THE INTERPRETATION OF THE REPORTS OF WATER ANALYSES.

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WHEN I read Professor Woodhead's paper on "The Water Supply Problem in Rural Districts," I thought that in order to illustrate the chief point he makes with regard to co-operation, I might give the analyses of the waters from two village pumps which he and I examined some two or three months ago. These pumps supplied two villages in the South of England.

	A.	B.
Free Ammonia	.060	.068
Albuminoid Ammonia	.156	.552
Chlorine	51.200	4.200
Oxygen absorbed in 3 hours at 80° F. ...	.100	.070
Nitrogen as nitrates	.800	.800

You will notice the very considerable amount of the two ammonias in A, almost by themselves sufficient to condemn the water. You will notice the enormous amount of chlorine. I put these numbers in parts per hundred thousand, not in grains per gallon. You will notice that the oxygen absorbed is large. I do not suppose that the whole of the chlorine comes from sewage contamination, or from surface water contamination. I am inclined to think there is a deposit of some salt of chlorine in some stratum through which this well is bored, and that it is partially dissolved by the water in the form, say, in part of ammonium chloride, or it may be, in part, of other chlorides. I do not think it is wholly ammonium chloride, because I think the amount of free ammonia would then be

considerably larger. Of course an analysis of the mineral constituents is necessary to decide. You will notice that the amount of nitrogen as nitrates is very high. Now, taking the analysis as it stands, the water must be condemned for drinking purposes. Also, not only does the chemical analysis condemn the water, but Professor Woodhead condemns it from a bacterial analysis.

The water **B** is also from a village pump in the South of England. You will notice again the large amounts of the two ammonias and of the chlorine, and also the suspicious amount of oxygen absorbed. I have very little doubt that this well water is contaminated either by sewage or by surface drainage. Bacteriologically Professor Woodhead confirms the judgment that this is a water which must be condemned. These analyses are two of four waters of four different village pumps, all of which were condemned. I have no doubt that the number can be multiplied by a thousand, or even by ten thousand, where people are regularly drinking water bad for their health. All over England people are regularly drinking such foul waters; and the wonder is that epidemics are not more frequent. I do not say the people would suffer from typhoid or any other bacterial disease, such diseases would show themselves sooner or later, but I do say that water containing such large quantities of organic matter tends to lower the system in such a way that it would never be normally strong, and also be a cause of a tendency to infection. As a fact, several people had suffered from diarrhoea caused by drinking these waters. These two instances illustrate Prof. Woodhead's argument with regard to co-operation: that if you want a hygienically pure water, the best plan would be to have some central organisation which can supply a large area. You will then get a constant supply. You could take the proper steps to see that the supply is always chemically and bacterially pure; and you can much more easily trace the advent of any dangerous appearances in the water, and so lessen the chances of the spread of infection, and you would also raise the general standard of health. I think that the supply of good sound water should be as much the care of a central authority as is the supply of a good education. It is to be hoped that steps will be taken by some such bodies as the County Councils to realise this supply.

My own particular part of the discussion is to illustrate the limitations in the reading of reports of water analyses. With regard to the two waters, **A** and **B**, there is no doubt that both would be condemned. But that is not always the case. The reading of a report is not always so easy. Sometimes a medical officer of health has to deal with the analysis

of a water which does not tell so clear a tale. On the other hand (and this is the result of my own experience) a water on analysis sometimes appears to the chemist as exceedingly dangerous. What I mean is this: I have here a water analysis, the figures of which I extracted from an official report—

C.					
Free Ammonia	...	...	...	...	·004
Albuminoid Ammonia	...	...	...	...	·014
Chlorine	...	...	...	...	2·100
Oxygen absorbed in 2 hours at 80° F.	...	...	...	...	0·124
Nitrogen as nitrates	...	...	...	...	0·285
Microbes	...	...	...	...	214 per cc.

In this analysis you will notice that the two ammonias are rather high. A chemist taking the analysis by itself would look upon the water suspiciously. The chlorine figure is not high. On the other hand, the oxygen absorbed, a most important factor in a chemical analysis of water, is very high. Now, taking these three constituents by themselves, and comparing each with the others, a chemist would, I venture to think, condemn the water as suspicious. I certainly should. What is the result of the bacterial analysis? Notwithstanding the three high figures just mentioned the bacterial analysis is low; that is to say the water contains 214 microbes per cubic centimetre, and I believe this figure would be passed by the bacteriologist. The water was supplied to the East End of London when this analysis was completed, and it is a good water. So far as I am aware no typhoid disease nor any particular bacterial disease which might have its origin in bad water was prevalent in the East End as a result of drinking this water. My point is, that if you take the chemical analysis of this water by itself, a chemist would reasonably view it with grave suspicion, even if he might not condemn it.

Now consider the next water analysis—

D.					
Free Ammonia	...	...	...	...	·0016
Albuminoid Ammonia	...	...	...	...	·1260
Chlorine	...	...	...	...	2·0000
Oxygen absorbed in 2 hours at 80° F.	...	...	...	...	·0970
Nitrogen as nitrates	...	...	...	...	·450

This analysis is my own. You will notice that the free ammonia is rather low. It is more or less well within the danger line. The albuminoid ammonia is very high, and by itself a chemist would view it with grave

suspicion. The chlorine is low. The oxygen absorbed is suspiciously high. Nitrogen as nitrates would pass. There would be no danger there. Taking the analysis as it stands then, it might be argued that these figures might be due to vegetable contamination. It might be so. But a chemist would, at any rate, argue that the albuminoid ammonia and the oxygen absorbed are higher than a normally good water should show, and until I knew more of the history of the water I should be inclined to condemn it. Now this water was supplied to the city of Westminster at the time of the analysis, and so far as I know was a good water from a hygienic point of view, anyway, no bacterial disease was prevalent at the time. My argument is, that looking at the water from a chemical point of view, and knowing nothing of its origin or its distribution, you would look upon it with a certain amount of suspicion.

Take another water, E—

	E.
Free Ammonia	·0032
Albuminoid Ammonia	·1400
Chlorine	5·2 '00
Oxygen absorbed in 2 hours at 80° F.	·0130
Nitrogen as nitrates	·0200

This is a water which I also analysed. I knew nothing about it; purposely I was told nothing about it; nothing of its origin; nothing of its history. You will notice the free ammonia is fairly low; you will notice the albuminoid ammonia is very high; you will notice also that the chlorine is very high; the oxygen absorbed is not dangerous, in fact, it may be considered to be low when compared with the figure for the albuminoid ammonia. The nitrates are negligible. Now, viewing the analysis from a chemical point of view, and knowing nothing of the history of the water, you would condemn it: primarily, because of the high albuminoid ammonia, and secondly, because of the chlorine. It is true there might be some deliberation in the final judgment, because the oxygen absorbed is rather low, but taking it as a whole the analysis tends to show, I think, that it is a dangerous water. Well now, what is the history of that water? It is a deep-well water coming from the Lower Greensand. The high chlorine figure is probably explained by the origin of the water from the Greensand strata. As you know, the Greensand contains a large amount of chlorine as chlorides; also, the albuminoid ammonia is possibly due to some vegetable contamination. If it were not due to vegetable contamination the chances are that the oxygen absorbed figure would be considerably higher. My point is that looking at the

analysis as it stands you would condemn the water as being suspicious, and you might easily condemn it as dangerous. Previous analyses had been made of this water, and they showed by the two ammonias a considerably greater contamination. The well was put in good order, and the analysis **E** is the result of an analysis completed some weeks later. It showed that the two ammonias were going down as compared with the previous analysis. I venture to think, if the analysis had been repeated, as it ought to have been repeated, some five or six weeks later, that the figures would have been considerably lower. Anyhow, there was no epidemic due to any bacterial diseases.

The principal point I wish to make with regard to these three waters is that, taking the analyses by themselves, you cannot deliver a *final* judgment as to whether any of them is good, bad, or indifferent. If you get similar analyses you will probably look upon the waters with grave suspicion. And so I think that some rules are necessary with regard to the instructions to the chemist, some of the more important of which I now suggest.

1. I hold that the chemist should know the whole history of any water given to him for analysis. As I say, I condemned the water **E** as dangerous. The condemnation was only modified when I knew the complete history of the water. Therefore I say, if you are to have any satisfactory results from the figures of a water analysis, the chemist should know the geological character of the particular district. He should know the general saline constituents of the geological strata, because, if you look at table **A** as an example of what I suggest is possible in solution, you might get considerable amounts of chlorides in the strata which would contaminate, as it were, the particular water. Only a few months ago I examined a deep-well water of which I knew nothing. Chlorine as chlorides amounted to some 25 parts per 100,000. The amount of free ammonia and the amount of albuminoid ammonia were proportionately large. The oxygen absorbed was exceedingly small. For a time there was some difficulty in reconciling the figures of the analysis. Finally it appeared that in this well there was no sewage contamination, and no surface contamination. The cause of the large amount of chlorine as chlorides, and the free and albuminoid ammonias, was due to the fact that the water had dissolved out of the strata a definite amount of ammonium chloride. Now, as chemists know, ammonium chloride is easily disassociated or decomposed, and part of the ammonia comes over as free ammonia. It does not end at that. The ammonia distills very slowly but continuously, and you finally give it up as endless, and proceed with the albuminoid

ammonia distillation. It is then found that the alkaline permanganate turns out a large quantity of ammonia, which is put down as albuminoid ammonia, whereas, as a matter of fact, it is nothing but the residuum of the original ammonium chloride. Therefore, I say, a chemist should know the geological history of the water he is to analyse. He should know where it has come from.

2. He should know the method of storage; he should know how it is stored.

3. He should know the method of distributing the water, because, as you know, there are serious sources of danger arising from imperfect storage.

4. He should also know the rainfall just before the analysis is made. If you get a heavy rainfall just before an analysis you generally find that the amounts of the constituents differ very considerably from an analysis completed before the rainfall.

5. The chemist should visit the place himself. He should see the outlet; he should examine the surface drainage; he should see the cover of the wells. He should see if the gathering ground is properly guarded, and if it comes up to the ideal condition of water supply and protection mentioned by Professor Woodhead. He should see if the well is as properly protected as Professor Woodhead's example. If he does not, depend upon it there will be some doubt in his judgment of the analysis.

6. Also, I do not hold that a chemical analysis is sufficient by itself. I think a bacterial analysis should always be completed as well. Nor should the final judgment rest with the chemist. The final judgment should rest with the chemist and bacteriologist in collaboration. A bacterial examination should be done, because, as you know, you may have a water which, from a chemical point of view, is organically pure, but it may still contain germs of disease. On the other hand, you may have a water bacterially pure, but which may, from a chemical point of view, be suspicious, or even dangerous. I do not say either will often occur.

7. Also both chemical and bacterial analyses should be done regularly and frequently, as is done in London.

There is just one word I would like to say with regard to the hardness or rather the softness of water. This is a danger which I think has been rather neglected. The more dramatic action of bacteria has, in these later years, tended unconsciously to put into the background dangers which may arise from the use of soft waters. Take for example this particular water:—

	F.
Free Ammonia	·002
Albuminoid Ammonia	·066
Chlorine	1·600
Oxygen absorbed in 3 hours at 80° F. ...	·003
Nitrogen as nitrates... ..	·160
Hardness—all permanent	6·000

The free ammonia is low. If you compare the albuminoid ammonia with the oxygen absorbed, it is possibly due to vegetable contamination, as is indicated by the low figure for the oxygen absorbed. The chlorine figure is exceedingly low. The danger arises, not from the organic constituents, but from the softness of the water. Its hardness or softness is determined by the low figure of 6. It is a dangerous water. In such a water, in continual use and distributed through lead pipes, the danger is that the water might dissolve a certain amount of lead. A striking example of this particular danger occurred in my own experience. A water was sent home from a Dartmoor district, and what was the result of the analysis? As regards the organic constituents the analysis showed that it was a very pure water. It was almost wholly free from the two ammonias. The chlorine was about 1, and the oxygen absorbed was very small. I found on further investigation that it contained half a grain per gallon of lead, dissolved by the water from the lead pipes. Now this district had not suffered from lead poisoning as far as I know; but it had suffered, and may be suffering now, from a species of gout. I do not know if gout is a result of lead-contaminated water, but the fact remains (it may have been a coincidence) that in this particular district some forms of gout were strongly prevalent. I am inclined to think that the gout was due to the large quantities of lead contained in this exceedingly pure water.

Therefore, apart from the general principles which we have been discussing with regard to organic pollution, I say that not only must the organic pollution be taken into consideration, but also the hardness or softness of the water. If a water analysis shows that although the organic constituents may be exceedingly low, the hardness is also exceedingly low, then I think it is as much the duty of the Medical Officer of Health to point to the dangers which might arise from lead poisoning, as it is to lay stress upon any possible dangers from the organic constituents.

PROFESSOR MCKENNY HUGHES (Cambridge) thought that in such questions as water supply, the advantages of co-operation between those who followed different branches of scientific inquiry must be obvious to those who had listened to the two papers just read, and he was entirely in accord with Professor Sims Woodhead and Mr. Purvis that there should be co-operation also with regard to the practical carrying out of schemes for the supply of water. The population shifted about from areas where water was abundant to areas where it was scarce, and the question of the supply of water should not be left to the discretion of ignorant people or the liberality of corporate bodies. They already recognised control in details of municipal life. No one was allowed to erect a building in Cambridge in such a way as to interfere with the traffic or public convenience generally. Everyone had to submit plans to the Town Council specifying what he proposed to do. That was not left to the public spirit of companies or of individuals. There would be no greater hardship in having to submit every scheme for wells or drainage in town or country to a properly constituted authority. When a man sunk a cesspool his object was to get rid of liquid, and so he went down till he found a stratum so pervious that it would absorb and carry it all away. Another man close by wanted water for domestic purposes and, knowing nothing of the cesspool, sunk a well down to the very same porous stratum and drew polluted water. The methods adopted for the purpose of preventing surface contamination at Maidstone would not do for the neighbourhood of Cambridge. Of course, when mischief had been done, and could be proved, there were authorities who might be appealed to and who could take action, but more than that was wanted. They wanted prevention, not cure only. No well or cesspool should be sunk without being duly registered, as underground workings were, in a mining record office, for the guidance and protection of later explorers. He would, however, go further than that, having regard to the larger centres of population as well as to rural districts, to which it more obviously applied. He thought that there ought to be a competent body to control the water supply of the whole country. It ought not to be left as now to be scrambled for. They might not be able to formulate exactly what the constitution and powers of that body should be, or the nature of the control exercised, but there should be some central authority for drawing up a general scheme for the distribution of water to the great centres of population, and to every homestead. Large water schemes were brought before Parliament and, if there were no objections to the character of the water and the financial proposals, they generally got through, but there was no office or minister whose duty it was to control the distribution of this, the most essential material of our individual and common life. Thus we had valleys in Wales dammed up, and lakes in the north of England raised, without any general scheme being worked out by which it might be possible to allocate the sources of supply in a less extravagant manner, to feed the smaller towns and rural

districts on the way, to provide everyone with water, the chief necessary of life, and to save thousands (especially of the poor) from being poisoned. The evil was very insidious; a mild attack arising out of neglect of precautions might be handed on in a more virulent form, and even where no fatal or serious consequences followed, there was often a general lowering of vital energy which might lead to dangerous results. Nature, however, was very kind and removed many a source of danger to which they had laid themselves open. For instance, a quarter-mile of tumbling water would, he believed, oxidize the sewage of a town as large as Cambridge, but the gently-flowing Cam could not do that for them so rapidly. Then their porous strata provided an excellent filter, placed by Nature in the path of percolating waters; and even when they had got some of the evil microbes into them, they often did no harm, as they did not find a suitable soil. But they should not presume upon that frequent immunity.

MR. HERBERT GEORGE FORDHAM (Chairman, Cambridgeshire County Council) referred to the tables exhibited by Mr. Purvis, and asked for some explanation of "oxygen absorbed" as a factor in analysis of water for organic ingredients, assuming that the absorption was not mechanical but purely chemical, and was adopted as a measure of the amount of organic impurity neutralized by the absorbed oxygen, based on some quantitative standard. Speaking on the position of County Councils as controlling authorities in matters of public health, he pointed out that, though their powers under the Local Government Act, 1888, are extremely limited, under the Act of 1894 they can, in the event of a proper complaint being lodged with them, and its allegations being sustained on a public inquiry, deal in a very drastic and complete manner with any district council which fails to discharge its duties under the Public Health Acts. No complaint in this matter had, however, come before the County Council of Cambridgeshire at any time. He pointed out also that a County Council having to act upon such a complaint in a judicial spirit, and to establish the facts of the case as between the parties, cannot with propriety initiate any such proceedings, and that thus, for want of a complaint, cases of default of minor local authorities may not receive adequate attention. In matters of general sanitation he mentioned the important powers of County Councils for the promotion of a general system of isolation hospitals, which can be made effective by a well-arranged plan of contributions in aid of buildings and equipments from the general county fund, and emphasised the practical value from the point of view of sanitation and Public Health of the Midwives Act, 1902, as administered by the Central Midwives Board (upon which body he is the representative of the County Councils Association), and by County Councils as the local supervising authorities. He dealt finally with the administrative difficulty arising from the non-natural character of the county area as a water-control district in reference to watersheds and hydro-geological basins, and expressed the view that administrative efficiency could only be completely secured by the creation of natural

areas, combining watershed boundaries as closely as practicable with those of unit areas of underground water supply.

MR. JOSEPH MARTIN (Chairman, Isle of Ely County Council) said he must take exception to the suggestion that, when a sample of water was sent for analysis, the nature of the soil and other surroundings should be given, as he considered that such information might more or less influence the analyst in making his report of the purity of the water. Doubtless the water supply to villages and small towns was one of the difficult questions of the day, especially in the Fen district in which he resided, as the expense in procuring water from the Chalk or Greensand was prohibitory. The rivers were the natural supplies of water, and he considered that power should be given to some authority to enforce the Rivers Pollution Act (1875) without having to obtain an injunction, which was always expensive and slow in progress.

DR. LEONARD P. KINNICUTT (Worcester Polytechnic Institute, Worcester, Mass.), said he had listened with great interest to the two papers, and had enjoyed greatly the privilege of meeting so many men well known in the United States for their work in sanitary science. In America they looked up to the work that had been and was being done in England, and studied most carefully the results of their work on sanitary problems. The danger from pollution of rural water supplies was most admirably described by Professor Woodhead, and what had been done in the neighbourhood of Cambridge to diminish that danger was a lesson showing what could be accomplished by local authorities. Would that the suggestion of Professor Woodhead as to central control of the water supply of the rural districts might, as it should, bear fruit. Typhoid fever, the most serious and the principal danger from the use of polluted water, was, he thought, not nearly so much an urban as a rural disease; the death-rate per hundred thousand of the living population was much greater in rural districts than in cities, and the cause of this was without question that water used for drinking purposes in the country was much more likely to be polluted than it was in the city. The character of a water supply of a city was known, and, if polluted, precautions could be taken regarding its use. In the rural districts (especially in the United States, where each householder was, as a rule, supplied with water from a well on his own land) the danger from pollution was very great. A well was dug without any regard to location, and in many cases one of the sources of supply of the water in the well was a cesspool sunk in the near neighbourhood. How this could be prevented was difficult to say. The authorities could certainly close the well if they knew it was polluted, but this knowledge was generally only obtained after a case of typhoid fever had caused an analysis of the water to be made. Much could be done in the United States if the Boards of Health had the authority to appoint inspectors, whom the householder would have to consult before sinking a well upon his land. Further, if

when a well was dug the plan mentioned by Thresh in his book on water supplies were more often followed (i.e., of filling the well to the height of high water with gravel stone, and from this point to the top of the well with sand, and sinking the iron pipe to the bottom of the gravel) danger of pollution of the water would be greatly diminished. Naturally following, came the question which had been so ably dealt with by Mr. Purvis in his paper, "The Interpretation of a Water Analysis." Dr. Kinnicutt agreed with Mr. Purvis when he said that whenever it was possible a survey should be made of the river, pond, lake, or well from which the water was derived; for very much depended on natural conditions surrounding the water supply as to the significance which should be placed on the data obtained in the analysis. Personally, he placed most dependence on the free and albuminoid ammonia, and the nitrogen as nitrites and nitrates; and not as much stress on the oxygen consumed. High free ammonia in ground water, without resulting from some explainable cause, was a danger signal, as was also albuminoid ammonia. In surface waters which had a high colour, high albuminoid ammonia was not so significant, as it might be due only to vegetable matter derived from peaty or swampy soil. Nitrogen as nitrites should certainly not be over .0002 parts in 100,000 parts in unpolluted ground water; while high nitrogen as nitrates indicated that the water at some previous time contained unoxidised nitrogenous matter. Where the normal chlorine of the water in the region was known, as was the case in all parts of Massachusetts, the chlorine figure gave valuable information. The oxygen consumed he did not regard as so valuable a factor, as it only indicated oxidisable matter and gave no information as to whether it was of animal or vegetable origin; further, none of the methods in use for determining the amount of oxygen consumed gave the total amount, the amount found depending entirely upon the method used. A bacterial examination should be included in all sanitary analyses of water, the quantitative determination and the test for bacilli coli. He did not quite agree with Mr. Purvis as to what he said about soft water. For general household use soft water was to be preferred. There was no question as regards the action of soft water on lead, but lead pipes should never be used in wells, and a special iron pipe should be used for conducting the water inside the house for drinking and cooking purposes in the case of city supplies.

DR. W. ARMISTEAD (Stapleford) said that, as medical officer of health for a large area in the administrative counties of Essex, West Suffolk, and Cambridge, he had for more than 30 years been brought intimately in contact with the many difficulties which arise in connection with the water supply problem in rural districts. The real deterrent in connection with the adoption of a water scheme for a village was the cost, and when the village was situated on the high boulder clay area at an elevation of over 300 ft. above ordnance datum the difficulties were considerable; but they could be overcome, and had been overcome, by some of

the Rural District Councils, by boring 250 or even 350 feet through the Boulder Clay into the Chalk and lining the bore-tube with steel tubes, from which the water was pumped by a borehole pump into a reservoir on high ground and distributed in pipes to standpipes in the village; the power used for pumping being either an oil engine or a windmill. These schemes were, however, very costly for villages with a small population and a small rateable value. Some villages which were formerly supplied by shallow dug wells, liable to surface and sewage pollution, were now supplied by wells bored 100 feet or more into the Chalk and lined with iron tubes, the water where it rises to within 20 feet of the surface being raised by hand-pumps bolted on to the iron bore-tubes, so that there was no possibility of pollution. Some of these villages, which were formerly very liable to outbreaks of typhoid fever caused by pollution of the water supply, were now free from that disease. Other villages on the Gault had been supplied by wells bored through the Gault into the Lower Greensand, from which a good supply of soft water had been obtained. It was at first proposed to bring before the meeting the distribution of water in county areas. With respect to the administrative county of Cambridge, all the area to the south and east of the county could be supplied from the Chalk, the only questions requiring serious consideration being the best scheme for obtaining the water and the cost. He called attention to the fact that a few years ago two schemes were brought before Parliament for obtaining a large supply of water for South Essex from the Chalk in the watershed of the Cam. Fortunately both these schemes were successfully opposed, but similar schemes might again be brought forward if nothing was done to utilize this excellent source of water supply for the county, including that part of Essex which is in the watershed of the Cam.

MR. J. L. LUBDINGTON, J.P. (Vice-Chairman, Ely Rural District Council) drew attention to a point connected with water supply which had not been touched upon, viz., the difficulties caused by the pollution of rivers. He lived in the midst of the fen country, where it was impossible to get water by sinking wells, and where the supply from any efficient springs would be from ten to twelve miles distant. A wide good river passed through the district, and seemed to form the natural supply. That, however, was polluted by a city about five miles higher up the stream, which poured its sewage in a crude state, and without any pretence of treatment, into the river. A strong representation was made to the County Council to put into operation the provisions of the Rivers Pollution Act, but this was refused, on the ground that the whole county would have to pay the expenses of it whilst only one village would benefit. Then an application was made to the Local Government Board to do it, but they refused to act, and the only course then was for the District Council to apply for an injunction, and this was thought too costly for them. The supply of water was of national importance, and that being so he considered that inspectors should be appointed

to see that matters like this were carried out and to help the local authorities. His experience was that everyone was very ready to criticise. What was wanted was not merely criticism, but real help and advice. This seemed to him to be a matter most closely connected with water supply in rural districts, and he was glad to have had a chance of bringing it before the attention of the members at that meeting.

DR. BUSHELL ANNINGSON (Cambridge) agreed with Professor Woodhead that the establishment of water boards would probably be needful to carry into effect his object of conveying water from an area of abundant supply to one of waterless geological strata. There were many clauses in the Public Health Acts imposing on owners of houses and local authorities the duty of providing a sufficient quantity of pure water; but not one of them quite met the object indicated in the paper; the only legal power for provision of water outside a district was contained in section 61, Public Health Act, 1875: "Any local authority for the time being supplying water within their own district may with the sanction of the Local Government Board supply water to the local authority of any adjoining district on such terms as may be agreed between such authorities or as in case of dispute may be settled by arbitration in manner provided by this Act"; and in section 63, which gave power to any water company to contract for the supply of water with any local authority.

MR. C. G. MOOR (London) said it was interesting to hear that a London company had refused milk from a Cambridgeshire farm on the ground of a bad water supply, and mentioned that at Oxford the local people, being unable to sell milk from a certain farm, sent it to London. He feared that all London milk-buyers were not so punctilious as the one referred to by Dr. Sims Woodhead. It had been stated by Mr. Purvis that organic matter in water was a cause of ill-health. This was the kind of statement that might be copied from one text-book to another, but he was not aware that any real evidence existed for it. In the case of two waters referred to, it was mentioned that they were condemned alike by independent chemical and bacteriological examination, and he did not doubt but that this would frequently occur. He had several times expressed a desire to see a tabulated statement of results on, say, a thousand samples, giving the bacteriological and chemical results, together with a description of the surroundings of the source of supply, and a record as to whether the water in question had before or since produced ill effects on health. He desired to draw attention to the limitations of both bacteriological and chemical analyses, inasmuch that while both of these methods could point out danger, they could not logically be used as a guarantee of safety. Some persons having had a particular well analysed, say a dozen years ago, would not hear of any possible danger in the future, and regarded the certificate of analysis as a kind of magic charm against pollution for all time. As an instance showing the necessity of inspecting the

source of a river supply, Mr. Moor mentioned the case of a city deriving its water supply from a river which received a large quantity of sewage from a town some twenty miles away. The water was of excellent quality so far as chemical and bacteriological examination showed, but for all that there were periodical recurrences of small groups of typhoid cases, which appeared to coincide with the scraping of the filter-beds. This was probably the case in many towns which derived their water supply from rivers, as there could hardly be a river in the whole country that was not used as a sewage outfall by some of the towns or villages on its banks.

DR. SAVAGE (Colchester) remarked that the subject could be dealt with from two points of view, that of the analyst and that of the administrator. As one who had frequently to look at the matter from both standpoints, he felt he could better appreciate the difficulties of both, for although Colchester was an urban district, yet the area was very large, and comprised a considerable purely rural population. Speaking first from the administrative aspect, there was no doubt that in rural districts the question of a satisfactory water supply was often a difficult one. As a bacteriologist he had, not unfrequently, to condemn a rural water supply, and that might be a simple matter; but the difficulty was that after the water supply had been stopped, there was in many cases no other source obtainable, and the last state was worse than the first. He believed that one way out of the difficulty was in regard to better construction of shallow wells. Shallow well water is usually looked upon with suspicion, frequently with justifiable suspicion, but often it was the only source available. If, however, many of these wells were properly made, they could be used to give satisfactory and drinkable water. For example, about a year ago he condemned the water from a shallow well, which was thoroughly bad. That was an easy matter, but the difficulty was how to supply the two cottages concerned with pure water since no other source of supply was available, and to sink a deep well was out of the question. The drainage was badly laid and defective: that was relaid and made satisfactory, the well was deepened and made impervious to a depth of fifteen feet, with also a good backing of clay, while it was properly covered in and fitted with a pump. The water is now a satisfactory one. He was very glad to notice that such an authority as Dr. Thresh advocated the use of properly made surface wells in suitable cases. Among the administrative difficulties may be mentioned the peculiar wording of section 70 of the Public Health Act, 1875, which requires a water to be so polluted as to be injurious to health before the well, etc., can be closed. A water may be sewage polluted, but it is not so easy to advance evidence that that water is injurious to health, or to prove that the two terms are identical. Dealing with analytical questions, he could fully endorse Mr. Purvis's remarks as to the need of data giving the source, etc., of the water before the interpretation of the analytical results could yield their greatest value. The old bad notions were dying hard, and during the

past few years he had frequently had waters sent him for analysis about which he was refused any information, and was indeed looked upon with suspicion because he asked for it. For an important matter such as ascertaining whether a water was fit to drink or not, there was no doubt that the more information given the better, and results must always be interpreted in the light of topographical information. In regard to the methods of analysis, as he had frequently pointed out, he was convinced of the great superiority of bacteriological over chemical methods. The examinations made of the Bridgend water supply served as a good illustration of the relative value of these methods of investigation. The water supply was from springs issuing from the Carboniferous Limestone, and topographically, until condemned bacteriologically, no fault was found with it. In 1901 he condemned it on the results of its bacteriological examination, while the chemical analysis, made with similar samples in the same laboratory, showed no evidence of pollution. Right up to October, 1902, frequent examinations yielded the same results, the bacteriological data furnishing marked evidence of pollution, which the chemical analysis failed to show. Subsequently a Local Government Board Inquiry was held, and Dr. Klein's bacteriological examinations quite confirmed his results, while Dr. Bulstrode traced the contamination. What he liked to do in investigating a water supply was to go and personally examine the sources of the water and to collect his own samples for bacteriological examination, making also chemical examination if required, while of course for poisonous metals and hardness, chemistry alone was available. In regard to the vexed question of standards, chemical or bacteriological, there was no doubt that they were never absolute and only helps, useful if not pushed too far. It was impossible to set up absolute standards applicable to all waters.

MR. WEST KNIGHTS (County Analyst, Cambridge) entirely agreed with the previous speaker who said that it was impossible to fix any standard by which waters from all sources could be condemned: a feature that would be satisfactory in one water might absolutely condemn another. He was struck by the simplicity and apparent efficiency of the means adopted at Maidstone to preserve the various springs from pollution; and if the same could be applied to improving the purity of waters obtained from surface wells in isolated rural districts, he thought it would be extremely valuable in many of the villages around Cambridge. With regard to the interpretation of the results of analysis, apart from any outside information, it depended upon whether the analyst was required to pronounce judgment on the sample of water actually before him, or to predict whether a certain well would be capable in the future, next week, next month, next year, continuously to supply pure and wholesome water. He thought there was considerable difficulty in getting those particulars. Some years ago, the medical officer of health of a large borough, of which he was the water examiner, urged his town council to pass a resolution that those particulars should be supplied by the inspector with each sample. That resolution

was not carried: it seemed to suggest to the minds of the council that if the analyst could not condemn the water on the results of his chemical analysis, he was to be induced to do so on the outside evidence supplied by the person who took the sample, possibly a prejudiced person.

MISS C. COCHRANE (St. Neots) said that the carrying out of all satisfactory work must depend on individuals, and every individual there probably had some influence in his own village; and if so, should use that influence, in his own village if he had the courage, or in a neighbouring village. Much might be done at trifling expense, such as raising the tops of wells and putting a sound cover, replacing a worn-out filter bed, cleaning a drinking-pond, railing round one used by cattle, and also storing a larger amount of rain-water. It would, at all events, be something until the excellent suggestions of Professor Woodhead were carried out. Water supplies should be administered by County Councils or a still wider authority.

PROFESSOR WOODHEAD (Cambridge) said he was delighted that there had been such an interesting discussion on his somewhat disjointed opening remarks. Without attempting to answer the whole of the questions raised by individual speakers, he would try to clear up one or two points concerning which he had evidently not made himself clear, and to supplement what he had already said on two points. It was perhaps scarcely advisable to enter into the question of standards of bacterial and chemical purity, but he thought they were now fairly entitled to state that that was not now determined by the number of micro-organisms or the amount of organic matter that was met with in any single sample of water. They relied far more upon a "constant" condition, and if a water did not vary from time to time, and if by long experience he knew where the organic matter came from, and that the micro-organisms were all water organisms, he felt far more satisfied than he should with a very much better sample of which he had seen only a single analysis. Bad results always indicated a bad water, but good results obtained on one or two occasions only did not necessarily indicate that we had to deal with a good water. The number of organisms, say 100 per cc., may mean much, but it may mean very little, unless it be read in connection with the number of species, the kind of micro-organisms, their source, surface pollutions, sewage pollution, and so on. In all cases the constancy as to numbers of the forms of the micro-organisms, and of the total number and the constancy of the chemical composition, gave the most valuable information. He agreed with one of the speakers, who stated that it was necessary to combine the information that could be obtained from various sources, but a sharp line of distinction must be drawn between a request for a mere analysis and a demand for a reasoned opinion. It was for that reason that he was anxious that they should have a Central Water Board, consisting, say, of a chemist, a geologist, a bacteriologist, and a legal expert as a nucleus, with a

series of "local" members appointed by county authorities. They had been told that human nature being what it was, they would find it difficult to put into force the regulations drawn up by any central organisation. What he desired to see was a central organisation which had feelers thrown out in all directions, and he had a kind of latent hope that under such conditions official nature might to some extent counteract the baser side of human nature. It was his experience of the small powers possessed by County Councils that led him to desire that these powers should be increased either directly or indirectly, and as water-collecting areas were seldom the same as county areas, and as therefore there was necessarily great overlapping, he would like to have a central authority which could act with and control the county committees. The central authority would have before them all the information that could be obtained; they would be able to co-ordinate such information and to mete out justice, especially with the aid of those on the spot, who were acquainted with the exact requirements of the various districts. A minister of hydrology, as chairman of such a Board, would not have an easy time of it, but he would be able to accomplish work of immense value to the community. From the remarks of several speakers he thought that he could not have made himself quite clear on one point. They seemed to think that he wished to minimise the value of their surface supplies. His object, on the other hand, was to draw attention to the fact that in the fen district, for example, the rivers must necessarily be the main sources of supply, and it was for that reason that he desired to see these rivers protected from pollution. Moreover, he considered that surface wells might be utilised to a much greater extent than they were. He brought forward the evidence adduced by the late Dr. Vivian Poore on that point. It was for that reason, too, that he spoke of those surface filters and of pure-water tanks, which, of course, might take the form of steel-tubed wells, though his idea was that deep wells might involve unnecessary pumping. Where, however, the question of space cropped up, these deep wells might be utilised with great advantage. There could be little doubt that typhoid, as one speaker remarked, was a rural disease. It became epidemic in larger communities only after it had been nurtured and had broken out in rural districts. They had done much to combat its ravages in towns, and something had been done in rural districts, but much still remained to be done. If this question of rural water supply could be thoroughly ventilated it was one, he believed, that would ultimately give a valuable return. England was a small country with a rapidly growing population, and unless the sewage could be prevented from getting into the water supplies, there would soon come a point at which they would have to set to work to undo what they might, with an expenditure of much less money and energy, prevent.

MR. J. E. PURVIS (Cambridge), in reply, said that there were some questions raised in the discussion which he thought should be more fully discussed. One was with regard to the statement by Mr. Moor as to the organic

matter in water and its effect in lowering the state of health. He seemed to doubt that statement because he said it was stated in text-books. He (Mr. Purvis) suggested that statements in text-books were often true, and it did not follow that because the statement was in text-books it must be viewed with suspicion. The point to be remembered was that it was not only a statement in text-books, but it was a statement based on the authority of medical men. He would point out that although people did not drink the large volume of water suggested by Mr. Moor, it was the *continual* use of the water which caused the danger. And where they had an analysis showing dangerous contamination by organic matter and chlorides, the matter became particularly serious when the water was used by infants and invalids. If they supplied infants and invalids with such water they were giving them a very dangerous and polluted water, whatever the bacterial examination might show. And then with regard to standards, if they had tables which represented a thousand analyses, as suggested by Mr. Moor, somebody would want a table which represented two thousand analyses, and so on. Besides, it would be almost a physical impossibility to compare an analysis with a thousand analyses; it would take a week to do it. They were living in a work-a-day world, and they had to put up with compromises. They must take a single analysis and judge it on its own merits: what it was and what it might be, and also compare it bacterially. There was another point brought out by Dr. Kinnicutt, of Massachusetts, whom he was extremely glad to have heard. The publications issued by the Massachusetts Board of Health were not only ideals, but they also gave us methods. They taught many important methods; and the method implied the ideal. If in England use could be made of some of these methods and equally satisfactory results be obtained, the people would be considerably better off as regarded their public health. The particular point he (Dr. Kinnicutt) mentioned was with regard to the oxygen-absorbed test. That was also the point that the Chairman of the Cambridge County Council wished to be cleared up. Also Mr. Moor said that oxygen absorbed did not affect the lower forms of life. It was not suggested that it did. The oxygen-absorbed test scarcely applied to these lower forms. In the first place it was usually applied to nitrites and to ferrous iron primarily. Then it represented the amount of oxygen which was taken from the potassium permanganate and used to oxidise organic matter in solution to water and carbon dioxide; and the measure of it distinguished if the organic matter was in a stable or an unstable condition. Then again, with regard to Dr. Kinnicutt's question as to the Massachusetts Board of Health not laying so much stress upon it. He (Mr. Purvis) was very interested in that statement, because he had always taken the opposite view. He had always considered that the oxygen absorbed was a most important figure, and for the reason that it dealt with three points: first with nitrites, secondly with ferrous iron, and thirdly with the dissolved organic matter. As regarded the dissolved organic matter, if they had a high figure for that experiment, in two or three hours

at 80° F., what it usually meant to the chemist was that the organic matter (say such highly complex bodies as organic nitrogenous compounds) was in an unstable state, and that it was breaking down; whereas if they got a low figure, it meant they were dealing with organic matter which was more or less stable, and it might be of purely vegetable origin. That was the reason why they laid such stress upon the quantity of oxygen absorbed. Then with regard to a point brought forward by Mr. West Knights, and also by Mr. Martin, that it was not necessary for the analyst to know anything about the history of any water sent for analysis. He would go with them thus far: that if the instructions to the analyst were that he should simply state his results with no report, or at any rate with only a provisional judgment, he would agree; but if he had to give a judgment, and that judgment was to be of far-reaching importance, then he said the analyst should know the origin and the history of the particular water. He was very pleased to hear that Dr. Kinnicutt laid great stress upon the instructions for collecting samples of water: it was most important. He would give one example of carelessness in collecting water: he had a sample once sent to him for analysis contained in a bottle which had previously contained eau de Cologne!