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If the problem of the measurement of the quality of water were as simple as it was once held in the judicial opinion of the Mississippi jurist Doctor Mason tells about, (1) there would not be the slightest excuse for this paper. It was the opinion of the court that any ordinary mortal could judge for himself whether or not a water was satisfactory for drinking purposes.

This decision was handed down somewhat more than twenty years ago, when it may be supposed that the use of water for the purpose in mind was somewhat more restricted than today. Nevertheless the writer has often wished that he had the ability to form just decisions on the satisfactory or unsatisfactory nature of a water supply with the unerring success which would seem to have attended the efforts of the average citizen living within the jurisdiction of the learned judge. Occasionally the writer has been inclined to think that perhaps the opinion was intended to convey the impression that the proper use of water was limited to such purposes as ablutions, making steam and placing beneath bridges. But, alas, nowadays even those uses involve definite measurements which are apt to be applied to the water employed and opinions regarding suitability must frequently be rendered in specific cases.

Measurements of the quality of water are far from being static. Ideas change as to what is desirable, as to how to find out whether the desiderata have been reached or approached, and as to the relative importance of the individual items which collectively determine the quality of a particular water.

The non-technical public has looked and probably always will look first upon the clarity, color, odor, taste and temperature of a water. Heath officials demand freedom from the possibility of disease production or distribution by a water supply. The industrial user, and to the lesser extent the individual, is interested in the mineral contents — in particular that portion of the mineral content which incrusts boiler tubes or causes a curdy precipitate with soap.

Generally speaking, the safety of a water is today considered first, its attractiveness second and its mineral content third when the quality of a particular supply is being investigated. Yardsticks of measurements for each of these have been set up and the supply is judged more or less successfully, and more or less accurately by each of these. Now and then a water supply varies so much from the normal in its physical condition or its mineral composition that the order of items considered is somewhat changed. Moreover each item is scrutinized to see what the situation of the untreated water is, and what improvement could be expected with a reasonably economical use of existing types of purification equipment. In what I shall have to say I shall, of course, assume that the quantity of water available, which is the first consideration of all, has been found in all cases to be ample.

Attention has already been called to the fact that the measurement of the quality of waters is subject to changeable ideas as to what is wanted in a water, and as to the most satisfactory ways to tell whether the demands have been met.

From remote antiquity people have known that certain waters were dangerous and certain waters apparently safe for use. They have known that water soiled by body refuse was unsafe, and that sometimes the cause of an unsatisfactory condition was due to dissolved minerals. Experience with individual waters was, however, the basis of most of the judgments regarding quality.

To one who is interested in these matters, the many incidental references to quality of water and the fantastic ideas expressed in some old books are worth consideration and are often surprisingly in accord with modern ideas. Pliny, for instance, said that other things being equal, the water which weighed the least in any given volume, and hence was softest, was the most desirable. He also suggested that the best way to purify an unwholesome water was to subject it to the rather heroic treatment of boiling it down one-half. On the other hand, Pliny is authority for the statements that the most refined parts of a water are expelled on freezing and that all bodies of water purify themselves at the time of the new moon. It is claimed that the Romans (2) even had colorimetric methods of measuring the hardness of waters. The principle was based on the coloring power of red wine. Alkaline or hard waters required more wine to produce a reddish color in a given volume of the water than did soft waters.

In an old French book by Fourcroy, translated and published at Edinburgh in 1784, the following characteristics of a satisfactory water are set forth:

"Drinkable waters may be easily known by the following characteristics:

1. They have a brisk, sharp taste.
2. They have no smell.
3. They boil easily.
4. They make ready pot-herbs well.
5. They dissolve soap without forming lumps.
6. They deposit nothing or very little by.tests."

In other words, if the water tastes all right and smells all right, and if it is soft, it is good water.

St. Clair Deville (3) in 1848 and other workers of about his time were much interested in the safety of waters as indicated to them by the amount of silica and calcium carbonate they contained.

The earliest attempts to measure the organic matter ot waters were conducted by igniting the residue obtained by evaporating a known quantity of water to dryness and noting the loss in weight during the ignition. Unfortunately other things than organic matter were also driven off.

After this we find water analysis concerning itself with determining crenic and apocrenic acids, the organic humic acids described by Berzelius. (4) Later came the oxidation of organic material by permanganate devised by Forchammer of Copenhagen (5) about 1849 and since developed into the oxygen consumed determination. Various other methods were elaborated for the estimation of organic matter, including the albuminoid ammonia process of Wanklyn in 1867. (6)

Fantastic theories regarding the solution of poisonous gases from the gases of nearby sewers and the faculty of communication of a "molecular disquietude" by fermenting organic matters appear in the literature. In 1862 came Pasteur's (7) famous paper on spontaneous generation and it was not long until we find the idea of the propagation of disease through microscopic organisms fairly definitely fixed. For instance Franklin and Armstrong had this to say in 1868: (8)

"Excrementitious matters, certainly sometimes, if not always contain the germs or ova of organized beings; and as many of these can doubtless retain their vitality for a long time in water, it follows that they can resist the oxidizing influence which destroy the excrementitious matters associated with them. Hence great previous sewage contamination of water means great risk of the presence of these germs, which on account of their sparseness and minute size, utterly elude the most delicate determinations of chemical analysis."

Such statements regarding the length of life of the pathogenic bacteria in water are today modified by the researches of Jordan (9) and others on the typhoid bacillus. Nevertheless such a statement, made at a time when cultural methods were so poorly developed, is interesting as indicating the alertness of the water analysts of that period to turn new facts to account in interpretations of the facts they observed.

In this connection it may be worth while recalling that although James Simpson, the English water engineer, installed his New Chelsea water filters in 1829 for the purpose of removing turbidity and improving the attractiveness of the river water supplied to the people of that part of London by the New Chelsea Water Company, he had no idea of the additional benefits he was confering. The reputation of his filtered water for increased wholesomeness soon became such, however, that about 1855 the officials of London declared that all river water supplies must also be filtered. It was not until the eighties, when the methods of Koch had become known and it was fairly easy to conduct bacterial counts, that the actual function of Simpson's slow sand filters was known.

About this time Koch set up his standard of 100 bacteria per c.c. for the maximum permissible bacterial count in a water supply. It has been regarded as a useful limit for many years. In fact until the 1922 revision of the requirements of the United States Treasury Department was made official, this numerical value had a legal status, in this country at least.

To Sir John Murray, (10) for his work on the mineral analysis of waters and to Dr. Thomas Clark, (11) for his work on the hardness, alkalinity and softening of water supplies, the water industry is deeply indebted. Here we see the early adoption of the methods of hypothetical combinations in boiler water determinations and the establishment of the grain per gallon unit. Organized opposition to these two practices seems to have been launched during the eighties, but they are still strongly intrenched at the present time in spite of the better scientific basis of the ionic method of stating results and of the part per million as a unit. Already in 1847 we find Clark advancing the statement that we hear today, that the non-technical user finds the older method of reporting results easier of comprehension. The better laboratories have today adopted the practice of reporting results of mineral analysis in the ionic form, and as a concession to the desires of the non-technical water users, accompanying their statement of ionic results by the hypothetical combinations. The more backward organizations continue to give the older hypothetical combinations alone — and usually in an incomplete manner.

Work on the standardization of methods of water examination in English-speaking lands appears to have been attempted by the American Association for the Advancement of Science during the 1880's. The British Association appointed a committee to coöperate with the American committee. Real constructive activity in this country did not begin until about 1897 in the American Public Health Association and the early efforts culminated with the appearance in 1905 of the first edition of the Standard Methods of Examination of Water and Sewage with which we are all familiar. The sixth edition of this book, now published jointly by the American Public Health Association and the American Water Works Association, appeared in 1925. It would be difficult indeed to estimate the services of this publication in unifying the laboratory practices in the United States, or indeed of its international influence in putting analytical practice on a more common footing. While most water laboratories follow procedures of their own to a certin degree even now, the standard methods of the examination of water and sewage have made it possible for results to be compared advantageously in many localities and have gone far toward the establishment of a common yardstick for the measurement of the quality of water.

No line of human endeavor is free from the danger of overemphasis of the novelty. A process is introduced and hailed as the curé all, the inaugurator of a new era which will dispel the difficulties and uncertainties of the procedures which have gone before it. For a time the new process has a great vogue and much more is claimed for it than it can be shown to accomplish. Much paper is devoted to its discussion and the process is generally tried out. Its short-comings are then noted and the method usually ultimately comes to be recognized at about a just valuation. Sometimes, however, from having been fashionable — as in matters of dress — a process becomes unfashionable and disused. After a period of time someone with antiquarian tastes looks up the old references, finds merit in the old process and adapts it to present use. Sometimes the process seems to be independently re-discovered. An example of this sort is our familiar phenol-sulphonic acid for nitrate determination which after having been discovered by Sprengel (12) in 1864 appeared as a new process under the signatures of Grandval & Lajoux (13) in 1885 and is today best known by their names. In like manner the reduction method for nitrates based on a discovery of Kulmann's (14) in 1838, was worked into a method adapted to water examination by Martin (15) in 1854 and is today best known by the name of Schulze whose work appeared in 1861. (16)

The history of the measurement of the quality of water seems thus to fall into about 9 stages:

1. The pre-analytical stage in which experience and reputation of a supply were the chief guides.
2. The period of mineral analyses.
3. The period of the recognition of the importance of organic contaminations.
4. The period of the study of the decomposition of organic matter as measured primarily by the forms of nitrogen.
6. The period when bacterial counts were introduced.
7. The period when the presumptive test for the so-called Bacillus coli communis was the novelty.
8. The period when standardization of method rather than of numerical results was emphasized.
9. The period of emphasis on the sanitary survey.

Perhaps today we should say that we are placing most emphasis on the necessity of frequent examinations, mass data and reliability of operation or continuous protection. However great attention has also been given recently to hydrogen ion concentration, fecal and non-fecal types of the colon group organisms, non-confirming spore-forming, lactose fermenting bacteria, and such plant operation tests as the ortho-tolidine test for free chlorine. Certainly this is a period of water purification. No other age has seen such rapid development and such wide extension of processes for the improvement of the safety of water, or for the betterment of its physical and chemical characteristics.

But safety of waters is a relative thing. The statement in the introduction to the new Standards for Drinking Waters of the U. S. Treasury Department (U. S. Public Health Service) (17) is well worth quoting:

"Safety in water supplies, as they are actually produced, is relative and quantitative, not absolute. Thus to state that a water supply is "safe" does not necessarily signify that absolutely no risk is ever incurred in drinking it. What is usually meant, and all that can be asserted from any evidence at hand, is that the danger, if any, is so small that it cannot be discovered by any available means of observation. Nevertheless, while it is impossible to demonstrate the absolute safety of a water supply, it is well established that the water supplies of many of our large cities are safe in the sense stated above, since the large populations using them continually have, in recent years, suffered only a minimal incidence of typhoid fever and other potentially water-borne infections."

At the present time the matter of the safety of a water as determined by bacterial tests, chiefly the detection of organisms of the colon group and secondarily the estimation of the bacterial count, seems to be reasonably satisfactory. In the opinion of the writer there is an unwise tendency to scrap some of the older chemical methods of examination tending to add testimony of value to the indications of the bacteriological investigation and the sanitary survey. This data is not so useful in the case of treated waters as it is in the case of waters which are used untreated. Untreated waters are apt to be intermittently contaminated and when such indications are shown by a chemical analysis, the water is often properly to be regarded as suspicious even though its bacterial quality may be excellent at the time of sampling.

With a reasonably satisfactory feeling — whether justified or not — regarding the safety of the supply, comes a desire to improve the physical properties if they are not altogether satisfactory. Turbidity, color, odor and taste, especially the two last items, receive much attention and cause many complaints. A great deal of attention is being given to these points.

Improvement of mineral characteristics, for example in an iron containing water, is often imperative. The modern tendency, however, is to soften waters and to improve them when notable improvement can be obtained, even though not absolutely essential. It seems likely that there will be a tremendous extension of this particular sort of work in the next few years.

The man who would attempt to prophesy what will be the requirements for the quality of water supplies twenty years hence — or even five years hence — from the standpoint of the bacterial content, the physical characteristics, or even of the mineral contents, would be indeed venturesome. One thing may be said with reasonable safety, and that is this: the requirements will be more rigid than they are now, and full advantage will have to be taken of all developments in water purification and control in order to meet the demands of the public.

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