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WATER PURIFICATION HYGIENICALLY CONSIDERED.

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A FEW years ago the author, in various articles giving the results of experimental investigations on some of the subjects touched upon in these pages, felt bound to offer considerable evidence to prove that pure water is necessary to health, and that thousands of lives are yearly lost because of impure water.[1] Many epidemics due to a bad water supply have been reported at more or less length in the medical journals and in the daily papers, which reach all classes. Thousands or even hundreds of thousands of deaths from cholera have occurred in Asia, in the Orient, in Egypt, and in Europe. The recent epidemic in Hamburg (1892) is still vividly impressed upon the minds of those who give any thought to the question of water-borne diseases.

Fortunately the broad oceans safeguard us to a large extent against cholera and other Asiatic plagues; but here, as well as elsewhere, typhoid fever, not to speak of various lesser diarrheal disorders which are likewise communicated by impure drinking-waters, yearly causes thousands of deaths and many more cases of disease of varying degrees of severity. Even malaria is regarded by numerous intelligent physicians and other acute observers as presumably a

[1] During the last few years there has been furnished so much statistic and other testimony to this effect that it would require too much space to reproduce it here.

water-borne disease, although the evidence offered does not suffice to prove that contention. Yet typhoid fever alone is a sufficiently grave peril to warrant an immense amount of agitation and the expenditure of many millions of money to prevent its occurrence. It is very well known that when the water-supply of any isolated household or of any community is naturally pure or adequately purified by artificial means, typhoid fever does not occur unless water be casually consumed from an impure source, or unless milk or other food, used in an uncooked condition, have come in contact with infected water, or unless the victims have acquired the disease directly from someone suffering from it. For all industrial and domestic purposes it is desirable that water be as pure as possible. Whether for "feeding" a boiler or quenching thirst, for watering the streets or cleansing a wound, the purest water is the most satisfactory. The enlightened economist and the sanitarian insist upon this, and, even if space permitted, a citation of the volumes of facts and figures available to prove it would not be necessary for those familiar with the rudiments of modern sanitation.

What then is pure water, hygienically speaking? Briefly, it may be said to be clear, palatable, free from bacteria in large numbers, and wholly free from bacteria which can cause disease; it must contain no lead or other poisons, and have only a permissibly small amount of mineral salts. The salts of lime and magnesia, in a supply for general industrial and domestic use, must not be much in excess of 15 parts in 100,000 of water, otherwise it is too hard. The water of the best lakes and rivers may be less than one-half or even one-fourth as "hard" as this. It should be mentioned that the salts present in the water which we drink do not count for much in the total amount needed daily by the human body (nearly two ounces of salts being required), as that amount is abundantly supplied by a mixed diet. The daily amount of water swallowed by a healthy man averages about a gallon. This quantity of good natural water usually does not contain more than ten grains of salts, and a mineral water having one hundred grains of salts to the gallon is altogether too strong for large amounts of it to be tolerated. A slight proportion of lime is hygienically desirable in water-supplies, for it restricts the tendency of the water to act upon metals. A very soft water more readily takes up lead, for instance, from lead pipes in which it is conveyed. A very soft moorland water, especially if acid and well oxygenated, is more apt to cause lead-poisoning to develop than is the case with limy waters.

Clearness, to the uninstructed, seems to be the most important quality of a water, and yet the clearest water, particularly that of wells, often causes typhoid fever, for the causative bacteria of that disease are not detectable by the senses when they have been introduced into a supply. On the other hand, turbidity is not usually due to a dangerous cause, however unpleasant it may appear to the eye. Water may be perfectly wholesome, and yet so colored by harmless vegetable matter as to arouse distrust among those unfamiliar with it. Chemic tests of water are of most importance nowadays as aiding one to determine its mineral constituents. In studying a proposed new supply, especially if it be from a peaty source, it is well to know its degree of solvent action upon lead, for it is quite expensive to construct and maintain the plant needed for counteracting such a tendency, by filtration through lime or by the suitable addition of lime or soda carbonates. Of the organic constituents, an undue quantity (more than .015 in 100,000 parts) of albuminoid ammonia is the important practical factor which aids us to determine whether a water is bad or not. Wanklyn, in his latest work on "Water Analysis," does not attach much importance to the presence of nitrates, although they are usually regarded as evidence against the purity of a water. The elaborate organic chemic testing of a sample of water is not of nearly as much hygienic value as a careful local inspection by a skilled hydrologist of the sources whence the water comes and a critical searching for possibilities of present or future contamination.

Chemistry, then, being an inadequate guide, except as regards the presence of metals and salts, can any degree of reliance be placed upon the revelations of the microscope as to whether a water contains or is likely to contain matters or organisms prejudicial to health? Not to any sufficient extent. Of course, if tapeworm eggs or partially digested meat fibers be detected in a sample of water, it evidently is polluted, and must be condemned; but it is hardly probable that such things, even if present, will be found to have come into the exceedingly small field of a microscope. Nor does the recognition of protozoa in water aid us hygienically, according to Neisser, who has made a special study of this subject. While a water rich in organic matter is likely to contain many micro-organisms, it may not have many protozoa. On the other hand, both bacteria and protozoa can thrive in water that is very pure indeed. Wash-water, sewage, privy-vaults, and manure-heaps are rather lacking in protozoa, although affording most unwholesome contaminations of drinking-water. Every leaf or blade of grass that falls into a well introduces more protozoa (*monadines, amebæ, ciliata*) than would human feces. Protozoa abound in hydrant water at all seasons.

During the last fifteen years an incontrovertible mass of evidence has accumulated to prove that when drinking-water causes cholera, typhoid fever, and other diseases it is because of the presence in the water of the bacteria peculiar to that disease. While heretofore none of the various methods in use have enabled us to always recognize with certainty the disease-producing bacteria which are present among the numerous microbes of harmless character always to be found in ordinary water, it seems as though we are on the threshold of important discoveries in this direction. Even the familiar gelatin-culture method is of considerable value in the service of an expert, although local inspection is always of paramount importance.

The usual way to make the gelatin test is to add some of the water to strong, specially prepared, sterile bouillon made solid by the addition of gelatin, as explained in THE MEDICAL NEWS by the writer (April 27, 1889). This is done carefully after the gelatin is softened by gentle heat. Then the gelatin is allowed to "set," and in two days, more or less, the isolated bacteria of the original drop or more of water added, being diffused evenly throughout the mass of nutrient gelatin, will have increased enormously in that favorable medium. Accordingly, each separate one of the bacteria ($\frac{1}{10000}$ of an inch in size), although of itself visible only by the aid of high powers of the microscope, has, by multiplying to millions, formed a visible dot, cup, or other peculiar appearance separate from the others.

Without taking the necessary space to explain the many details of bacteriologic work which do not bear directly upon the subject of this paper, it may be briefly stated that, after years of discussion of the value of the mere counting of the number of bacteria present in a cubic centimeter of a carefully taken fresh sample of water, as a rule a water which has few bacteria is better than one which has many. The best waters have usually less than one hundred bacteria in each cubic centimeter (nearly one-fourth of a teaspoonful). Yet a large number of the organisms should not necessarily be considered as indicating that the water is unfit for use; and, on the other hand, disease bacteria entering a water which normally has few bacteria may produce serious infection. Of course, the species of bacteria present must be considered in forming an opinion. Elsner's method, consisting in using "potato gelatin" containing one per cent. of iodid of potash, promises to aid materially in the recognition of typhoid germs in water. For testing the efficacy of filters or other means of rendering an infected water fit to drink, the gelatin-culture test is all-important. It is the bacteria in such a water that the sanitarian regards as the element of danger. If the process removes all of these, it effectually purifies the water; and if it removes or destroys all but a minute proportion of these micro-organisms, it is safe to assume that practically all of the disease-producing germs, if any were present, have been removed. That the water produced is clear or palatable is, of course, readily determined by the senses.

In testing a filter in operation, the original water is examined from time to time by collecting average samples in heat-sterilized bottles. A cubic centimeter, or half as much, of a sample is taken in a sterile glass pipette and added to a cotton-plugged test-tube containing ten cubic centimeters of nutrient gelatin which has been softened by gentle warmth. After these are commingled the gelatin is poured upon a cool plate of sterile glass or a flat glass dish, and this is then promptly covered and labeled. Another test-tube of gelatin is treated in the same way, but is plugged with its sterile cotton as soon as the water is added. After mixing this in by gentle agitation, it is marked and laid upon its side so that the fluid gelatin and water reaches almost up to the cotton. Frequent samples of the filtered water are taken with care to prevent the entrance of bacteria from without. These are plated and tubed in the way just indicated, and all the plates and tubes are then kept away from dust and strong light, under identical conditions of free air, light, and moisture. Those in which the water introduced was sterile will show the gelatin unchanged even after a week, while those into which bacteria entered with the water will show a varying number of colonies corresponding to the number of bacteria entering. Usually those from