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ON THE PRESENT AND FUTURE OF SANITARY WATER ANALYSIS.

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The investigation by Professor Mallet, for the National Board of Health, marks an important period in the history of water analysis. This work was carried out in 1881; but the full report has only recently been published, and its appearance, showing definitely what value attaches to present methods, suggests an inquiry as to the future.

But to appreciate the present and forecast the future, a brief notice of the past is needful. Usually in historical inquiries into questions akin to medicine, we drop back to Hippocrates; but in this instance the dark ages lasted until most of the members of this association had seen the light. Water, it is true, was analyzed before this recent time, but the analysis dealt and continued to deal with the saline matters, until sanitary inquirers discovered that injurious effects are seldom due to these when existing in the quantities usually present in ordinary potable water. They came, therefore, to look upon the formal inorganic analysis of the chemist, tabulated in grains per gallon, as a parade of accurate chemical work which had little bearing on the practical question of wholesomeness. They concluded that the knowledge they desired lay hidden in the intangible organic matter dissolved in the water, and they instituted experiments on it. Their methods were crude, and their results lacked precision, as this obscure organic matter refused to be precipitated and brought to the balance for a rule-of-three calculation to determine its quantity. What the sanitarians wanted was what many people want at the present time,—a something which, when dropped into a specimen of the water, would give information as to unwholesomeness by some striking reaction, such as a change of color, or the formation of a characteristic precipitate. But the scientific chemist knew, from the constitution of the organic matter, that the realization of this desire was as impossible as the discovery of the philosopher's stone or of the elixir of life, the pursuit of which absorbed so much of the energies of the alchemists, and discovered so much that is valuable to the human race.

The sanitary analysis of water may be said to date from the time when Forchammer, of Copenhagen, proposed the decolorization of permanganate of potash solution as a test for its organic matter. For a long time the status of this reaction was that of a curious laboratory experiment, as
the action of permanganate on organic matter, when present in the minute quantities usually found in water supplies, was too slow and ill-defined to admit of any practical advantage from its employment.

In the meantime, the recognition of the importance of the organic matter led, in the absence of a generic quantitative test, to a chemical attack upon it by the method of ultimate or elementary analysis. As organic matter consists mainly of carbon, nitrogen, hydrogen, and oxygen, it was believed that if an accurate determination of the carbon and nitrogen could be effected, an expression might be given to the relative amounts of organic matter in different water supplies, although the absolute weight of the organic substance would remain unknown. From this was finally developed the combustion process of Frankland and Armstrong, in which the residue of the water procured by a carefully conducted evaporation is burned in vacuo with copper oxide, and from the volume of the evolved gases the quantities of carbon and nitrogen in the organic matter are calculated. If the organic matter of water did not vary in its constitution, and were its unwholesomeness proportioned to its quantity, this would have been an excellent method of sanitary analysis. But it was readily appreciated that the organic matter collected by water is a mixture of many substances, some of which may have much carbon and little nitrogen, and others less carbon and relatively more of the nitrogen; and that while some of these substances are harmless, others may be deleterious. Animal matters, for instance, were credited with being more harmful, weight for weight, than matters of vegetable origin. But as the ratio of carbon to nitrogen is greater in the latter than in the former, the process of Frankland and Armstrong was found to be capable of indicating, in some instances, from which of the kingdoms of nature the organic matter was derived, and in so far of suggesting the possibility of harmful qualities.

But, in view of the preponderance of nitrogen in the more deleterious animal matters, and of its presence in all tissues that are vitalized (as contradistinguished from certain organic matters which, like starch and sugar, are simply the products of vital action), other experimenters regarded it alone, when accurately determined, as giving expression to the relative quantities of probably dangerous organic matter to be found in waters. The nitrogen in these organic substances was ascertained to be susceptible, in part at least, of ready transformation into ammonia, which could be estimated with great accuracy. And as the process of Wanklyn and Chapman, which is based on this transformation, required less time, special training, and manipulative tact than Frankland's method, it became extensively used and carefully studied by the sanitary analysts. This process also is capable of itself, and especially in connection with another process to be mentioned directly, of affording as definite evidence concerning the derivation of the substance which furnished the nitrogen as may be obtained by the more scientifically accurate method of combustion. But although, as has been shown by the writer, it is capable of detecting and estimating the urea of undecomposed sewage, it fails, as
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does the combustion process, in the majority of instances to afford any direct testimony as to the character of the organic matter, and hence as to its wholesomeness or unwholesomeness.

Meanwhile, also, the capabilities of the Forchammer test by permanganate were assiduously studied, and methods were found not only of hastening the oxidation of the organic matter accomplished by its means, but of indicating with precision the quantity of permanganate required to effect this oxidation. It was found, however, that while the quantity of oxygen used is susceptible of accurate measurement, the whole of the elements of an organic matter known to be present is not in every case oxidized. Urea, for example, is not even effected by these permanganate processes. Other matters are susceptible of more or less oxidation; so that similar results are not obtained from equal weights of carbon and nitrogen in two or more water samples, unless the organic matters containing these weights are identical in chemical constitution. Waters containing the same kinds of organic matter may be graded in quality by these tests, but not those containing different kinds of organic matter. Nevertheless, in general terms, a water which contains a large quantity of organic matter will destroy a larger amount of permanganate than one which contains a small quantity; and hence the processes have a certain value. Dr. Tidy, whose name has been applied to one of the methods of using the permanganate, claims that animal matter is more rapidly oxidized than vegetable matter; but the experiments performed under Prof. Mallet's direction, to test this point, demonstrated that the animal or vegetable nature of the matter has but little influence on the rapidity of the action. If, however, these oxidations are viewed in connection with the nitrogen results yielded by Wanklyn's process, an opinion may in some instances be formed as to the origin of the matter. Thus, if a large amount of permanganate is destroyed, and a small quantity of nitrogen eliminated as albuminoid ammonia, the organic matter may be considered of vegetable origin with as much certainty as if a large amount of carbon and a small amount of nitrogen had been found by the combustion process, while converse results would indicate, with as much probability, an animal derivation.

It is readily seen that none of the processes mentioned convey more than that the water contains more or less of the elements of organic matter. But their authors have claimed for them the capability of deciding on the quality of the water by establishing limits on the scale of relative impurity within which a water is to be accounted wholesome, and beyond which it is to be considered suspicious or dangerous. In England these limits are accepted as the dicta of the authorities; and they are entitled to consideration as embodying the opinions of men who have had a large experience, biased perhaps by a partiality for or advocacy of a given process. But it is doubtful if any of the analysts of this country, in making use of the processes, have accepted without question the rules laid down for formulating the results into an opinion on the quality of a water. In fact, this doubt as to the value of the opinion based on the analytical
results, developed the investigation so thoroughly carried out by Professor Mallet for the National Board of Health. Proof was required that waters which fell within the limits were wholesome, and that those which exceeded them were more or less harmful. To elicit this, a number of water samples were procured, and submitted to the three methods of analysis by chemists who were in ignorance of the history of the waters on which they operated. Some of these waters were known by long experience to be productive of no harmful effects; others were regarded, on more or less sufficient evidence, as of doubtful or dangerous quality; while others, again, were specially contaminated with various organic substances which are likely to find their way into water-supplies. Of nineteen natural waters which were regarded as wholesome, only five were pronounced good by all the processes, although eight others were returned as good by some, and as fair, medium, or allowable by the others; three were accounted bad by one of the processes, one by two of the processes, and two by all the processes. Of twenty natural waters of doubtful but more or less suspected character, nine were reported good or allowable by all the methods, five bad by one method, three by two methods, and three by all the methods. Of twenty natural waters which there seemed fair ground for believing had actually caused disease on the part of those drinking them, ten were accounted good or allowable by all the processes, six bad by one of the processes, one by two of the processes, and three by all the processes.

In view of this record, Professor Mallet appears fully warranted in concluding that "It is not possible to decide absolutely upon the wholesomeness or unwholesomeness of a drinking-water by the mere use of any of the processes examined for the estimation of organic matter, or its constituents."

These results placed on a basis of experimental proof the opinion held by the analysts of this country, that the processes were valuable only as estimating with more or less accuracy the quantity of the organic elements present in water; but that the wholesomeness of the water, depending on the quality of the matter and not on its quantity, could not be determined by the analytical results. The words good, fair, usable, allowable, doubtful, bad, foul, &c., had at first been used by them not so much with the intention of expressing a positive opinion, as of conveying an appreciation of the results of the analysis to those who were not acquainted with its technicalities. That the sum of the organic elements, the free and albuminoid ammonia, or the oxygen required for the oxidation of organic matter, amounted to so many parts per 100,000 of the water, conveyed no meaning to the uninitiated, and required translation into an expression that could be understood. Good, usable, foul, &c., meant, therefore, merely that the results were similar to those which the analyst had obtained from waters known, on more or less satisfactory grounds, to be wholesome or otherwise. There was thus an apparent acquiescence in the principle of the British limit of wholesomeness, although not an acceptance of the specified limit. But afterwards these
adjectives became in many instances the expression of an actual opinion, though not based entirely upon the analytical results. The quantity of the organic matter, as determined by the chemist, led to inquiries into its derivation, with a view of throwing light on its quality. Many of these inquiries were conducted in the laboratory as a part of the systematic analysis. The quantity and character of the dissolved solids, the chlorides, nitrites, and nitrates, when considered in connection with the various points developed by the albuminoid and permanganate processes, often discovered much of value concerning the probable quality of the organic matter. The tables in Mallet's report, giving the analytical results of the series of one hundred and forty waters examined, contain also the remarks of the analysts on the probable history and character of each water. These are interesting as showing how closely, in most instances, they approached the truth, and as suggesting that, since the analysts had discovered so much concerning the organic matter, an inspection of the source and surroundings of the water-supply would enable them to point out the origin of the contamination. A knowledge of the history of the water sample, taken in connection with the results of the analysis, and with a knowledge of the normal characteristics of waters of similar history, will in all likelihood permit an opinion to be formed concerning the probable derivation and quality of the organic matter. This opinion necessarily modifies that which is based solely on the analytical results; for a water need not be reported as bad if its organic matter, although large in quantity, is manifestly harmless; and, on the other hand, a caution may be necessary concerning the use of a supply, if its organic matter, although trifling in quantity, is of manifestly dangerous origin.

The two natural waters, which were believed from actual use to be of good and wholesome character, yet were condemned as bad by all the analytical methods in Mallet's investigation, were the Cochituate water of Boston and the Mississippi river water of New Orleans. The quantity of organic matter in both exceeded the limits of wholesomeness assigned by the English authorities. But in these cases it would seem that the testimony as to their good and wholesome character may be questioned with as much propriety as the opinion based solely on the analytical results. Sewage in water may or may not be harmless: neither position has been proved. But it has been proved that after sewage has been in the water for some time it ceases to be sewage. Its organic matter becomes transformed into inorganic substances, and the water not only gives satisfactory results on analysis, but is probably wholesome. The organic matter of sewage containing the typhoid poison likewise becomes transformed, but the water, although giving satisfactory results on analysis, may be far from wholesome; for the transformation into ammonia and nitric acid, which takes place in ordinary sewage matters, does not affect the germ of that disease. Well waters, which on more or less satisfactory evidence have been associated with the spread of typhoid fever, have been found free from organic matter on analysis, though showing by the nitrates and nitrites present that they had not always been free from it. The typhoid
germ is therefore believed to be capable of resisting the destroying influences by which ordinary dead organic matter is reduced. River or lake waters which are exposed to sewage contamination must also be considered of doubtful quality, irrespective of the analytical results, until the cases of typhoid fever that occur in the cities supplied by them are traced to other sources than the water-supply. The recent researches of Koch indicate that cholera may be propagated by the diffusion of its microbe in water; and the theory that malarial fevers are due to a micro-organism which may enter the system with the drinking-water, is not without support.

In fact, it is not the dead organic matter in a water which renders it dangerous, but the minute and unknown organisms which are living, and perhaps growing and multiplying in it. There is ample proof that to cause intestinal troubles, the dead or putrescent organic matter, whether vegetable or animal, must be present in quantity easily recognized by the senses. At the same time the evidence is convincing that the organic matter, which should be the special object of sanitary analysis, is not to be detected by any purely chemical process.

It does not follow, however, that the work of the sanitary analyst is without value. So far as our knowledge extends, these micro-organisms are on the one hand connected with vegetable decomposition, and on the other with sewage. The detection of either of these points to a possible danger which in every instance should be avoided. Sanitary inspection is frequently able to indicate this danger; but where it fails to do so, chemical analysis will usually succeed. When an excess of organic matter is detected, and especially when its character is appreciated, a close investigation into the surroundings of the water gives full promise of discovering the source of the pollution. As a case in point: The cistern water at a gentleman's summer residence was suspected of having caused typhoid fever. The cistern was cleaned out and put in what seemed to be perfect condition, but the water, on analysis, was found to contain, with other organic matter, a certain quantity of undecomposed urea. The owner declared this to be simply impossible; but when the cistern was again emptied and subjected to examination, it was found to present three apertures of inflow, while only two conductors connected it with the roof. This discovery led to the remembrance that some years before certain alterations had been made in the building; and the third aperture was supposed to be the mouth of a disused conductor. This was found to be the case: the other end of the pipe was unearthed just below the surface near the porch, where grew some vines that were occasionally nourished with chamber slops.

Chemical methods are therefore of value, though they do not indicate the presence of the particular virulent matters which render drinking-water dangerous. It is impossible for them, in view of the principles on which they are based, to pronounce on the actual presence or absence of danger, but they afford the surest means of determining the possibility of danger. The true position of these chemical methods should be appre-
ciated by sanitary workers, that some of the energies spent upon them may be diverted into channels which promise more definite results. The living organisms should become the subject of persevering study. More than a dozen years ago Burdon Sanderson called attention to the bacterial fecundity of water. He added a few drops of the water under examination to a sterilized and protected nutritive liquid, and suggested that the quality of the water in some respects might be ascertained from the density of the resulting bacterial turbidity, and the rapidity of its development. But although the culture method as applied to water was thus long ago suggested, the idea has not been followed up except in a few of the European laboratories. Under Koch's direction, for instance, tests of the bacterial fecundity of the Berlin water supply are made daily by the culture method. The pursuit of the elements of organic matter has carried the analysts past the real object in view; but it is time that their retorts and combustion tubes should give place, in part at least, to the microscope and culture experiments. These offer the best prospects of a solution of that difficult sanitary problem,—the quality of our water supplies. Ultimately they will probably render the chemical methods unnecessary. By working in this direction the analysts will prepare themselves for the change of methods, while their labors will undoubtedly hasten the arrival of the time when they will be able to give an opinion embodying certainties instead of probabilities—when they will be able to say with truth, that a given sample of water is wholesome or unwholesome, as the case may be.