

SECTION III.

CHEMISTRY, METEOROLOGY, AND GEOLOGY.

ADDRESS

BY AUGUST DUPRÉ, Ph.D., F.C.S., F.R.S.

PRESIDENT OF THE SECTION.

IN this jubilee year there is a very general tendency in those occupying a position such as I now occupy before you, to review the progress made during the fifty years just elapsed in the various sciences to which our attention will be directed. The accomplishment of such a task would, however, involve too great a claim on your time and patience, even if it were in my power to do justice to the theme.

On the general subject I will therefore content myself in stating that, as far at any rate as modern times are concerned, sanitary science is, practically, a product of the last fifty years, and surely no other advance in art, science, or industry made during Her Majesty's reign has contributed more to the welfare and happiness of the nation.

In the following remarks I shall restrict myself to two questions, regarding which I may claim some special acquaintance, namely, the questions of water analysis and the treatment of sewage. Both subjects, I am afraid, have been frequently treated of at former sanitary congresses, and we are promised several papers on the subject to-day; but as they are, perhaps, the two most important questions on which the chemist can assist the sanitarian, I hope you will bear with me for a short time while I endeavour to bring some of the more salient features before you. In doing this I shall have to point out defects in our present methods, and shall venture to point out directions in which, in my opinion, further advance should be sought; for I believe that the function of a Congress such as this is not only the taking note of any progress made, but also to stimulate research and facilitate further progress. And now let us, in the first instance, turn to the question of water. Here, strictly speaking, all the chemist has to do is to find out the various sub-

stances contained in a given sample of water, and leave it to the medical man and sanitary engineer to draw their own conclusions, and apply their own remedies. Such a division of labour would be, ideally, the most perfect; and it is, I think, frequently carried out, as between the sanitary engineer and the chemist. The provinces of the medical man and the chemist are not however, as a rule, kept so strictly separate; nor are they, perhaps, so readily separable. The chemist thus frequently usurps the functions of the medical man, and the medical man those of the chemist; the result is not always such as would be most desirable or beneficial. As a chemist I trust I may be pardoned in saying that, in my opinion, the fault is more often on the side of the medical man than on that of the chemist. Questions, strictly medical, that arise in relation to our ordinary domestic water supply are, after all, but few; whereas, on the other hand, water analysis becomes every year more and more complicated and specialized, and requires a greater and greater amount of skill and knowledge for its successful prosecution, so much so that the time seems almost to have come for the setting up of a special class of chemists devoting themselves entirely to the examination of water.

Thirty or so years ago water analysis, I speak of it of course merely in relation to its sanitary aspect, was, comparatively speaking, a very simple matter. It consisted mainly, and I well remember the time, in the estimation of the total dry solid residue left by the water on evaporation, of the loss suffered by this residue on ignition, a loss usually put down as organic matter, and perhaps, a more or less rough examination of the nature of the mineral matters present. Gradually however, as the influence on health, exerted by the quality of the water consumed, became more and more recognised, the necessity for a more complete knowledge of the matters present in a water required for domestic use became increasingly pressing. New methods of analysis were devised and perfected until at the present day we are in possession of analytical processes which, so far as the detection and estimation of dead matters are concerned, leave but little to be desired. Without going minutely through these various processes, I may be permitted to glance shortly at some of them, mainly however in regard to the various constituents which it was, or is, desired to estimate.

The various substances found in a water, as far as they are of interest to the sanitarian, may be roughly divided into three classes. *Firstly*, mineral matters derived solely from the soil or rock through which the water has percolated; *secondly*, mineral matters derived either directly from organic matter, such as

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nitric acid and ammonia, or which, as being frequently found associated with certain kinds of organic matters, indicate by their presence the probable or possible pollution of the water by these organic matters, such as chlorine and phosphoric acid, always associated with the urine of men and animals; and *thirdly*, organic matters. Living organisms I leave out of consideration for the present.

In regard to matters falling into the first class, little or nothing need be said here, for unless they are present in excessive proportions they need not, as a rule, trouble the sanitarian. I of course exclude from this general statement all distinctly poisonous mineral matters occasionally found in potable waters, and also, for the present, such mineral matters as may exert an injurious action on the materials with which the water, in the course of domestic use, is brought into contact.

The next class, namely, those mineral matters directly derived from organic matters, or those the presence of which indicates the probable presence of organic matters, offers however far greater difficulties; not so much in regard to the analytical processes to be employed as in the interpretation to be put on the results obtained. This latter point, though by no means the only, is by far the main difficulty we have to deal with, and very serious differences regarding it exist among analysts. The matters falling into this category are mainly *nitric acid*, *ammonia*, *chlorine* and *phosphoric acid*, and, in a minor degree, sulphuric acid and the alkali metals, sodium and potassium.

Nitric acid.—This was early recognized as a most important feature in a sanitary analysis of water, and there is probably no single point connected with water analysis regarding which so many analytical processes have been elaborated, or which has raised more discussion in relation to the significance of the indications furnished. As regards the processes used for its quantitative estimation I need not trouble you here, they may be found fully described in many books and papers, and it must suffice to say that the analyst has a choice of a number which fulfil all requirements as regards accuracy and ease of execution. The choice of any particular process is greatly a question of training and convenience. As far as I myself am concerned, the process I chiefly employ is the indigo process, which, when carefully conducted, is accurate enough for all practical purposes. When however we come to the interpretation of the analytical data obtained, difficulties begin to crowd upon us. In the first place very few, if any, unpolluted waters are found free from nitric acid, and the mere presence of this acid cannot be taken as of any significance, and quantity has to be taken into account. The question thus presents itself, how does this nitric acid get

into the water? Now, in the first place, rain-water, which is the source of all our wells, spring or river water, always contains traces of nitric acid, and this nitric acid is probably produced mainly by purely physical agencies. The nitric acid from this source is, however, as far as we know at present, the only nitric acid thus produced, and its amount is, fortunately, extremely small, not more than a few hundredths of a grain per gallon on an average. The presence of this nitric acid clearly cannot be taken as indicating organic pollution. The main quantity of the nitric acid, however, is derived, there can I think be no doubt, from nitrogenous organic matters, chiefly of animal origin, which have been decomposed or destroyed by the vital action of certain micro-organisms. It would thus appear that whenever we find more than a mere trace of nitric acid in a water, we should be justified in concluding that the water under consideration had, at some previous stage of its history, been polluted by nitrogenised organic matters, mainly of animal origin, or, as in the case of water, these matters are, practically, mainly derived from sewage or surface drainage, that the water had been polluted by sewage or drainage from manured land or some similar source.

It was this consideration, I suppose, which led Prof. Frankland to use the expression, "previous sewage contamination," for which he has been so severely criticised by many.

Now in great measure I agree with Prof. Frankland in the notion this term was intended to express, although in its practical application it requires some modification and caution. This modification is required because we are acquainted with certain waters which contain appreciable quantities of nitric acid in excess of that derivable from rain-water, and which, nevertheless, from their position, depth, &c., cannot possibly have been subjected to any recent pollution by sewage or drainage from manured land, &c., and, therefore, as applied to such waters, the term is somewhat, not to say entirely, misleading. Not but that I believe that even in these cases the nitric acid is derived from nitrogenised animal matter by the intervention of micro-organisms; but this animal matter is not of recent origin, and may have been deposited contemporaneously with the chalk itself; it certainly is not derived from any recent sewage.

We are thus reduced to this position: the presence of nitric acid by itself, even when in appreciable quantity, cannot be taken as indicating sewage pollution (when I speak of sewage pollution I do not mean merely the liquid flowing in our sewers, but any organic matters derived from a similar source). What then is the amount of this acid, which, when found, must be

taken as proving such pollution? I shall try to answer the question, as far as I can, later on.

Ammonia.—There is such a concensus of opinion regarding ammonia that I will pass it over, and merely indicate an exception to the general rule which I know sometimes misleads analysts.

In some cases waters contain considerable proportions of ammonia derived from nitric acid, probably due to the reduction of the latter by micro-organisms, sometimes by the metal pipes conveying the water. In such cases, the presence of ammonia therefore does not indicate more than the nitric acid would have done; this is the case, for example, with some of the London chalk water.

Chlorine.—This is one of the most important of the purely mineral constituents to take into consideration, in judging the quality of a water; chlorine, as before stated, being a constant constituent of urine, and one which, unlike some other mineral matters, when once it has found its way into the water, remains there and can be traced with certainty. In our endeavours, however, to draw conclusions, the same difficulties confront us as we found in the case of nitric acid. Chlorine is present in waters, its amount varies greatly even in unpolluted waters, according to the character of the soils or geological formations from which the water is derived, or even according to its geographical positions. Thus water from wells or springs in the neighbourhood of the sea, or of tidal rivers, even though considerably above high water, but within the influence of spray carried by winds, frequently shows an amount of chlorine greatly in excess of what it would be if removed from these influences.

Phosphoric acid.—This, like chlorine, is a characteristic constituent of urine, and, like the substances just considered, is also found in every natural water, but, unlike these, it is, according to my experience, rarely or never found in any notable quantity in a pure unpolluted water. The presence therefore of phosphoric acid in anything beyond minute traces, is in my opinion, perhaps the strongest evidence we can obtain, from mineral matters alone, that the water under consideration is polluted by sewage. In the long series of analyses which I made some years ago in conjunction with Dr. Cory, for the Medical Department of the Local Government Board, I could not unfrequently pick out the polluted samples by the fact of their containing a greater proportion of phosphoric acid than the unpolluted water, even when all other analytical methods failed to bring out any clear distinction. But although the presence of phosphoric acid in any notable quantity may be

taken as one of the strongest proofs of pollution, its absence must not be taken as proving the absence of pollution, for there are many natural causes at work tending to the removal of phosphoric acid.

The Alkali Metals.—In relation to these I will merely state that whereas sodium is the greatly predominating alkali in the urine of men, the urine of horses and cattle contains a considerable proportion of potassium, and hence a careful estimation of these two alkali metals in a polluted water may sometimes enable us to find out the particular source of its pollution. In some cases this may be of importance from a sanitary point of view.

The presence, or absence, of the various mineral matters so far considered is, however, of interest mainly as throwing light on the previous history of the water. In themselves they are not injurious, and undoubtedly a water may be perfectly wholesome in spite of its containing considerable quantities of these various matters. So much so is this the case that, as is well known, one of our foremost water analysts, in judging of the suitability of a water for drinking, practically ignores the presence of most of them, notably that of nitric acid. This is bad enough in the hands of a master, but in the hands of his followers it leads to serious mistakes. For, although these animal matters throw light mainly on the past, they also enable us, to a great extent, to read the future. A water containing these matters in certain proportions must, at some previous period of its flow, have been contaminated by animal matters, or what comes to the same thing, must have passed through soil thus contaminated. In its passage through soil or rock the organic matters are removed or changed into mineral matters, some of which remain in the water and testify to the prior presence of the organic matter. The mineral matters with which the organic matter was associated also remain in greater or less proportion in the water. Now it is well known that this destruction of the organic matters depends upon a variety of circumstances, such as the amount of pollution, temperature, aëration of the soil, &c., &c. These conditions vary during the seasons of the year, and also from year to year, and hence a water which at one time contains these mineral matters only may, at another time, contain the organic matters from which these were derived, or with which they were associated. These mineral matters therefore indicate the possibility, in some cases the absolute certainty, that the water in which they are found will, at some other period, be charged with organic matter. It is this consideration that gives importance to these mineral matters in water analysis.

It is, however, the proportions of actual organic matter present in judging of the fitness or otherwise of a sample of water which, for domestic use, has been, and still is, our chief guide. Various processes have been devised to enable the analyst to form some approximate estimate of the amount of organic matter present in a water, but no process as yet known enables him to determine its absolute quantity. The old process, namely, of heating the dry residue to a red heat and finding the loss it sustained thereby, has now, I suppose, been universally discarded as useless for the purpose. Nevertheless, for all those at least who do not employ the organic carbon and nitrogen process, the simple ignition of the dry residue often yields valuable results. A pure water residue is white and does not change colour on heating. A residue from a water containing organic matter is usually more or less yellow or brown; it darkens or blackens on heating, but becomes white on continued application of heat, the carbon gradually burning off. Carbon derived from vegetable sources generally burns off readily, whereas the carbon derived from animal sources usually burns off with difficulty. For myself I never omit this simple process.

The next process in point of time, and which is still in use, is what is known as the permanganate process, the object of the process being the estimation of the amount of oxygen which the organic matter present is capable of abstracting from a solution of permanganate; and from this forming some sort of estimate as to the amount or nature of the organic matter present. Many chemists have worked at this process, but the modification which in my opinion gives the best results consists in acting on the water with the permanganate and acid, in a stoppered bottle and at a given temperature. The advantages gained by this are: 1st, all influence which the atmosphere of the laboratory may have on the permanganate solution is excluded, and no correction for it is necessary; 2nd, the presence of even considerable proportions of chlorides does not prevent the application of this test, even sea water may be tested;* and 3rd, uniformity of temperature insures uniformity of results—and strictly comparative results. A modification of this process employed by some, namely, boiling the acidulated water in a flask with permanganate solution for ten minutes, is, as a rule, quite inadmissible,

* The hydrochloric acid liberated from the chlorides by the sulphuric acid decomposes permanganate, and chlorine is produced. When the process is carried on in an open vessel much of this chlorine escapes into the air, and is lost; if however a closed bottle is employed the chlorine is retained, and when at the end iodide of potassium is added for the purpose of estimating the amount of permanganate remaining, this chlorine liberates as much iodine as the permanganate would have done which was destroyed in its production, and is thus estimated in terms of permanganate.

for chlorides, under the conditions of the experiment, decompose permanganate, and the chlorine thereby produced is expelled by the boiling, and appears in the final result as organic matter. This permanganate process does not give us the actual amount of organic matter contained in the water examined, nor will it give us even the relative proportions of organic matter contained in different waters, unless the nature of the organic matter is the same, for different kinds of organic matter absorb widely different proportions of oxygen from permanganate. If, however, the nature of the organic matter is the same this process gives us relative quantitative results. Moreover, as I hope I shall be able to show, it is not so much the absolute proportion of organic matter as the relative proportion of oxygen absorbed, that is of value as a guide.

The next process in point of time is, I believe, the so-called albuminoid ammonia process proposed by Wanklyn, Chapman and Smith. This process has for many years enjoyed, and still enjoys, a very wide popularity in this country, in spite of the frequent attacks to which it has been subjected. This popularity is owing in the first place, I have no hesitation in saying, to the intrinsic merits of the process, but in the second place undoubtedly to the comparative ease with which it can be applied; and let us not be too ready to sneer at those making use of a process because it is easy to carry out. Ease of manipulation often means accuracy of results, or at least uniformity of results, which in most analytical processes is the great desideratum. The albuminoid ammonia process gives us, as most of you will know, in the first place the amount of free ammonia present in the water, and in the second place a certain, or perhaps I should say an uncertain proportion of the organic nitrogen, also in the form of ammonia, and this latter is known as albuminoid ammonia. The proportion of the total nitrogen yielded in this form by various kinds of organic matter undoubtedly varies within very wide limits, and it would be easy to make up two samples of water of which the one containing the least amount of organic matter would yield by far the greater proportion of albuminoid ammonia. In practice however this objection loses much of its force. The organic matters found in natural waters, although no doubt they differ from each other, do not range through the whole series of organic compounds and, as a rule, show a considerable degree of similarity, particularly when waters from similar sources are compared with each other, and the experienced analyst will not easily be misled by such variation. Moreover, let me emphasize once again, that our estimate of the quality of a water depends, in great measure, on a comparison between similar waters.

The last process, as applied to non-living organic matter contained in water, I propose to glance at, is the so-called organic carbon and nitrogen process devised by Professors Frankland and Armstrong. The process, when carried out skilfully, gives very good results as far as organic carbon is concerned; the results are less satisfactory in regard to organic nitrogen, particularly in the presence of much nitric acid. The process does not, as little as those previously considered, give us the actual amount of organic matter contained in the water analysed, inasmuch as it takes account of only two of the elements, but those, certainly the most characteristic, and leaves the rest out of consideration. It gives us, however, with a considerable degree of accuracy, the *actual* amount of one of the two elements, namely, the carbon, and that of the second, the nitrogen, with a more or less close approximation to the truth. In this respect the process has certainly the advantage over those previously considered. This advantage is, however, at present, to a great extent neutralized by the fact that the material at our disposal which can serve as a guide is incomparably smaller than that available in regard to the other two processes; and also by the far greater trouble and difficulty involved in its application. The former disadvantage will probably gradually diminish; the latter, however, will remain, and will act as a bar against its general adoption, as long at least as its superiority over the other process alluded to as a method of practical water analysis, is not definitely established, which can hardly be said to be the case at present.

Not improbably the estimation of organic carbon and of organic nitrogen will in future be carried out in two operations. Both estimations will thereby gain in accuracy, and the two processes can be carried out more readily in ordinary analytical laboratories than can the original process. Detmar's process for organic carbon and nitrogen; Dupré and Hake's organic carbon process; Kjeldahl's organic nitrogen process.

Thus far the analytical processes shortly passed in review deal with mineral and non-living organic matter merely, and on the whole they fulfil the object for which they were devised in a very satisfactory manner. When once, however, it was recognised that the injurious effects produced by the drinking of impure water were due not so much to the dead organic matter it contained as to the presence in it of living organisms, the importance to be attached to the dead organic matter naturally diminished.

This dead organic matter hence has occupied a position practically similar to that previously occupied by nitric acid, chlorine, &c., that is, the presence of the dead organic matter might in most cases be taken as an indication of the presence, or possible

presence, of living organisms also. It was then that doubts began to be expressed as to the value of water analysis; some, I believe, going so far as to deny its value altogether. This doubt is, I think, best expressed by Dr. Buchanan in his report to the Local Government Board for 1881. In this he states, "The chemist can, in brief, tell us of impurity and hazard, but not of purity and safety. For information about these we must go, by the aid of what the chemist has been able to teach us, in search of the conditions surrounding water courses and affecting water services."

Now taken in the abstract there can, I think, be no doubt that Dr. Buchanan is right; but in practice this principle should not be applied too rigidly. There can of course be no doubt that an artificially polluted water may be prepared which, while containing an amount of infectious material which would render the water dangerous to those drinking it, would yet be passed as pure by the analyst. In practice, however, such cases very rarely occur, and ought never to occur. As a general rule the proportion of infectious matter that finds its way into a well or water-course is extremely small compared with the amount of non-infectious matter that finds its way into the same; and hence whilst the analyst might be unable to discover the presence of the infectious matter, if it alone were present, he will as a rule have no difficulty in detecting the presence of organic matter, or of products of its decomposition or those accompanying it, due to the far larger proportion of non-infectious material which has entered the well or water-course, &c. Such cases as that of the well at Caterham are, it is to be hoped, extremely rare. They are of the utmost value as showing how small a proportion of infectious matter may prove dangerous, but they must not be taken as proving that chemical analysis by itself is valueless. They should however teach this lesson to the analyst: whenever his analysis shows him undoubted indications of present or past pollution he should condemn the water, or rather, I should say, he should condemn the well or spring, &c., from which the water came, bearing in mind that the non-infectious matter, the presence of which can be proved, indicates the possibility of the presence of infectious matter, the presence or absence of which he cannot at present demonstrate.

The question yet remains to be answered: when, if ever, are we justified, from the results of chemical analysis, in pronouncing a water free from pollution and safe, and when must we pronounce it polluted and unsafe? This lies at the root of the matter, and is by far the most difficult question that comes before the analyst. The mere working out of an analysis is,

comparatively speaking, a simple matter : it is the true interpretation of the results obtained that tasks the knowledge and experience of the analyst.

This difficulty was felt very early in the progress of water analysis, and many attempts have been made to overcome it by laying down certain general standards to judge by, and waters were divided into good, bad and indifferent.

Against the setting up of such general standards I have already repeatedly raised my voice, and wish to do so again before this Section. All such standards are fallacious : they serve only as crutches, so to speak, for the ignorant to lean on ; the chemist who thoroughly knows his work does not require them, and those who do require them are not fit to undertake water analysis at all. It is the existence of these general standards that so frequently leads to mistakes. One sample of water is condemned because it contains a little more organic carbon, or yields a little more albuminoid ammonia, or absorbs a little more oxygen from permanganate than has been laid down as a standard, while another water is cheerfully passed because in these particulars it falls within the standard ; and yet the first water may be perfectly wholesome and unpolluted in the proper sense of the term, while the second may be entirely unfit for use. As long as we are dealing with definite compounds or with non-living organic matters, however injurious they may be, it is always possible to state a quantity below which, if taken, they will not prove injurious ; and general standards may have been of use. The moment however that we are dealing with living organisms capable of self-multiplication, this ceases to be the case, for what may be an infinitesimal quantity in the water may become a dangerous quantity in the body of the consumer. As long however as we cannot by analysis detect the infectious living matter, we must have some guide for drawing correct conclusions from the results of our analysis ; and even should we gain this power, chemical analysis and the necessity of its true interpretation will not lose their value ; and in fact the analyst who bases his conclusions solely on the presence or absence of dangerous organisms, commits the same mistake as he who only regards organic matter and neglects mineral matter derived from organic matter. For at the time of examination a water may not contain any infectious matter but may nevertheless show signs of general pollution, and thereby show that infectious matter may find its way into the water. What guide then do I recommend ? For some kind of guide we must have. This guide was first, I believe, strongly insisted on by my friend Mr. Hehner and myself, in a paper read before the Society of Public Analysts in February, 1883.

It is the conformity of the water to, or its divergence from, the general character of the waters of the district from which it comes, or of the geological formations from which it springs, which from their position and surroundings may fairly be taken as unpolluted. In other words, district standards instead of general standards should be used.* This of course implies a knowledge of district standards, and these are not always easy to obtain, and the obtaining of them frequently necessitates the co-operation of the Sanitary Engineer to select the unpolluted samples; such co-operation is in every respect desirable, and should always be had recourse to in important cases. I freely confess that I have repeatedly been saved from error by such co-operations. District standards might also be obtained if analysts in all parts of the country would freely communicate their analytical results to their professional brethren. In the paper previously referred to we appealed for co-operation in the establishment of such standards to the members of our Society; professional jealousy, however, stands in the way. Perhaps this Society might give effective aid towards the accomplishment of so desirable an object by collecting and publishing standard analyses from all parts of the country from which they are obtainable. By the aid of such district standards, the analyst has, as a rule, no difficulty in giving an opinion regarding the purity or impurity of any water submitted to him, although he may not be able to prove the presence or absence of infectious matter. In the before mentioned paper several series of analyses are given of water collected along the Undercliff, I.W., which clearly demonstrate the polluted character of waters which, on the strength of any conceivable general standard, would have been pronounced as perfectly pure.

I cannot leave this subject without recording my high appreciation of the value in this respect of the sixth Report of the Royal Commission on Rivers Pollution.

BIOLOGICAL METHODS.

I have already several times had occasion to allude to the fact that the injurious effect of polluted water is, in all probability, not to say certainty, due to the presence in it of living

* It is of course desirable, when possible, to collect the waters to be used as standards simultaneously with the suspected sample; but this is not absolutely necessary. It is one of the characteristic features of unpolluted waters, particularly in the case of deep wells, to remain practically uniform in composition through considerable periods of time, and a carefully chosen district standard will therefore remain available for some length of time.

organisms. Attempts have accordingly been made to detect these organisms, and a considerable degree of success has been achieved in this direction. Most careful water analysts have for many years been accustomed to the use of the microscope in the examination of water, and very often valuable results were thereby obtained. The first, however, who, so to speak, aided the microscope by adding a cultivating material to the water was, I believe, Mr. Charles Heisch. Mr. Heisch added some pure cane sugar to the water and examined the fungus found growing in sewage polluted water, in consequence of this addition, microscopically. The process has quite recently been again taken up with promising results. The best known biological method is, however, that brought forward by Professor Koch, of Berlin, which consists in adding a small but known quantity of the water under examination to a gelatinizing cultivating material. This mixture is spread on glass slides and examined after a time. If the water is free from organisms no growths make their appearance in the cultivating material, whereas, if the water contained any living organisms, or the germs of such organisms, these will grow and multiply, and thus become visible, each centre of growth corresponding to at least one germ or mature organism, and the number of such germs or organisms in a given bulk of water very approximately ascertained, and special organisms may even be identified. This method has been taken up warmly in this country by Dr. Percy Frankland, who has already published a number of valuable papers on the subject, and who, I am happy to see, is here and will favour us with a paper, and also by Dr. Bischoff and others, and we may look forward with confidence to valuable results from their hands. In theory nothing could well be better than this method; in practice, however, serious difficulties will have to be overcome before this method can be pronounced thoroughly reliable. Thus, some of these organisms grow best in the dark, others require light; some grow only at a moderately low, others only at a moderately high temperature; some like one, some another cultivating material. Hence the number of centres which one and the same water will yield may vary with all these conditions, and some kinds of organisms may not appear at all under one set of conditions, which appear in abundance under a different set of conditions. All these points, as well as others not mentioned, will have to be studied and cleared up before the method will become generally available.

A second biological method which I should like shortly to bring before you is one of my own, but for the working out of which, as far as I have gone, I am strongly indebted to aid afforded me

by Dr. Buchanan. As a chemist it has always been my endeavour to use chemical means in my researches, in preference to any other, whenever possible. Accordingly when the question of these micro-organisms came forward I sought for chemical means for their detection, and I believe I have to some extent succeeded. The method adopted still requires a great deal of work to be expended on it, and I bring it forward here in the hope of inducing some of those present to take it up. The subject is too large for one worker, who moreover is otherwise busily engaged, to work it out in any reasonable time. The process will be found fully described in the reports of the Medical Officer of the Local Government Board for the years 1885 and 1886. Shortly stated it is as follows. If a pure, thoroughly aerated water be kept out of contact with air for say ten days, it will be found to have remained fully aerated. The same will be found to be the case even with an impure water, provided the water contained no living organisms. Sewage polluted water when sterilized by heating remains fully aerated. If however the water contains living organisms, the state of aeration will alter, and in the majority of cases will diminish; and the degree of diminution will give some measure of the number of organisms present. The experiment may be varied by adding some sterilized cultivating material to the water previous to bottling, by keeping the water at various temperatures or varying the amount of light to which the bottle is exposed during keeping, &c. Again, some kinds of organisms are killed in all their stages of development when heated to a comparatively speaking, low temperature; others, particularly in certain stages of development, are capable of withstanding a comparatively high temperature without losing their vitality. By thus varying the conditions of the experiment it becomes possible not only to distinguish, by chemical means, between dead and living organic matter, but even different kinds of organisms may be distinguished from each other.

There is one other question connected with water I should wish to allude to, as it has scarcely received the amount of attention from chemists that it deserves, namely, the action exerted by some waters on metals, notably on lead and on iron, these being the principal metals used in connection with water supplies, &c.

Action on Lead.—Up to within the last few years it was generally supposed that the action exerted by some waters on lead was due, mainly, to their softness, that is, chiefly to the insufficient proportion of lime salts they contained. In addition to this, the main cause, it was ascribed to the presence of nitrates, nitrites, organic matter, &c. Within the last few

years, however, an elaborate research has been undertaken by Drs. Tidy, Odling and Crookes, by which they were led to the conclusion that the real protective agent, that is, the agent which prevented the action of water on lead, was silica. According to this explanation, waters will act on lead if they do not contain a sufficient proportion of silica. They will not act on lead if a sufficient proportion of silica be present, not less than half a grain per gallon, whatever, speaking broadly, the rest of the constituents might be. Drs. Tidy, Odling and Crookes have brought forward many facts tending to bear out their contention; and although they have not, in my opinion, quite proved their case, they have at any rate made out a strong case for investigation, and in future analysts will do well to direct their attention to this point. The question is one beset with difficulties, inasmuch as so many factors have to be taken into consideration before a definite conclusion can be arrived at. The chief points to be kept in view are, in my opinion: The reaction of the water, whether acid, neutral, or alkaline, the most delicate reagents to be used for detecting the same; if the reaction is acid, the amount of this acidity, and if possible its nature; the amount of free carbonic acid; the total dry residue; the proportion of lime and magnesia salts in this; the proportion of chlorine; the proportion of nitric acid; organic matter; and lastly, the amount of silica. It is only by taking all these points into consideration that a satisfactory final result will be arrived at.

Action on Iron.—This has not received anything like the attention which has been bestowed on the preceding question; mainly I suppose because iron not being a poisonous metal, a slight degree of action may be, and generally is, overlooked. In not a few cases, however, the action is so powerful as to constitute a serious nuisance, leading sometimes to considerable expense. This action is observed mainly in connection with a hot water supply, and is, in my experience, due chiefly to the presence of an excess of magnesium salt, particularly of chloride of magnesium. The action may be prevented, or at any rate greatly reduced, by submitting the water to Clark's process. Of course pipes other than iron may be employed. The selection of the kind of pipe to be taken is, however, of some difficulty, particularly in cases in which expense is an object, and the thorough treatment of the question well merits the attention of the sanitary engineer and the chemist.

While I am on this question I may mention another frequent cause of the corrosion of water pipes. This is the setting up of galvanic action whenever two kinds of metal are brought into contact. As far as possible the use of different metal in water

conduits should be avoided, and where it cannot be avoided the two metals should be kept from metallic contact by the interposition of a non-conducting material.

SEWAGE.

I have often thought, and have given public expression to the thought, that, from a sanitary point of view, the production of sewage, ordinarily so-called, that is the water carriage of our house refuse, was a mistake. However, for good or for evil, the plan has been adopted, and we must do the best we can for its satisfactory disposal. The question is a very large and important one, and I cannot treat it in any but a very fragmentary manner here.

The first point I would mention is, that all authorities who have to deal with the disposal of sewage should clearly understand that sewage is a nuisance to be got rid of, and not a thing to make a profit out of.

The next is, that if sewage is to be disposed of to the greatest advantage of the community, the sewage of every place will have to be dealt with on its own merits; no general scheme will do equally well for all.

Many schemes—good, bad and indifferent—have been elaborated for the proper disposal of sewage, but I cannot deal with them here; perhaps we shall hear something about them at this meeting. But with your permission I will throw out some suggestions on the general aspect of the question.

In the first place, I am decidedly of opinion that whatever scheme may be adopted (except destruction of the sewage material by fire), the agents to which the ultimate destruction of sewage is due are living organisms (not necessarily micro-organisms), either vegetable or animal. If this be so, our treatment should be such as to avoid the killing of these organisms or even hampering them in their actions, but rather to do everything to favour them in their beneficial work. Now in order to avoid this danger, and at the same time reduce to a minimum the nuisance due to the existence of sewage, we must begin our treatment in the sewers themselves, a step further back than it is usually begun. Of course I am aware that sewers are laid out with a view of bringing the sewage in the shortest possible time from the sources of production to the general outfall; but even in towns of moderate size the time elapsing in the passage of the sewage between these two points is sufficient to render the sewage offensive, at least in summer time, while in large towns the sewage has time to become very highly offensive. No doubt the great bulk of the sewage as a rule reaches the outfall in a short time, but the time which has to elapse before the whole of

the sewage contained in the sewers at a given time is discharged is far longer than is generally supposed. This offence ought to be avoided; how can it be done? It should not be done in a manner to destroy our beneficial organisms, or even seriously to check their action; in other words, the use of disinfectants or of powerful antiseptics should be avoided. I have the less hesitation in saying this, because, on the score of expense, it is practically impossible to really disinfect infectious matter when once it has found its way into the sewers. All that is usually done in this direction is really a deception—no doubt a self-deception—on the part of those employing such means. All we can therefore really do is to deodorise the sewage, and this can be done without in the least interfering with the immediate or subsequent action of the organisms on which we depend for the final destruction of the sewage. The best material for this purpose is, in my opinion, a solution of permanganate of potassium, prepared on the spot from crude manganate by the addition of acids or suitable salts to the same. Sanitarians are, I think, greatly indebted to Mr. Dibdin, of the Metropolitan Board of Works, for bringing, by his energy and courage, the manganates, and consequently also the permanganates, within the reach of practical sanitation. And let it not be supposed that all we effect is simply deodorization of the sewage; but we also in great measure check putrefaction, and thus do away with what seems to be the chief agent in carrying disease germs into our streets and houses, namely, the rising and bursting of gas bubbles from the sewage.

Sewage thus treated will arrive at the outfalls in a practically inodorous condition, or nearly so, according to the amount of manganate used, and is fit for any kind of treatment we wish to adopt, such as:

Sewage farming with untreated sewage.

Sewage farming with sewage clarified by subsidence.

Sewage farming with sewage clarified by precipitation.

Precipitation and filtration.

Precipitation and discharge, if necessary previously deodorised, into a river of sufficient volume to prevent the production of a nuisance. According to the exigencies of each particular locality.

As regards processes of precipitation, I will merely remark that inasmuch as no proportion of chemicals which can practically be employed will do much more than clarify the sewage, the proportion of chemicals employed should be kept as low as is consistent with the object to be obtained, namely, clarification, and that, more particularly, the use of large quantities of lime should be avoided.

To sum up: let natural agencies have their way, assist and direct them into proper channels as far as you can, but interfere with them as little as possible.

Mr. ROGERS FIELD, M.Inst.C.E. (London), moved a vote of thanks to Dr. Dupré for his admirable address. As bearing on the subject matter of that address he might say he had known of more than one case in which water had been analysed by a local chemist and pronounced to be good, when he himself had been nearly certain from the surroundings that it had been polluted with sewage. The discrepancy had been cleared up for him by Dr. Dupré. The opinion that the water was unpolluted was given simply on the general grounds that water which contained only such and such ingredients was unpolluted. But directly a sample of unpolluted water of the district was obtained and compared with the water in question it was found that the water was clearly polluted.

Mr. J. B. GASS (Bolton) seconded the vote of thanks to Dr. Dupré for his admirable address, and remarked on the vital importance of correct and high standards for the purity of water for domestic purposes, as a question, the application of which directly affected the health of the whole population.

Dr. A. DUPRÉ, F.R.S. (London), expressed his thanks for the compliment, and then called on Mr. Frankland and Dr. Parkes to read their papers, saying it would be better to discuss them both together.

On "*The Application of Bacteriology to questions relating to Water Supply*," by PERCY F. FRANKLAND, Ph.D., B.Sc. Lond., F.C.S., F.I.C., Associate of the Royal School of Mines.

ALTHOUGH the modern development of the study of bacteria and other allied micro-organisms has now attracted the attention of the public for a number of years, and has excited such general interest that references to "bacteria," "germs," "microbes," and the like are frequently to be found in the daily papers and other prints freely circulated amongst all classes of the population, yet it is often only too palpable from these very allusions that but little sound knowledge concerning these micro-organisms has penetrated beyond a comparatively limited circle.

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