensive odour. Nevertheless, chloride of lime is a costly agent; for, if it be used in the proportion of only 8 grains to the gallon, it will cost nearly £57,000 a year, for the deodorization of the City Sewage, and nearly £237,000 for the Sewage of all London.† As for the gas itself, it is almost impossible so to apportion and manage the diffusion of it in the Sewers as not to have either the chlorine or the Sewer gases in excess. There may be cases where the generation of chlorine in a foul Sewer might be easy of management, but it is scarcely applicable to the deodorization of the whole of the City Sewers, where there is a space of more than three millions of cubic feet to deal with, in channels that are about 48 miles in length.

Sulphurous acid and nitrous acid are still less manageable. Besides which they are exceedingly costly, and are not nearly as powerful in their action

* See Table XIII. † Ibid.

as chlorine. Like chlorine, however, they disorganise the putrid molecules, and decompose the hydro-sulphur compounds, and fix ammonia; but, like it also, they are powerful irritants, and could scarcely be let loose into the Sewers without danger to the workmen: in fact, this is the great objection to all the members of this class of deodorizers; for if they were used in excess, as most likely they would be, they would not only be injurious to the workmen, but by escaping through the untrapped openings in the streets and houses, they would likewise be a source of great annoyance to the public. The difficulties, therefore, in the way of their general application are such as to deprive them of their otherwise undoubted chemical value. Even in those cases where chlorine is employed for the destruction of foul gases that have accumulated in a cesspool or stagnant Sewer, there must also be effective ventilation; for although the gas has power to destroy the putrid miasms, it has no power to furnish a supply of oxygen or to remove carbonic acid.

C.—The last of the disinfectants are those which expedite the process of decay, and cause the putrid matters to combine with oxygen, and to become inert. Of this class there are two members—namely, those which act chemically and supply oxygen of themselves to the offensive compounds;

and those which merely facilitate oxydation by their physical properties. The manganates and permanganates of potash are the best examples of the first class. They contain a large proportion of oxygen, which they freely give up to putrid organic matter, and so destroy it. These compounds have been patented by Mr. Condy, of Battersea, and he supplies them in a state of solution of various strengths. That which I have used in my experiments contained nearly 6 per cent. of the permanganate, and could be supplied at a shilling a gallon. One hundred and fifty drops of it were sufficient to deodorize a gallon of ordinary Sewage; but the disadvantage of it is, that it has no power to destroy the foul gases which have already escaped into the Sewer air; and, as I have before said, it is difficult to apply such an agent to the liquid refuse of a large city. There are doubtless occasions where it might be profitably and advantageously employed; but the use of it in the Sewers of this metropolis would demand a great alteration in the present arrangements, for there would be required a means of introducing the liquid so that it might mix thoroughly with the Sewage at the head of every drain and Sewer. Besides this, the cost of the material, even if it were used in the proportion of 150 grains to the gallon, would be about £753,000 a year for the City Sewage, or more than three millions per annum for that of the whole metropolis.* Looking, however, merely at the chemistry of the subject, it must be admitted that Mr. Condy's solution is a powerful and valuable disinfectant; for like chlorine its action is permanent and complete; and in the solid form it is about equal in deodorizing power to the same weight of chloride of lime.

The second of this class of disinfectants are the agents which promote oxydation by a physical property,—that is by bringing the putrid matters into contact with atmospheric oxygen. There are three of them, namely, fire, water, and porous solids. The first effects the change by active combustion, and the others by a slower process of oxydation, which is called *eremacausis*, or slow burning. All of them, however, are complete in their action, and are, under different circumstances, more or less manageable and useful.

The value of fire as a disinfectant is well known, and has been recognised from the remotest time. The sacrificial altars of early nations were the rude methods by which the agent was employed; and so fully did the ancients believe in its salutary action, that in times of pestilence it was often resorted to as the only effective means of purifying

* Vide Table XIV. in the Appendix.

the atmosphere.* In the popular mind there has always been a notion, that the Plague of London was exterminated by the great fire. Powerful, however, as the agent is, it does not appear to be applicable to the destruction of the Sewer gases, notwithstanding that the use of it for such a purpose has always been a favorite idea with every new Commission of Sewers, and is the basis of most of the amateur schemes of the present day. Mr. Bazalgette has stated, in his evidence before the House of Commons, that putting aside all the difficulties of controlling the course of the air in the main channels of the Sewers, and of stopping the leakage from the thousands of openings in the streets, closets, and drains, the mere cost of the fuel for the furnaces would not be less than £80,000

* Caius, in his Boke of Counsel against the sweating sickness of 1552, advises the use of "Fyres, either in houses or chambers, or on that side the cities, townes, & houses that lieth toward the infection and wynde commyng together, chefely in mornynges & eueninges, either by burnyng the stubble in the felde or windfallynges in the woodes, or otherwise at pleasure. By which pollicie skilful *Acron* deliuered Athens in *Gretia*, and diuine *Hippocrates abdera in Thratia* frō ye pestilēce & preserued fro the same other the cities in *Grece*, at diuerse times cōyng with the wynde frō *Æthiopia*, *Illyria*, & *Pœonia*, by puttyng to the fyres wel smelling garlādes, floures, & odoures, as *Galene* and *Soranus* write. Of like pollicie for purgyng the aier were the bonfyres made (as I suppose) frō long time hetherto vsed in ye middes of sommer, and not onely for vigiles. Op. Cit., p. 370."

a year, and perhaps it might reach to upwards of £200,000.* Your own Engineer has also considered this mode of disposing of the Sewer gases, and his Report on the subject leaves nothing for me to discuss. In point of fact, the least knowledge of the present condition of the City Sewers, with their 47,819 openings, placed at the most irregular intervals, will satisfy any one who inquires into the matter, that the disposal of the Sewer gases by ventilation and fire is almost impossible.†

The destruction of the Sewer miasms by the agency of water is not quite so unmanagable, and has therefore received attention from many of the leading engineers of the present day. Mr. Bazalgette says of it, that it is the best and only available means of purifying the Sewers. As to its salutary action there can be no doubt, for its power as a disinfectant in the presence of atmospheric air, is manifested in every river in the kingdom. Wheresoever the putrid refuse of a town mixes with a large volume of fresh water, there the process of oxydation is quickly

* Evidence before the Parliamentary Committee for Inquiring into the State of the Thames. 1858.

† I have purposely avoided the question of the temperature at which the sewer miasms are destroyed; but it may be stated that experiments have proved that in a dry atmosphere infectious matters and living organisms are not destroyed except at a temperature a little short of 300°, whereas if much moisture is present they are rendered innocuous at 212°.

carried out, and the offensive matters are rendered innocuous. Even the River Thames, except at a peculiarly dry and hot season, finds within itself a means of purification, which is quite equal to the contaminating influence of the soluble organic matter that flows into it. This is effected by the physical power which water possesses of transferring oxygen from the atmosphere to the putrid products; and this power is so great that it will even destroy the soluble organic constituents of ordinary Sewage, without further dilution with water. I have ascertained by repeated experiments that when the clear liquid of common Sewage is exposed to the air it quickly absorbs oxygen, and loses its offensive odour. It is the insoluble organic matter which keeps up the putrefaction, and evolves the noxious gases. This happens because of its being beyond the reach of the salutary influence of atmospheric oxygen. In those Sewers therefore, where the supply of water is large, and the current is rapid, there is little or no deposit of mud, and the atmosphere is not particularly offensive; but on the contrary, where the Sewage is nearly stagnant and the water supply is small, there the mud accumulates to a dangerous extent, and the gases are extremely noxious.

I cannot inform you very accurately what quantity of water is necessary for the purpose of disinfection.

Already there is a daily supply of about 31 gallons to each of the inhabitants of this metropolis; but this is evidently not sufficient to cleanse the Sewers; for independently of the existence of a putrid atmosphere within them, there is the stronger evidence of their foulness in the condition of the Sewage which is discharged immediately after a heavy fall of rain. And even if it could be determined precisely what amount of water would effect the purpose, there is still the difficulty of distributing it so as to scour out all the channels, to the very smallest; for this could not be accomplished without special contrivances for delivering the water at the head of every drain. I do not therefore see much prospect of success in this mode of dealing with the subject; besides, if hereafter it should come to pass that chemistry is able to furnish a means of utilising the Sewage, and making it available as manure, the dilution of it almost to the degree of its destruction would manifestly be an injury that could not easily be repaired.

The last means of destroying the offensive matters of Sewage is by the agency of a porous solid; and this may be applied either to the Sewage itself or to the gases which are evolved from it. The best examples of such an agent are common clay and charcoal.*

* The power of charcoal as a deodorizer, and as a means of removing colour as well as smell from liquids, has long been

Both of them operate in the same way—namely, by condensing the putrid vapours within their pores and upon their surface, so as to cause them to unite with atmospheric oxygen: they produce, in fact, a species of slow combustion, by which the miasms are gradually consumed. To effect this, however, there must be free access of atmospheric air: hence it is, these substances have but a limited power of deodorization when they are mixed with the liquid Sewage, or are so overcharged with water as to be incapable of absorbing oxygen.

Every one is familiar with the deodorizing power of common earth: in fact, the grave-yards of every city testify of the enormous quantities of organic matter that can be disposed of through its agency; and no one who has witnessed the rapidly deodorizing power of clay when Sewage or night-soil is distributed upon the land, can doubt its efficacy. The Chinese have long taken advantage of this power, for they mix night-soil, with about one-third of its weight of fat marl, and knead it into cakes, which are common articles of commerce. In practice here

known. Lowitz directed attention to it at the close of the last century, and in 1805 Giraud proposed it for deodorizing night soil. Since then its action has been carefully studied by Figuier, Bussy, Peyen, Desfosses, Bertrand, Warrington, and Garrod; and it has been noticed that it will also remove the poisonous principles of vegetables from their solutions.

also it is found that a ton of clay will deodorize about three tons of the solid matter of Sewage. But powerful as this action is, it is not applicable to liquid Sewage. Even in the case of charcoal, which is a much more energetic deodorizer than common clay, the power is speedily lost when it is mixed with fluid refuse. Dr. Hofmann found that four cubic feet of charcoal began to lose their power of deodorization when about seventy-eight gallons, or rather more than three times their bulk of Sewage had passed through them;* and Mr. Blyth's experiments are to the same effect.† To this I may add that the cost of this mode of deodorization, would be upwards of £230,000 a year for the City Sewage, or nearly a million for the Sewage of all London;‡ and even then the remedy would be but imperfect, to say nothing of the fact that it would contribute largely to the solid matters already in the Sewers.

The most effective way of using charcoal as a deodorizer is to take advantage of its power of absorbing the putrid miasms when they are in a vaporous condition. This power is remarkably great. It was noticed by Saussure, as far back as 1814,

* Report to the First Commissioner of Works on the Main Drainage of the Metropolis. 1857. Appendix, p. 23.

† Report on the means of Deodorizing and Utilizing the Sewage of Towns.—*Austin*, 1857, p. 98.

‡ Vide Table XIV. for details.

that charcoal took up from 1·75 to 90 times its bulk of various gases.* Count Morozzo had also observed the same fact,† and had directed attention to it; and later still, Messrs. Allen and Pepys found that different kinds of charcoal had different powers of absorption.‡ But it is only

* M. Theodore de Saussure experimented with boxwood charcoal, and his mode of proceeding was to heat the charcoal to redness, and then after cooling it in mercury, to introduce it into the gas. The following are the volumes of gas which one of charcoal absorbed :—

	Vols.		Vols.
Ammonia	90	Bicarburetted hydrogen	35
Muriatic acid gas	85	Carbonic oxide	9·42
Sulphurous acid	65	Oxygen	9·25
Sulphuretted hydrogen	55	Nytrogen	7·5
Nitrous oxide	40	Light carburetted hydrogen	5·0
Carbonic acid	35	Hydrogen	1·75

Thompson's Annals of Philosophy, Vol. VI., p. 241.

† Count Morozzo experimented with a cylinder of charcoal, 1 inch long, and ¾ inch diameter, and he obtained less accurate results, namely :—

	Vols.		Vols.
Ammonia	11	Sulphurous acid	5·5
Muriatic acid gas	11	Atmospheric air	3·5
Sulphuretted hydrogen	11	Oxygen gas	2·2
Carbonic acid	11	Hydrogen gas	2·1
Nitrous acid	6·75		

‡ Messrs. Allen & Pepys found that the following kinds of charcoal absorbed the undermentioned weights of air, &c., on exposure to the atmosphere.

	Per cent.		Per cent.
Lignum vitæ charcoal	9·6	Beech-wood charcoal	16·3
Fir ditto	13·0	Oak ditto	16·5
Box ditto	14·0	Mahogany ditto	18·0

very recently that we have been well informed of this matter; and we owe our knowledge of it to the researches of Dr. Stenhouse, who, in 1853, had his attention directed to the fact that, when the dead bodies of large animals are covered with a layer of charcoal, they putrefy without evolving any unpleasant odour, notwithstanding that they are kept for many months. The charcoal next to the bodies of the animals was found to contain appreciable quantities of nitric and sulphuric acids with super-phosphate of lime; but there was no sulphuretted hydrogen, and only a trace of ammonia. The results were so remarkable that Dr. Stenhouse repeated the experiment. He covered the bodies of two dead rats with a layer of charcoal to the depth of two inches; and two days afterwards he treated the carcase of a cat in the same way. Putrefaction went on with great activity, but there was no bad smell; for the charcoal absorbed the putrid gases, and caused them to enter into combination with the oxygen of the air—forming compounds which are inodorous.

He then charged some atmospheric air with ammonia, sulphuretted hydrogen, and sulphide of ammonium, and passed it through a vessel containing charcoal. The air was instantly deprived of its offensive properties, and could be breathed with impunity. These results suggested the use of charcoal as a respirator and an air filter; and soon after Dr. Stenhouse proposed it as a purifier of the foul gases which escape from the street gullies, the Sewer ventilators, and the drains of private houses.* One of his air filters is, I believe, in action in the Justice-room of the Mansion House, and another in the Justice-room of Guildhall; and Dr. Stenhouse reports that their operations have been successful and continuous for a long time.†

I have myself repeated some of Dr. Stenhouse's experiments during the last twelve months; and have ascertained that the offensive gases from a close cesspool are completely deodorized by passing them through a small box containing about 36 cubic inches of coarsely powdered peat charcoal. I have had this in continual action for about three months; and, although the charcoal has not been renewed, yet it does not show any sign of derangement or loss of power.

* Journal of the Society of Arts, February, 1854: also Pharmaceutical Journal, Vol. xiii., p. 454, and Vol. xiv., p. 329; and Dr. Stenhouse's published Lecture on the "Economical Applications of Charcoal to Sanitary Purposes," delivered at the Royal Institution on Friday evening, March 2nd, 1855.

† The air filters or charcoal ventilators at the Mansion House and Guildhall are each of them several feet in diameter, and the layer of charcoal is about an inch and a half in thickness, and consists of fragments of charcoal from the size of a pea to that of a largish bean.

All kinds of charcoal, however, are not equally valuable for this purpose. Dr. Stenhouse found that wood charcoal and peat charcoal are the most effective.* Mr. Blyth's experiments at the Board of Health, and the inquiries made in my own laboratory by Mr. Fewtrell, are to the same effect. The cause of this superiority is doubtless due to the great porosity of vegetable charcoal. Liebig states that the pores in a cubic inch of beech-wood charcoal must at the lowest computation be equal to the surface of 100 square feet;† and several other chemists have estimated it at more than double this amount. Hence the extraordinary physical power of wood charcoal in absorbing and condensing gases and vapours within its pores; so that when it is exposed to an atmosphere containing the putrid products of decomposition, it

* Half a gramme (7·717 grains) of the following kinds of charcoal absorb the undermentioned numbers of centimetres (0·39371 of cubic inches) of different gases:—

	Ammoniacal Gas.	Muriatic Acid Gas.	Sulphuretted Hydrogen.	Carbonic Acid.	Oxygen.	Sulphurous Acid Gas.
Wood	98·5	45·0	30·0	14·0	0·8	32·5
Peat	96·0	60·0	28·5	10·0	0·6	27·5
Animal	43·5	—	9·0	5·0	0·5	17·5

Lecture, p. 6; see also Pharmaceutical Journal, January 1857, for other kinds of charcoal.

† Letters on Chemistry, p. 132.

absorbs and oxydises them by a species of combustion that is as effectual as if they were passed through the ignited coals of a furnace. This power, says Dr. Stenhouse, is easily demonstrated by an old experiment of M. Thenard. "When some pieces of dry charcoal are introduced into sulphuretted hydrogen gas over mercury, the charcoal absorbs about 55 times its volume of the gas; the charcoal is then transferred into a jar of dry oxygen; and in the course of a short time a tolerably energetic action ensues—the sulphuretted hydrogen is decomposed; heat is evolved; water is formed; and the whole of the sulphur is deposited within the pores of the charcoal."*

Now in making a practical application of these facts it is manifest that we have in common wood charcoal a powerful means of destroying the foul gases of Sewers. How it is to be applied is fortunately a question of but little embarrassment; for let the Sewers be ventilated as they may, either by open gratings in the street, or by the rain-water pipes of the houses, or by the pillars of the gas lamps, or by tubes carried up at the landlord's expense from the drains of every house, or by especial shafts in the public streets; in fact, let the gases go out of the Sewers how they will and where they will, you have but to place a small box con-

* Lecture, p. 11.

taining a few pennyworths of charcoal, in the course of the draft, and the purification of the air will be complete. As far as we know, the strength and the endurance of this power is almost unlimited, so that when once the air filter has been set up, it will last continuously for years. Its action also upon the draft is not particularly injurious; and I have no doubt that the temperature of the Sewers, and the agencies which are now at work in circulating the air, and ventilating them will be sufficient to keep up a current of foul air through the filters; and if these were multiplied to a large extent, the friction of the gases upon the charcoal would be reduced to an insignificant amount.

My duty here ends; and it is for your Engineer to consider the facts and the suggestions which I have brought under your notice. All that I can say in conclusion is that the chemistry of the subject has been exhausted, and it does not appear that any of the processes which are known for the destruction of these offensive miasms is so applicable to our purpose as the physical power of charcoal; and if this also is found to be inapplicable, then, as far as I know, the Citizens of London must continue to endure the unwholesome influences of the Sewer gases, until chemistry has made much further progress in the art of disinfection.

One thing, however, is certain; that these unwholesome influences may be kept largely in check by certain sanitary measures which ought never to be lost sight of. It has been shown, for example, that the putrid miasms are chiefly produced by the solid matters of Sewage. Every precaution, therefore, should be taken to prevent these matters from accumulating in the Sewers. Again, the influence of water as a disinfectant has been thoroughly established, and consequently every encouragement should be offered for an abundant use of it. Lastly, the action of the air as a slow but certain oxydiser suggests the value of free and perfect ventilation.

And in addition to these there are several precautions which ought to be observed for the sake of the men who are accustomed to work in the Sewers. Three or four of the gases which they may encounter are very dangerous. These are, carbonic acid, sulphuretted hydrogen, and the inflammable hydrocarbons of marsh gas, and coal gas; besides which there may sometimes be danger from a deficiency of atmospheric oxygen. The first and last of these are known by the flame of the candle, which either becomes dim, and is languid in its combustion, or else is extinguished altogether. The second and fourth may be recognised by their peculiar smell; for sulphuretted hydrogen can be discovered in this way when it exists in the Sewer air in the proportion of 1 in about 10,000 of air, and coal gas when its proportion is about 1 in 500. Neither of these proportions is immediately dangerous, but the warning which is afforded by them ought not to be neglected.

A more delicate test for the recognition of sulphuretted hydrogen is a piece of white paper moistened with a drop of a saturated solution of sugar of lead. If this becomes black immediately on exposure to a Sewer atmosphere it indicates a large quantity of the foul gas, and great danger: if it blackens in the course of ten minutes or a quarter of an hour it shows the presence of about one part of gas in not less than 10,000 of atmospheric air.

The existence of marsh gas is not so easily discovered. All that we know of it is, that it is found only in the air of badly ventilated Sewers, and in the stagnant mud of them. The danger from it is not from its poisonous action, but from its explosive properties; and this may be easily guarded against by using a lamp that is protected with a wire gauze. The gauze need not obstruct the light, for it may be placed as a screen at the bottom of the lanthorn where the air enters. In almost all the cases where accidents have occurred from the explosion of this gas, they have resulted from the incautious introduction of a light into an old confined Sewer, or from the disturbance of the stagnant mud.

Lastly. When it is necessary to purify a dangerous channel, it may be done by generating a little chlorine in saucers containing equal weights of peroxide of manganese and muriatic acid; and the diffusion and displacement of the gas, should always be effected by proper ventilation.

With these several precautions, the workmen may pursue their labours, without risk, from those terrible accidents which have so frequently occurred.

I have the honor to remain,

GENTLEMEN,

Your obedient Servant,

HY. LETHEBY.

GUILDHALL,

September 14*th*, 1858.

APPENDIX.

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Supplemental List of Accidents in the Metropolitan Sewers since 1849. *These are not mentioned by Mr. Haywood in his List, at page* 125 *of his Report on the Ventilation of Sewers; and I am indebted to Mr. Bazalgette for them.*

September 28th, 1849. In Friar Street, during experiments on ventilation by means of Messrs. Anderson and Catley's furnace. No person injured.

November, 1853. In Gravel Lane, Southwark, during the construction of a new Sewer, by Messrs. Lucas. Cause—escape of coal gas from a broken main into a section of the new Sewer, about 200 feet in length, temporarily stopped up at both ends to prevent the back water from coming in upon the men when at work.

July 11th, 1855. In Suffolk Street, Borough, one subterranean surveyor and two labourers were nearly suffocated whilst in a Sewer recently constructed.

June 17th, 1857. In the Green Bank Sewer, Wapping, three men killed, and a fourth died on the 22nd of same month.

December 1st, 1857. In the Earl Sewer, near its outlet. One subterranean surveyor and two of his labourers burnt; apparently caused by the ignition of the refuse from two manufactories of tar, asphalte, varnish, and turpentine, which was seen floating on the surface of the sewage.

May 3rd, 1858. In Parker's Row, Bermondsey. Six flushing men burnt by an explosion of gas, whilst they were at work in the Sewers. The gas had no smell, and was in all probability marsh gas which was liberated from the mud while the men were endeavouring to remove it in the usual way with their shovels.

Out of a total of 47 accidents from foul gases in the London Sewers, 43 were from explosions, and the other 4 were from the mephitic effects of the gases, causing the death of 14 men by almost immediate suffocation. Many of the explosions were evidently caused by light carburetted hydrogen, and not by sulphuretted hydrogen, as is erroneously supposed.

No. I.—*Average Amount of Excrements (Fæces and Urine) Voided every twenty-four hours by each member of the population; and the proportions of each of the principal constituents. (Lawes.)*

Sexes and Ages.	Fresh.		Dry.		Salts.		Carbon.		Nitrogen.		Phosphates.	
	Fæces.	Urine.	Fæces.	Urine.	Fæces.	Urine.	Fæces.	Urine.	Fæces.	Urine.	Fæces.	Urine.
	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
Mean of Males under 15	2·96	19·53	0·760	0·560	0·101	0·297	0·343	0·155	0·064	0·166	..	..
,, ,, from 15 to 50	4·17	46·01	1·041	1·735	0·116	0·527	0·443	0·539	0·053	0·478	0·068	0·189
,, ,, over 50	6·20	42·05	1·160	2·260	0·228	0·340	0·480	0·748	0·088	0·383	..	0·142
,, ,, at all ages	4·24	41·38	1·034	1·703	0·131	0·451	0·432	0·510	0·059	0·397	..	..
,, Females over 16	1·24	36·66	0·330	1·380	0·044	0·323	0·148	0·495	0·028	0·294	..	..
,, ,, at all ages	1·24	31·04	0·330	1·380	0·044	0·323	0·148	0·495	0·028	0·255	..	..
Mean of both Sexes at all ages ..	3·32	36·11	2·010*		0·453		0·739		0·348†		0·201	
Average per day for the whole Population of London in the middle of 1858‡ (2,721,000)	tons. 252·06	tons. 2741·5	tons. 152·60		tons. 34·392		tons. 56·105		tons. 26·420		tons. 15·260	

* Professor Way reckons that the average amount of solid matter in the excrements of each individual (taking the average of both sexes at all ages) is $2\frac{1}{4}$ ozs. per day.

† Professor Way estimates the nitrogen at 0·36 of an oz.

‡ This calculation has been made by me from the number of the population given in the Quarterly Report, No. 38, of the Registrar General.

No. II.—*Table of the Composition of the Washings of the London Streets. (Way.)*

Name of the Street.	Quality of the Paving.	Quality of the Traffic.	Solid Matter in an Imperial Gallon.		
			Soluble.	Insoluble.	Total.
Duke Street, Manchester Square	MacAdam.	Middling.	92·80 grs.	105·95 grs.	198·75 grs.
Foley Street (Upper Part)	"	Little.	95·13 "	116·30 "	211·43 "
Gower Street	Granite.	Middling.	126·00 "	168·30 "	294·30 "
Norton Street	"	Little.	123·87 "	3·00 "	126·87 "
Hampstead Road, above the Canal	Ballasted.	Great.	96·00 "	84·00 "	180·00 "
Ferdinand Street	"	Middling.	44·00 "	48·30 "	92·30 "
Ferdinand Place	"	Little.	50·80 "	34·30 "	85·10 "
Oxford Street	Granite.	Great.	276·23 "	537·10 "	813·33 "
" "	MacAdam.	"	194·62 "	390·30 "	584·92 "
" "	Wood.	"	34·00 "	5·00 "	39·00 "
Average of all	....	....	113·34 "	149·26 "	262·60 "

The soluble residue consists of organic matter, sulphate of lime, sulphate of potash, and common salt (chloride of sodium.)

No. III.—*Table of the Proportions of Solid Matter (Mineral and Organic) in a Gallon of the Sewage discharged by each of the City Sewers*, at Noon.

Names of Sewers.	Average rate of flow per minute, in cubic feet. (Haywood.)	Date when taken (1857.) Noon.	Mean external temperature of the day. ° Faht.	Rainfall of the day preceding. Inches.	Soluble Constituents.			Suspended Constituents.			Grand Total.
					Mineral. Grains.	Organic. Grains.	Total. Grains.	Mineral. Grains.	Organic. Grains.	Total. Grains.	Grains.
The Fleet	1642·39	May 29	55·6	0·00	33·00	11·60	44·60	12·60	16·40	29·00	73·60
London Bridge	1396·71	,, ,,	,,	,,	37·09	20·96	58·05	15·40	7·04	22·44	80·49
Dowgate Dock	58·85	July 17	63·0	0·00	38·36	27·31	65·67	13·26	16·64	29·90	95·57
Irongate..............	170·18	May 23	56·7	0·28	65·01	11·20	76·21	16·32	15·80	32·12	108·33
Paul's Wharf..........	117·15	,, ,,	,,	,,	51·35	21·79	73·14	32·21	17·21	49·42	122·56
Whitefriars Dock	63·36	,, 29	55·6	0·00	23·02	3·53	26·55	4·89	9·59	14·48	41·03
Custom House, West ..	22·16	July 17	63·0	0·00	64·30	9·22	73·52	42·21	36·28	78·49	152·01
Custom House, East....	7·13	,, 24	70·8	0·00	37·82	20·19	58·01	14·82	12·31	27·13	85·14
Hambro' Wharf	7·64	May 23	56·7	0·28	32·79	14·24	47·03	12·75	4·26	17·01	64·04
Wool Quay	4·02	July 20	69·3	0·00	23·84	10·76	34·60	46·41	35·04	81·45	116·05
Tower Dock	4·69	,, 24	70·8	0·00	846·30	43·96	890·26	14·60	16·14	30·74	921·00
Average, exclusive of Tower Dock	348·96	..	..	..	40·66	15·08	55·74	21·09	17·06	38·15	93·89

N.B.—The Tower Dock is excluded because of the peculiar composition of the Sewage—dependent on the trade operations among the fishmongers and shell-fish boilers of the neighbourhood.

No. IV.—*Table of the Proportions of Solid Matter (Mineral and Organic) in a Gallon of the Sewage from each of the City Sewers*, at Midnight.

Names of Sewers.	Average rate of flow per minute in cubic feet. (Haywood)	Date when taken (1857.)	Mean external temperature of the day.	Rainfall of the day preceding.	Soluble Constituents.			Suspended Constituents.			Grand Total.
					Mineral.	Organic.	Total.	Mineral.	Organic.	Total.	
		Midnight.	° Faht.	Inches.	Grains.	Grains.	Grains	Grains.	Grains.	Grains.	Grains.
The Fleet	512·61	Oct. 12	59·7	0·19	56·40	12·09	68·49	2·72	6·91	9·63	78·12
London Bridge	500·98	Sept. 23	60·2	0·08	174·86	8·58	183·44	2·34	4·42	6·76	190·20
Dowgate Dock	27·40	Oct. 5	49·4	0·10	35·21	4·36	39·57	2·31	6·64	8·95	48·52
Irongate.............	35·71	Sept. 7	61·4	0·00	48·80	7·72	56·52	3·24	5·28	8·52	65·04
Paul's Wharf..........	36·08	Oct. 12	59·7	0·19	47·36	1·09	48·45	5·24	8·91	14·15	62·60
Whitefriars Dock	20·55	,, ,,	,,	,,	36·41	4·11	40·52	3·15	5·89	9·04	49·56
Custom House, West ..	22·30	Sept. 23	60·2	0·08	61·30	9·32	70·62	6·76	7·68	14·44	85·06
Custom House, East....	4·21	Sept. 13	,,	0·05	51·58	15·01	66·59	17·43	14·49	31·92	98·51
Hambro' Wharf	3·19	Oct. 5	49·4	0·10	38·21	5·40	43·61	1·32	2·10	3·42	47·03
Wool Quay	2·77	Sept. 13	60·2	0·05	26·52	6·52	33·04	17·06	15·98	33·04	66·08
Tower Dock	1·13	Sept. 7	61·4	0·00	48·80	7·72	56·52	3·24	5·28	8·52	65·04
Average, exclusive of Tower Dock	116·58	..	..	..	57·67	7·42	65·09	6·16	7·83	13·99	79·08

N.B.—The Tower Dock Sewage has been excluded, for the reasons mentioned at foot of Table III.

No. V.—*Table of the Proportions of Solid Matter (Mineral and Suspended) in a Gallon of the Sewage from some of the principal Metropolitan Sewers.*

Names of Sewers.	Authority.	Date when taken.	Mean external Temperature of the day. ° Faht.	Rainfall of the preceding day. Inches.	Soluble Matters. Mineral Grains.	Soluble Matters. Organic Grains.	Soluble Matters. Total. Grains.	Suspended Matters. Mineral Grains.	Suspended Matters. Organic Grains.	Suspended Matters. Total. Grains.	Grand Total.
Ranelagh	Letheby.	18 Dec., 1857, 10.45 A.M.	48·7	0·03	40·18	13·36	53·54	14·92	5·14	20·06	73·60
"	"	7 Dec., 1857, 2 P.M.	31·2	0·00	36·70	9·34	46·04	7·61	12·53	20·14	66·18
King'sScholars'Pond	"	18 Dec., 1857, 11 A.M.....	48·7	0·03	35·06	10·43	45·49	22·46	14·07	36·53	82·02
" " "	"	7 Jan., 1858, 2.45 P.M. ..	31·2	0·00	38·66	7·52	46·18	11·46	14·15	25·61	71·99
" " "	Hofmann & Witt	18 March, 1857, 10 A.M...	47·4	0·00	32·64	5·71	38·35	14·59	12·04	26·63	64·98
" " "	"	8 April, 1857, 7.45 P.M...	51·0	0·09	43·34	7·07	50·41	25·91	15·19	41·10	91·50
Fleet	"	19 March, 1857, 12.15 P.M.	48·6	0·00	32·00	5·26	37·26	19·30	10·86	30·16	67·42
"	Letheby.	18 Dec., 1857, NOON	48·7	0·03	45·59	11·92	57·51	20·07	14·58	34·65	92·16
"	"	8 Jan., 1858, 2 P.M.	44·6	0 00	43·13	8·89	52·02	23·22	25·61	48·83	100·85
Mean of Savoy	Hofmann & Witt	13 May, 1857	58·6	0·03	55·61	20·16	75·77	10·58	8·35	18·93	94·70
"	"	11 June, 1857	54·4	0·04	58·89	19·33	78·22	19·23	13·55	32·78	111·00
Earl Street........	"	20 March, 1857, 10. 10 A.M.	41·4	0·06	44·65	1·32	45·97	1·46	1·42	2·88	48·85
Falcon Brook......	"	18 March, 1857, 1.25 P.M.	47·4	0·00	38·22	2·38	40·60	1·94	1·60	3·54	44·14
Northumberland St.	"	16 May, 1857, 10 A.M.....	64·6	0·00	55·24	52·36	107·60	16·09	36·40	52·49	160·08
" "	"	28 May, 1857, 10 A.M.....	49·5	0·00	57·63	30·09	87·72	21·48	35·42	56·90	144·62
" "	"	13 June, 1857, 10 A.M. ..	53·5	0·00	67·26	41·19	108·45	14·44	25·04	39·48	147·93
Average......	....	....	....	....	45·63	14·97	60·60	14·94	14·83	29·77	90·37

No. VI.—*Table showing the Composition of Sewage during and immediately after heavy Storms, as compared with that of Dry Weather.*

Names of the Sewers.	Authority.	Date when Taken.	Mean external temperature. Farenheit.	Rainfall directly before.	Soluble Matters.			Insoluble Matters.			Grand Total.
					Mineral. Grains.	Organic. Grains.	Total. Grains.	Mineral. Grains.	Organic. Grains.	Total. Grains.	Grains.
London Bridge (storm) . .	Letheby	22 Oct., 1857	44·3	2·57	36·64	11·92	48·56	23·48	27·58	51·06	99·62
,, ,, ,, . .	,,	9 April, 1858	37·1	0·59	47·34	14·85	62·19	15·66	27·15	42·81	105·00
,, ,, ,, . .	,,	29 ,, ,,	48·8	0·60	51·51	14·50	66·01	14·43	11·10	25·53	91·54
,, ,, ,, . .	,,	2 May, ,,	42·5	0·15	59·23	14·80	74·03	35·03	53·45	88·48	162·51
Do. (dry weather)	,,	. . . .	. .	. .	37·09	20·96	58·05	15·40	7·04	22·44	80·49
Irongate (storm)	,,	9 April, 1858	37·7	0·59	76·93	20·60	97·53	2·62	7·35	9·97	107·50
Do. (dry weather) . .	,,	. . . .	. .	. .	65·01	11·20	76·21	16·32	15·80	32·12	108·33
Fleet (storm)	,,	29 April, 1858	48·8	0·60	47·15	8·95	56·10	17·42	23·50	40·92	97·02
,, ,, ...	,,	2 May, ,,	42·5	0·15	35·91	9·11	45·02	14·15	12·34	26·49	71·51
,, ,, ...	Hofmann & Witt	9 April, 1857	49·7	0·13	58·14	4·36	62·50	110·54	35·46	146·00	208·50
Do. (dry weather)	,,	. . . .	. .	. .	40·24	8·69	48·93	20·86	17·02	37·88	86·81
King'sScholarsPond(stm)	,,	9 April, 1857	49·7	0·13	34·57	5·13	39·70	110·48	30·85	141·33	181·03
Do. (dry weather)	,,	. . . .	. .	. .	37·42	7·68	45·10	18·60	13·86	32·46	77·56
Savoy Street (storm)	,,	20 June, 1857	69·1	0·85	. .	. .	. .	. .	. .	. .	296·97
Do. (dry weather)	,,	. . . .	. .	. .	. .	. .	. .	. .	. .	. .	102·85
Mean of Storms	. . . .	. . . .	. .	. .	49·71	11·58	61·29	38·20	25·42	63·62	124·91
,, Dry Weather . .	. . . .	. . . .	. .	. .	44·94	12·13	57·07	17·79	13·43	31·22	88·29

No. VII.—*Showing the Proportions of the Principal Constituents of London Sewage.*

Names of Sewers.	Time of taking.	Total Constituents per gallon.	Constituents of the Soluble Part.							Constituents of the Insoluble.					Authority.
			Organic Matter.	Ammonia.	Phosphoric Acid.	Sulphuric Acid.	Alkaline Chlorides.	Carbonate of Lime, &c.	Total.	Organic Matter.	Ammonia.	Phosphoric Acid.	Debris, &c.	Total.	
The Fleet	Day	73·60	11·60	4·26	0·74	6·13	18·32	7·81	44·60	15·51	0·89	0·09	12·52	29·00	Letheby
,, ...	Night	78·12	12·09	8·19	0·92	13·55	16·49	25·44	68·49	6·60	0·31	0·04	2·68	9·63	,,
,, (mean of 2)	Storm	84·26	9·03	6·93	0·78	10·15	9·77	20·83	50·56	17·05	0·87	0·08	15·70	33·70	,,
London Bridge	Day	80·49	20·96	5·99	0·63	8·75	12·82	14·89	58·05	6·34	0·70	0·06	16·34	22·44	,,
,, ,, ...	Night	190·20	8·58	7·89	0·64	16·52	122·90	34·80	183·44	4·21	0·21	0·02	2·32	6·76	,,
,, (mean of 4)	Storm	114·67	14·02	9·77	0·81	8·58	17·17	22·12	62·70	28·50	1·32	0·13	22·02	51·97	,,
Dowgate Dock	Day	95·57	27·31	9·14	0·79	2·03	31·14	4·40	65·67	15·75	0·89	0·09	13·17	29·90	,,
,, ,, ...	Night	48·52	4·36	3·21	0·49	5·15	11·60	17·97	39·57	6·42	0·22	0·02	2·29	8·95	,,
Irongate............	Day	108·33	11·20	7·25	0·94	9·78	33·55	20·74	76·21	14·92	0·88	0·10	16·22	32·12	,,
,, ...	Night	65·04	7·72	5·99	0·74	6·52	22·00	19·54	56·52	5·07	0·21	0·04	3·20	8·52	,,
,, ...	Storm	107·50	20·60	9·76	1·49	8·94	17·58	48·92	97·53	7·09	0·26	0·02	2·60	9·97	,,
Paul's Wharf........	Day	122·56	21·79	11·03	1·01	5·15	10·38	34·81	73·14	16·23	0·98	0·08	32·13	49·42	,,
,, ,, ...	Night	62·60	1·09	2·84	0·52	6·18	10·95	29·81	48·45	8·62	0·29	0·03	5·21	14·15	,,
Whitefriars Dock	Day	41·03	3·53	5·04	0·36	3·60	3·67	10·35	26·55	9·28	0·31	0·02	4·87	14·48	,,
,, ,, ...	Night	49·56	4·11	3·15	0·69	6·18	7·13	22·41	40·52	5·63	0·26	0·03	3·12	9·04	,,

Custom House, West	Day	152·01	9·22	4·41	1·00	6·52	32·97	23·81	73·52	34·44	1·84	0·17	42·04	78·49	„
„ „ „	Night	85·06	9·32	7·88	0·98	3·60	33·98	22·74	70·62	7·39	0·29	0·03	6·73	14·44	„
„ „ East	Day	85·14	20·19	6·62	1·51	6·16	20·95	9·20	58·01	11·65	0·66	0·06	14·76	27·13	„
„ „ „	Night	98·51	15·01	14·18	0·80	6·66	25·03	19·09	66·59	13·66	0·83	0·08	17·35	31·92	„
Hambro' Wharf......	Day	64·04	14·24	7·25	1·02	5·14	4·89	21·74	47·03	3·82	0·44	0·05	12·70	17·01	„
„ „	Night	47·03	5·40	5·67	1·06	4·12	14·04	18·99	43·61	2·08	0·02	0·01	1·31	3·42	„
Wool Quay	Day	116·05	10·76	5·04	0·51	4·46	10·99	7·88	34·60	33·13	1·91	0·20	46·21	81·45	„
„	Night	66·08	6·52	4·10	0·07	2·24	10·99	13·22	33·04	15·08	0·90	0·09	16·97	33·04	„
Tower Dock	Day	921·00	43·96	9·14	0·99	82·32	695·63	67·36	890·26	15·26	0·88	0·09	14·51	30·74	„
„	Night	65·04	7·72	6·93	0·76	6·69	30·92	10·43	56·52	5·06	0·22	0·02	3·22	8·52	„
Swan Street	Day	284·93	19·51	19·14	0·49	2·57	25·49	27·43	75·49	77·24	4·26	0·43	127·51	209·44	„
Wormwood Street....	„	291·04	21·48	23·62	1·07	4·12	32·95	23·89	83·51	79·02	4·98	0·51	123·02	207·53	„
Bevis Marks	„	278·49	30·60	25·31	1·26	7·82	38·17	18·68	96·53	98·17	5·34	0·49	77·96	181·96	„
Angel Alley	„	160·18	22·13	20·20	1·56	8·79	20·30	15·95	68·73	52·61	2·02	0·30	36·42	91·45	„
Barrett's Court	„	492·26	121·50	36·72	7·71	10·71	31·52	71·86	243·30	175·76	4·56	2·73	65·91	248·96	Way
Dorset Square	„	209·70	57·32	15·16	2·53	0·28	27·27	21·60	109·00	20·20	2·80	1·64	76·06	100·70	„
Average of Main Sewers	Day	93·89	15·08	6·60	0·85	5·77	17·97	16·07	55·74	16·11	0·95	0·09	21·00	38·15	—
„ „ „	Night	79·08	7·42	6·31	0·69	7·07	27·51	22·40	65·09	7·48	0·35	0·04	6·12	13·99	—
„ „ Storm	Day	102·14	14·55	8·82	1·03	9·22	14·84	30·62	70·26	17·55	0·81	0·08	13·44	31·88	—
„ Branch Sewers	„	286·07	45·42	23·36	2·44	5·71	29·28	29·90	112·75	83·83	3·99	1·02	84·48	173·32	—

No. VIII.—*Table of the Composition (approximative) of Human Excreta, and of the Solid Matters derived therefrom in Sewage, &c.*

	1000 Parts.		100 of Dry Solid.		Principal Constituents of 100 Dry Solid.					Money Values of the Dry Solid per ton.
	Water.	Dry Solid.	Organic.	Mineral.	Nitrogen.	Phosphoric Acid.	Potash.	Magnesia.	Worthless.	£ s.
Urine	952	48	74·56	25·44	23·85	3·01	1·77	0·38	20·28	17 4
Recent Fæces	751	249	88·52	11·48	5·63	4·27	1·19	1·20	4·82	4 16
Fæces from Sewage (Croydon)	774	226	70·24	29·76	4·10	3·63	0·21	0·91	25·01	3 8
Dry solid matters of Sewage (soluble and suspended) obtained by evaporation	....	1000	36·55	63·45	1·79	1·09	3·05	1·78	57·53	2 6
Dry soluble matters of Sewage, obtained by evap.	....	1000	27·15	72·85	1·28	1·57	4·95	2·96	63·37	2 13
Dry suspended matters of Sewage	....	1000	42·51	57·49	2·55	0·36	0·19	0·02	56·92	1 17
Solid matters precipitated from Sewage by Lime (as taken from press)	548	452	27·25	72·75	1·59	1·38	0·20	0·03	71·14	1 6
Ditto ditto as Leicester Brick	47	953	22·62	73·38	0·98	1·59	0·23	0·09	71·53	0 19
Ditto ditto as Tottenham Brick	75	925	25·20	74·80	1·10	2·14	0·10	0·62	71·94	1 2

These are the average results of a large number of experiments made by me during this inquiry. In the case of the urine and fæces, they are the mean of the analyses of Berzelius, Simon, Marchand, Lehmann, Becquerel, Way, and others.

The Money Values are from the valuations by Professor Way, viz., Ammonia, at £56 per ton; Potash, at £31; and Phosphate of Lime, at £7.—*Journ. of Agric. Soc.*, xvi., p. 533.

No. IX.—*Table showing the difference of Temperature between the Interior of Sewers and the External Atmosphere (in shade). From observations made in the City Sewers, under the superintendence of Mr. Haywood.*

SUMMARY OF OBSERVATIONS.

Time of Year.	Temperature in External Atmosphere (in Shade.)			Temperature in Sewer.			Mean Temperature of Sewer.	
	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Above External Atmosphere.	Below External Atmosphere.
	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.
Summer	72	55	65·04	68	56	61·92	0·28	3·40
Winter	34	30	32·37	52	40	43·98	11·60	0·00
Spring	61	46	52·46	59	48	52·52	1·34	1·28
Autumn	68	48	59·90	70	53	62·97	3·91	0·86
Average of whole Year	58·75	44·75	52·44	62·25	49·25	55·35	4·28	1·38

No. X.—*Table of the Amount and Composition of the Gases Evolved from Sewage.*

WHENCE OBTAINED.	Date when taken 1858.	Constituents per Gallon.		Amount of Gas evolved per Gallon.	Per centage composition by Volume of the Dry Gas.					
		Mineral.	Organic.	Cubic inches.	Nitrogen.	Oxygen.	Carbonic Acid.	Marsh-Gas.	Sulphd. Hydrogen.	Ammonia.
Sewage from Bevis Marks ..	May 29	149·7	128·8	....	....	....	.....	....	....	..
During 1st week of fermentation	June 5	....	....	3·00 per hour.	11·531	traces	10·647	77·621	0·201	abundance
" 3rd "	" 19	....	....	1·56 "	10·943	none	10·894	78·020	0·143	"
" 5th "	July 3	....	....	0·96 "	9·605	"	14·474	75·901	0·020	"
" 7th "	" 17	....	....	0·33 "	9·173	"	19·130	71·677	0·020	"
" 9th "	" 31	....	....	0·17 "	9·682	"	24·353	65·945	0·020	"
Mean of the whole time ..	....	....	....	1·20	10·187	"	15·899	73·833	0·081	"
Sewage from Catherine Wheel Alley	June 14	1085·1	828·6	....	14·144	0·034	17·587	68·031	0·204	"
Slush at the Tottenham Works	Feb. 6	3231·8	2159·2	....	7·168	none	8·756	84·076	none	"
" Leicester "	" 13	2973·6	991·2	....	6·219	"	10·859	82·922	"	"
Sewage of Bevis Marks, heated	May 29	149·7	128·8	76·49 per gall.	4·379	"	71·911	20·555	3·157	"
" Angel Alley, "	"	85·9	74·7	76·52 "	4·261	"	72·579	20·150	3·010	"
" London Bridge "	July 27	53·6	26·8	32·10 "	50·266	traces	35·905	12·827	1·002	"
" Fleet "	"	45·4	27·1	34·03 "	49·184	"	36·018	13·877	0·921	"
Thames Water at Shore at Blackfriars, lowtide, heated	June 30	54·8	24·4	17·49 "	28·778	"	71·222	traces	traces	traces
" " "	July 16	96·3	19·9	5·34 "	56·720	"	47·280	"	none	"
Thames Water at Shore at London Bridge, high tide, heated	" 3	114·1	15·3	8·00 "	39·663	"	60·337	"	"	"

No. XI.—*Table of the Composition of the Atmosphere of some of the Principal of the City Sewers, and of Atmospheric Air in its normal condition.*

NAMES OF SEWERS.	Date when taken. 1857-58.	Mean External Temperature.	Per Centage Composition by Volume of the Dry Atmosphere from the Sewers.						Products obtained by igniting 100 grains, or about 323 cubic inches of the Gas deprived of its Moisture and Carbonic Acid.	
		Degrees.	Nitrogen.	Oxygen.	Carbonic Acid.	Marsh Gas.	Ammonia.	Sulphd. Hydrogen.	Carbonic Acid.	Aqueous Vapour.
Noble Street	Dec. 7	50·9	80·113	19·574	0·313	traces	rather abundant	traces	1·027	1·014
Jewin Street	" "	"	81·267	18·036	0·697	"	"	"	1·970	0·960
Aldermanbury	May 31	67·7	80·594	18·664	0·742	"	"	"	1·375	0·938
Philip Lane, London Wall	" "	"	79·626	20·166	0·208	"	"	"	1·369	0·947
Chapel Street, Milton Street	June 1	70·7	80·473	19·313	0·214	"	"	"	1·625	1·250
Bowling Alley, Whitecross St.	" "	"	79·761	19·734	0·505	"	"	"	1·667	1·275
Ebenezer Square	" 3	70·0	79·584	19·583	0·833	"	"	"	0·938	1·250
London Bridge	" 7	59·3	79·650	19·658	0·692	"	"	"	0·996	1·521
Fleet	" "	"	79·591	19·705	0·704	"	"	"	0·989	1·493
Angel Alley, Old Sewer	" 11	65·1	80·169	19·409	0·422	"	"	"	1·060	1·485
Bishopsgate Street, Without	" "	"	79·725	19·851	0·424	"	"	"	0·764	0·625
Catherine Wheel Alley	" 14	72·0	79·525	20·169	0·316	"	"	"	1·298	0·974
New Street, Cloth Fair	" "	"	79·453	19·701	0·846	"	"	"	1·138	0·909
Mean of City Sewers	..	..	79·962	19·506	0·532	"	"	"	1·247	1·126
Atmospheric Air	..	..	78·959	21·000	0·041	none	traces	none	none	none

The Composition of the Atmosphere is from data furnished by Saussure, Brunner, Dumas, Bunsen, Regnault, Verver, Boussingault, & others.

No. XII.—*Table of the Composition of the Air in the Paris Sewers—Amelot, De la Roquette, Saint Martin, and others. (M. Gaultier de Claubry.)*

Number of the Analysis.	Date when made.	Per-centage composition by Volume of the Dry Air.			
		Nitrogen.	Oxygen.	Carbonic Acid.	Sulphd. Hydrogen.
1	1829	78·75	18·00	2·45	0·80
2	„	78·75	18·00	2·45	0·80
3	„	78·75	18·00	2·00	1·25
4	„	78·80	17·40	2·90	0·90
5	„	79·00	18·00	2·80	0·20
6	„	78·50	18·50	2·20	0·80
7	„	78·75	18·00	2·30	0·95
8	„	78·80	18·30	2·00	0·90
9	„	79·00	18·10	2·00	0·90
10	„	78·60	18·00	2·50	0·90
11	„	79·00	18·20	2·40	0·40
12	„	79·00	17·70	2·35	0·95
13	„	79·00	19·00	1·20	0·80
14	„	78·25	17·40	3·40	0·95
15	„	78·50	17·50	3·00	1·00
16	„	78·55	18·45	2·00	1·00
17	„	78·45	17·60	3·00	0·95
18	„	78·75	17·90	2·40	0·95
19	„	79·00	20·55	0·45	0·00
20	1823	81·21	13·79	2·01	2·99
21	„	78·70	18·10	2·30	0·90
Mean of above	..	78·86	17·93	2·29	0·92
Mean of City Sewers......	1858	79·96	19·51	0·53	traces
Mean of a Cesspool*......	„	79·02	18·14	1·93	0·01
Atmospheric Air	..	78·96	21·00	0·04	none

The Analyses of the Air of the Paris Sewers were made by M. Gaultier de Claubry, and are quoted by Parent-Duchâtelet, in his "Rapport sur le Curage des Egouts Amelot, &c." "Hygiène Publique ou Memoires de L'auteur par Fr. Leuret." Tome Premier, p. 389.

* In the cesspool air there was a notable proportion of carburetted hydrogen.

No. XIII.—*Quantities required of each of the Principal Deodorizers to remove the odour, more or less completely, from ordinary London Sewage; and the Annual Cost of each of the Materials for Deodorizing the Sewage of the City, and of the Metropolis.*

NAMES OF THE DEODORIZERS.	Price of the Deodorizers.	Strength of the Solution (specific gravity.)	Quantity required per gallon of Sewage. (grains.)	Results as to the Deodorization.	ANNUAL COST OF MATERIALS FOR DEODORIZING.	
					The City Sewage (20,316,442 gals.) per day.	The Sewage of Metropolis (84,759,150 gals.) per day.
Quick Lime	10s. per ton	....	12	Incomplete	£2,837	£11,838
Chloride of Lime	£15 "	....	8	Complete	56,751	236,955
McDougall's Powder	£12 "	....	40	Incomplete	227,004	947,053
Peat Charcoal	£3. 5s. "	....	150	Ditto	230,573	961,851
Condy's Liquid	1s. per gall.	1,055	150	Complete	753,165	3,141,884
Sir Wm. Burnett's Liquid	4s. "	1,594	100	Incomplete	1,329,181	5,545,275
Ledoyen's do.	4d. "	1,160	1000	Ditto	1,522,065	6,349,975
Ellerman's do.	6s. "	1,443	470	Ditto	10,351,308	47,983,474

NOTE.—Condy's Liquid .... of specific gravity 1055, contains 5·9 per cent. of permanganate of potash.
Sir Wm. Burnett's Liquid " 1594, " 53·8 " chloride of zinc.
Ledoyen's ditto " 1160, " 10·0 " nitrate of lead.
Ellerman's ditto " 1443, " 43·0 " muriate and pyrolignate of iron.

The thick matter of cesspools and stagnant sewers requires about a 20th part of its weight of chloride of lime to deodorize it, and the corresponding proportions of the other deodorizers.

In those cases where the deodorization is incomplete, the peculiar smell of sewage remained,—sulphuretted hydrogen, and, except in the case of quick lime, ammonia being the only matters removed.

No. XIV.—*Proportions of Solid Matter (Organic and Mineral) precipitated from a gallon of Day Sewage from each of the City Sewers by means of 12 grains of Lime.*

Names of the Sewers.	Acres Drained.	Rate of flow per minute from 6 a.m. to 9 p.m. in cubic feet.	Total amount of solid matter per gallon.	Dissolved.		Suspended.		Amount of precipitate with 12 grains of lime.		Soluble organic matter removed.	Soluble organic matter still in solution.
				Mineral.	Organic.	Mineral.	Organic.	Mineral.	Organic.		
			Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
The Fleet	4220·00	1265·18	73·60	33·00	11·60	12·60	14·40	29·71	19·34	2·94	8·66
London Bridge	2250·00	1154·94	80·49	37·09	20·96	15·40	7·04	27·69	12·46	5·42	15·54
Dowgate Dock	113·50	55·55	95·57	38·36	27·31	13·26	16·64	26·52	23·94	7·30	20·01
Irongate............	104·00	118·76	108·33	65·01	11·20	16·32	15·80	29·07	18·81	3·01	8·19
Paul's Wharf........	69·00	108·27	122·56	51·35	21·79	32·21	17·21	44·69	23·18	5·97	15·82
Whitefriars' Dock....	55·50	53·74	41·03	23·02	3·53	4·89	9·59	16·97	10·45	0·86	2·67
Custom House, West..	22·70	28·36	152·01	64·30	9·22	42·21	36·28	50·01	39·02	2·74	6·48
Custom House, East..	14·59	9·59	85·14	37·82	20·19	14·82	12·31	24·97	17·55	5·24	14·95
Hambro' Wharf......	10·00	6·38	64·04	32·79	14·24	12·75	4·26	25·03	7·99	3·73	10·51
Wool Quay	4·95	6·68	116·05	23·84	10·76	46·41	35·04	59·32	37·85	2·81	7·95
Tower Dock	3·25	4·15	921·00	846·30	43·96	14·60	16·14	26·86	24·44	8·30	35·66
Average, exclusive of the Tower Dock..	686·42	255·60	93·89	40·66	15·08	21·09	17·06	33·39	21·06	4·00	11·08
Total	6867·49	2811·60	93·89	55·74		38·15		54·45		4·00	11·08

No. XV.—*Proportions of Solid Matter (Organic and Mineral) precipitated from a gallon of Night Sewage from each of the City Sewers by means of* 12 *grains of Lime.*

Names of the Sewers.	Acres Drained.	Rate of flow per minute from 9 p.m. to 6 a.m. in cubic feet.	Total amount of solid matter per gallon.	Dissolved.		Suspended.		Amount of the precipitate with 12 grains of lime.		Soluble organic matter removed.	Soluble organic matter still in solution.
				Mineral.	Organic.	Mineral.	Organic.	Mineral.	Organic.		
			Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
The Fleet	4220·00	527·50	78·12	56·40	12·09	2·72	6·91	14·83	9·96	3·05	9·04
London Bridge	2250·00	477·21	190·20	174·86	8·58	2·34	4·42	13·96	6·55	2·13	6·45
Dowgate Dock	113·50	23·73	48·52	35·21	4·36	2·31	6·64	14·00	8·24	1·60	2·76
Irongate	104·00	38·60	65·04	48·80	7·72	3·24	5·28	16·11	7·65	2·37	5·35
Paul's Wharf........	69·00	37·20	62·60	47·36	1·09	5·24	8·91	17·04	9·82	0·91	0·18
Whitefriars Dock	55·50	20·13	49·56	36·41	4·11	3·15	5·89	15·93	6·99	1·10	3·01
Custom House, West..	22·70	24·10	85·06	61·30	9·32	6·76	7·68	19·47	9·94	2·26	7·06
Custom House, East..	14·59	4·82	98·51	51·58	15·01	17·43	14·49	30·62	18·51	4·02	10·99
Hambro' Wharf	10·00	2·85	47·03	38·21	5·40	1·32	2·10	14·01	3·44	1·34	4·06
Wool Quay	4·95	2·78	66·08	26·52	6·52	17·06	15·98	29·43	17·88	1·90	4·62
Tower Dock	3·25	1·27	344·56	199·88	17·77	62·18	64·73	75·68	69·83	5·10	12·67
Average, exclusive of the Tower Dock ..	686·42	105·47	79·07	57·66	7·42	6·16	7·83	18·54	9·90	2·07	5·35
Total	6867·49	1160·19	79·07	65·08		13·99		28·44		2·07	5·35

No. XVI.—*Results of Experiments made by Professor Davy, F.R.S., &c., to determine the Deodorizing Power of different substances on Night Soil.*

NUMBER OF GRAINS EMPLOYED TO DEODORIZE 125 GRAINS OF NIGHT SOIL.

Volatile and Fixed Oils.		Acids, &c.		Alkalies.		Salts, &c.	
Musk	0·1	Vinegar and creosote	1	Strong solution of ammonia	2	Sal-ammoniac	2
Oil of lavender	1·0	Pyroligneous acid	4	Potassa	5	Saturated solution of chloride of lime	47
„ peppermint	1·0	Nitro muriatic acid	4	Barytes	5	Sulphate of iron had but little deodorizing power; and the saturated solutions of chloride of zinc, and bichromate of potash had none.	
„ rosemary	1·0	Strong nitric acid	7	**Spirit of Wine, Ether, &c.**		Lamp black	44
Naptha	1·0	Vinegar	8	Sulphuric ether	5	Powdered coal	359
Oil of turpentine	1·0	Chromic acid and strong sulphuric	8	Oil of olefiant gas	15	Powdered galls	40
Rectified ditto	2·0	Ditto with 4 water	12	Alcohol	21	Powdered coffee	21
Highly ditto (camphine)	4·0	Formic acid	17			Powdered tea	20
Napthaline	2·0	Strong sulphuric acid	22				
Gas tar	2·0	Saturated solution of euchlorine	41				
Creosote	2·0	Saturated solution of chlorine	94				
Linseed oil	4·0	Muriatic, oxalic, and chromic acids would not deodorize.					
Castor oil	4·0						
Poppy oil	5·0						
Cod liver oil	6·0						
Colza and rape oil	7·0						
Mustard oil	7·0						
Olive oil	8·0						
Palm oil	13·0						

No. XVII.—*List of substances proposed for Disinfecting and Utilizing the Matters of Sewers and Cesspools.*

Name of Substances.	Inventor.	Date.	Name of Substances.	Inventor.	Date.
Acetate of Lead & Protosulphate of Iron	Deboissieu.	1762	Nitrate of Lead	Ledoyen.	1847
Quicklime	Estienne.	1802	Waste Salts of Lead, Iron, &c., with Coal Tar, Ashes, Earth, &c.	Brown.	1847
Powdered Charcoal	Giraud.	1805	Pyrolignate and Perchloride of Iron	Ellerman.	1847
Chlorine	Guyton Morveau	1805	Impure Chloride of Manganese	Young.	1847
Ashes	Chaumette.	1815	Dried Seaweed, Lime, and Sulphate of Lime and Zinc	Salman.	1848
Sand	Duprat.	1818	Peat Charcoal	Rogers.	1848
Sulphate of Iron	Briant.	1824	Charcoal, and Soot	Legras.	1849
Chloride of Soda	Labarraque.	1824	Spent Tan, carbonized	Tarling.	1850
Impure Chloride of Manganese	Peyen & Chevalier.	1825	Sulphate of Iron, and Peat Charcoal	Angely.	1850
Sulphate of Lime	Siret.	1827	Subsulphate of Iron, and Alumina	Brown.	1850
Animal Charcoal	Frigerio.	1829	Lime	Wicksteed.	1851
Peat	Guibourt & Sanson.	1833	Lime, Sulphates of Iron and Zinc, and Magnesian Earth	Gilbee.	1852
Charcoal, and Marl	Pottevin.	1835	Boghead Coke	Herapath.	1854
Sulphates of Iron & Zinc, with Tan & Tar	Siret.	1837	Superphosphate of Lime, Wood Ashes, Soot, and the Sulphates of Lime, Magnesia, and Alumina	White.	1854
Peat Ashes	D'Arcet.	1840	Lime, Sulphate of Alumina, & Charcoal	Stothert & Gotto.	1855
Metallic Oxides and Carbon	Krafft & Suequet.	1840	Peat Charcoal, carbonized with Oil of Vitriol	Longmaid.	1855
Chloride of Zinc	Sir Wm. Burnett.	1840	Sulphuric Acid	Manning.	1855
Schist Coke	Hompesch.	1841	Sulphites of Lime and Magnesia, and Carbolic Acid	McDougall.	1855
Trade Refuse, and Charcoal	Frick.	1842	Manganates and Permanganates	Condy.	1857
Powdered Lignite	Jourdan.	1843	Superphosphate of Lime, with Magnesia and Lime	Blyth.	1858
Impure Alum	Siret.	1843			
Sulphate of Zinc, Charcoal, and Clay	Gagnage & Regnault.	1844			
Persulphate of Iron	Baronnet.	1845			
Schist Coke, and Ammonia	Buisson.	1845			
Chlorides of Iron and Zinc	Dubois.	1846			
Trade, Refuse, Oak Bark, Pyroligneous Acid, Sulphate of Iron, and Alum	Evans.	1846			
Lime	Higgs.	1846			

Plate I. *Sewage from the Fleet Sewer, examined under the Microscope with a magnifying power of* 350 *diameters.*

Fig. 1.—The Supernatant Liquid after standing 24 hours.

a Husk of Wheat.
b Hair of Wheat.
c Mineral matter—Flint and Sulphuret of Iron.
d Globule of Fat.
e Vibriones.
f Spirulina.
g Filaments of Fungi.
h Paramecium.
k Monads.
l Decaying organic matter swarming with Monads, &c.
m Crystal of Triple Phosphate.
n Spiral vessel.
o Muscular Fibre.
p Vegetable Cells.
q Vegetable Spores.

Fig. 2.—The Deposit from the above.

a Muscular Fibre.
b Human Hair.
c Spiral Vessels.
d Cells of Potatoe.
e Potatoe Starch.
f Decaying organic matter.
g Dotted Duct.
h Various Confervoid Growths.
i Vegetable Spores.
k Various Fungoid Growths.
l Acineria.
m Monads.
n Vibriones.
o Oscillatoria.
p Mineral matter—Flint, Granite, and Sulphuret of Iron.

SEWAGE FROM FLEET SEWER.

PLATE I.

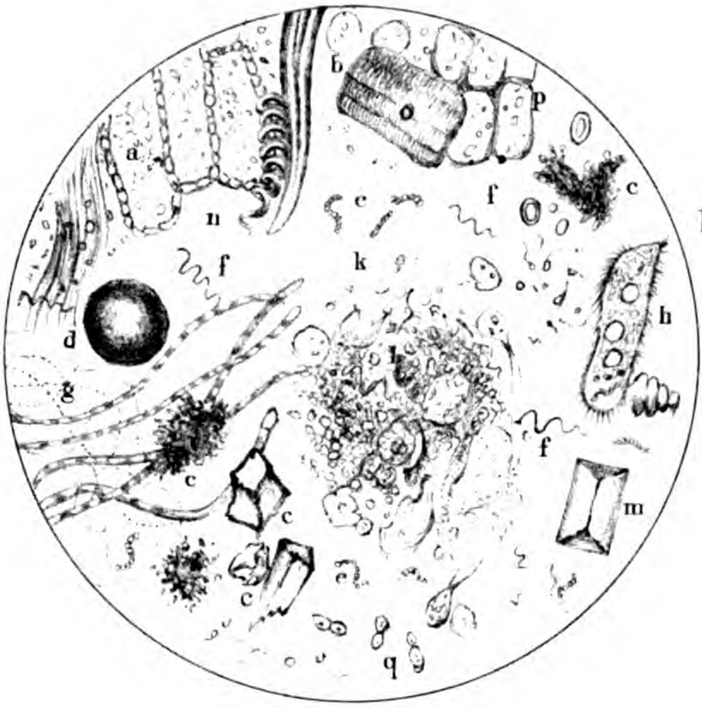

Fig 1.

Fig. 2.

Dr Andrew Clark, del.

PLATE II. *Sewage from London Bridge Sewer, magnified 350 diameters.*

Fig. 1.—The Supernatant Liquid after standing 24 hours.

a Decaying organic matter, traversed by fine Fungoid Growth and surrounded by Monads, and Vibriones.
b Crystal of Triple Phosphate.
c Fungus.
d Vegetable Spores.
e Spirulina.
f Simple form of Oscillatoria.
g Uvella.
h Zoospore.
k Monas.
l Chilomonas.
m Undescribed Monad.
n Acineria.
p Globule of Fat.

Fig. 2.—The Deposit from the above.

a Spiral Vessels.
b Muscular Fibre.
c Fibrous Tissue.
d Feculent matter, consisting of Yellow Pigment, Husk of Wheat, Muscular Fibre, Fungoid Growths, and decaying Organic Matter with Monads.
e Crystal of Uric Acid.
f Crystal of Triple Phosphate.
g Scale from Insect.
h Paramecium.
k Tricodina.
l Chilomonas.
m Uvella.
n Sarcina in numbers.
o Monas.
p Spirulina.
q Conferva.
r Oscillatoria in large numbers.
s Flinty matter.
t Hair of Wheat.

SEWAGE FROM LONDON BRIDGE SEWER.

PLATE 2.

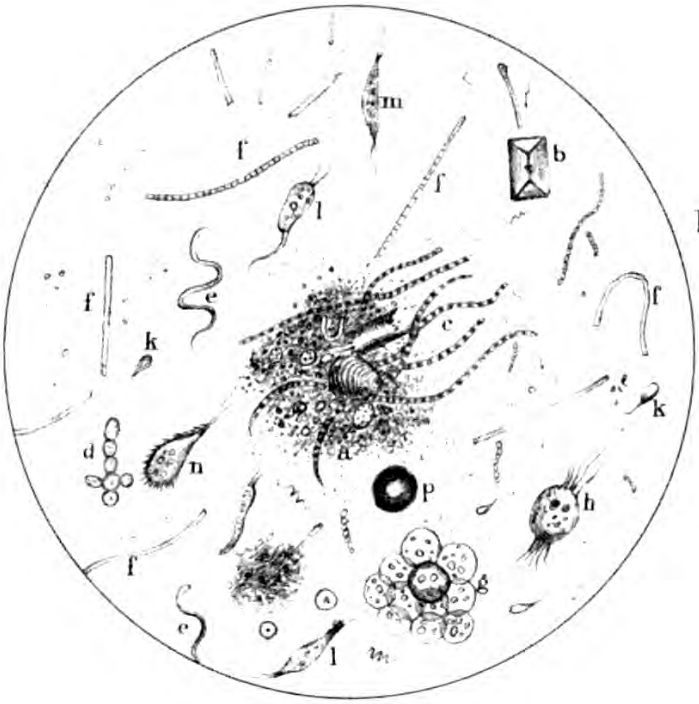

Fig. 1.

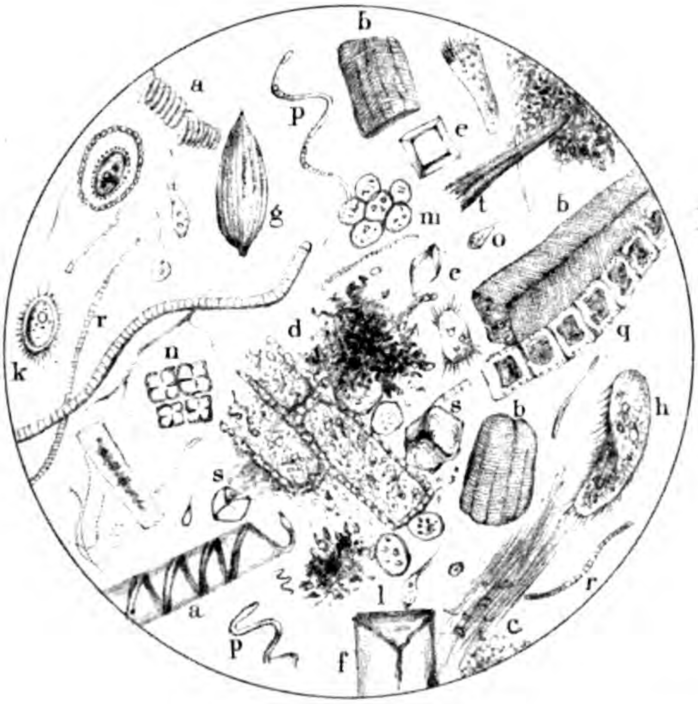

Fig. 2.

D^r. Andrew Clark del.

PLATE III. *Sewage from somewhat foul Sewers, magnified 350 diameters.*

Fig. 1.—Sewage from the Sewer in Bevis Marks, after exposure to the air.

- *a* Mineral matter—Granite, Flint, &c.
- *b* Hair of Wheat.
- *c* Decaying organic matter with Sulphuret of Iron and Monads.
- *d* Muscular Fibre.
- *e* Vibrio fluviatilis
- *f* Vorticella.
- *g* Rotifers.
- *h* Paramecium.
- *k* Trinema.
- *l* Chilomonas.
- *m* Rotifer at rest.
- *n* Spiral Vessel.
- *o* Sarcina.
- *p* Peculiar Conferva.
- *q* Chilomonas.
- *r* Zoospore.
- *s* Fungoid Filaments.
- *t* Husk of Wheat.
- *u* Potatoe Starch.

Fig. 2.—Sewage from Angel Alley Sewer.

- *a* Mineral matter—Flint, Granite, &c.
- *b* Decaying organic matter with black Sulphuret of Iron.
- *c* Vegetable Tissue.
- *d* Husk of Wheat.
- *e* Hair of Wheat.
- *f* Spiral Vessels.
- *g* Cells of Potatoe.
- *h* Filaments of various Fungi.
- *k* Sarcina.
- *l* Crystal of Triple Phosphate.
- *m* Muscular Fibre.
- *n* Oscillatoria.
- *o* Paramecium.

SEWAGE FROM BEVIS MARKS SEWER.

PLATE 3.

Fig. 1.

SEWAGE FROM ANGEL ALLEY SEWER.

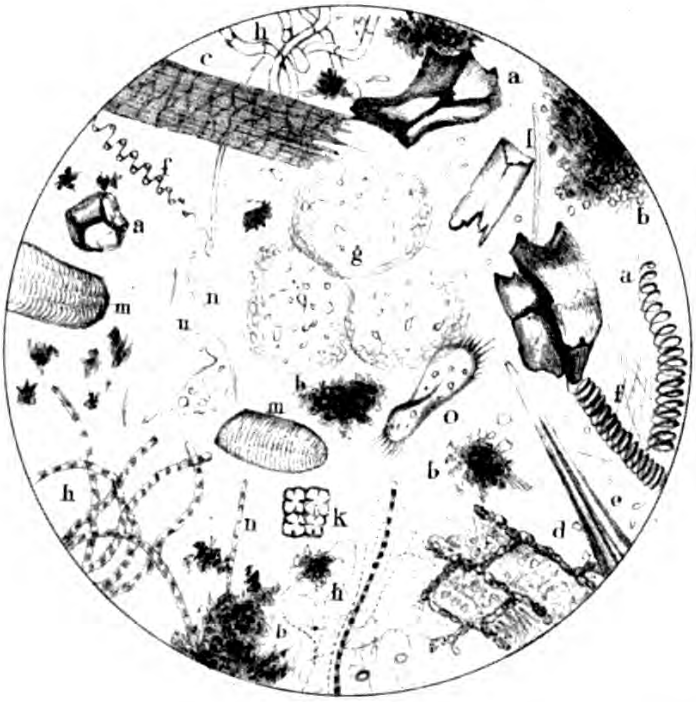

Fig. 2.

Dr Andrew Clark del.

Plate IV. *The Condensed Vapour of the Air of Sewers, obtained by cooling the atmosphere by means of a glass globe filled with ice. The Liquid examined with a magnifying power of* 420 *diameters.*

Fig. 1.—Condensed from the Air of the Sewer in Angel Alley.

a Debris of fine organic matter with Ovules and Monads imbedded in it.
b Free Ovules and Ovisacs.
c Conferva.
d Various species of Fungi.
e Vorticella.
f Spirulina.
g Monads and Vibriones in abundance.
h Amphileptris.

Fig. 2.—Condensed from the Air of South Place Branch of the London Bridge Sewer.

a Monas numerous.
b Zygoselmus (?) numerous.
c Parameceum very numerous.
d Vorticella very numerous.
e Amœba Diffluens very numerous.
f Actinophrys.
g Kerona.
h Vegetable form.
k Vegetable Sporules.
l Decaying organic matter with Monads.
m Various species of Fungi.

VAPOUR CONDENSED FROM SEWER AIR.

PLATE 4.

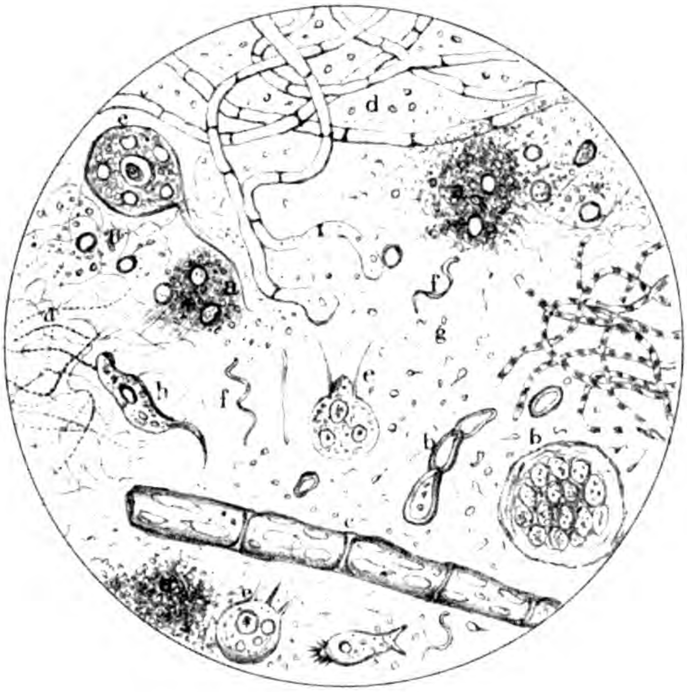

Fig. 1.

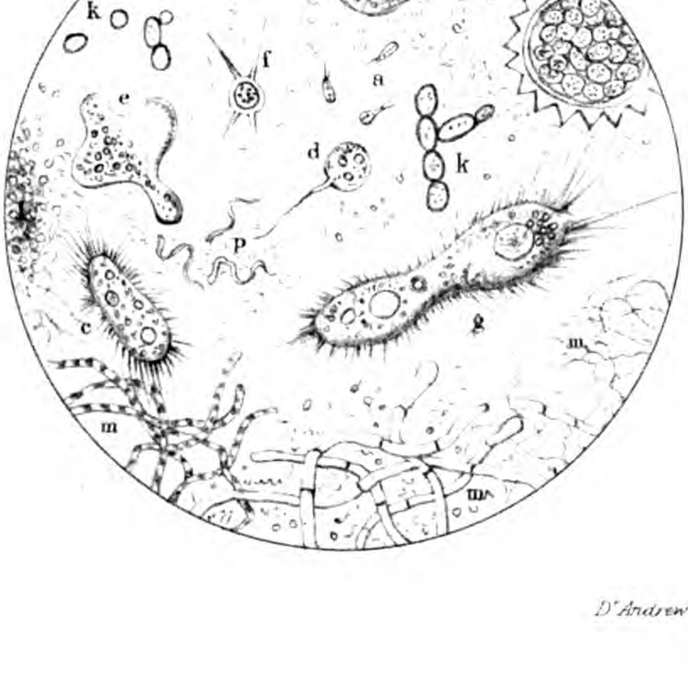

Fig. 2.

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