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Sanitation of Drinking Water

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We do not take possession of our ideas, but are possessed by them.
They master us and force us into *the arena*,
Where like gladiators we must fight for them.—*Heine.*

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THE SANITATION OF DRINKING WATER.

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THE number of bacteria present in rain water or in snow which has recently fallen, varies greatly at different times. Naturally the number is greater when the surface of the earth is dry and the atmosphere loaded with dust, and less when the surface is moist and the air purified by recent rains. As many as 384 bacteria have been found in one cubic centimeter, or fifteen drops, of fallen snow. In rain water collected in Paris, nineteen bacteria per cubic centimeter were found. The organisms are present in the dust of the air, which is taken up by the rain in falling.

Hail has also been found to contain bacteria in considerable numbers. The maximum number recorded in one instance is 21,000 in one cubic centimeter. This is an exceptional case, however, and is supposed to have been due to surface water having been carried into the air and frozen. Tontin found an average of 729 bacteria per cubic centimeter in melted hail which fell in the city of St. Petersburg.

As a rule lake water contains fewer bacteria than river water. Wolffhügel, in researches extending from July, 1884, to July, 1885, obtained from the water of the Tegeler Lake an average of 396 bacteria per cubic centimeter. From the water of Lake Zurich, during the months of October, December, and January, 1884, Cramer obtained an average of 168 per cubic centimeter. In June of the same year the average was 71 per cubic centimeter. In Lake Geneva, Fol and Dunant obtained from water collected some distance from the shore an average of 38 bacteria per cubic centimeter.

The ice used in Berlin, collected from the surface of lakes and rivers in the vicinity of the city, contains from a few hundred to 25,000 bacteria to the cubic centimeter (Fränkel). In the experiments of Heyroth samples of ice from the same source gave less than 100 per cubic centimeter in three, from 100 to 500 in eight, and from 500 to 1,000 in six.

The simple fact that ice appears clear is no proof that it is pure. You cannot see microbes with the naked eye. The clearest ice may be the most dangerous, and the popular delusion that ice is purified in being frozen is a very sad one. Water will retain its impurities in spite of being frozen for months and even years. The number of microbes in ice is not reduced even by freezing. Only lately it was shown that ice taken from the River Spree in Germany contained 1,700 microbes to the cubic centimeter, while ice from the Lake of Geneva contained 210 bacteria. Prof. Christomanar, of Athens, has shown that freezing may protect from certain impurities, but these are not the injurious ones.

Usually ice companies cut their ice as near as possible to the large cities so as to reduce the expense of transportation. This is the case with New York, where ice is taken from the Hudson just outside of the city. Only a small quantity of the ice supplied to New York is shipped from the lakes of Maine and the Adirondacks, but much of it comes from near-by lakes which receive the sewage discharges of numerous villages. There is only one absolute protection against the disease germs that ice carries. This is *distillation* and *sterilization* of the water before it is frozen. But the quantity of this kind of ice on the market is very minute.

The question of the contamination of water previously pure, by adding to it ice from an uncertain source, is a very important one. This consideration applies particularly to invalids and sick people, to whom ice is such a delicacy and, at times, even a necessity, and with whom it is important that only the purest of food and drink should be used. It is, however, of no trivial importance to the *general public.* If the people could but see the lifelike creatures contained in ice as shown by some drawings executed by Dr. Walter T. Scheelee, analytical chemist of New York, they would pause in terror before they would use the stuff; but, as previously stated, these dangerous microbes are invisible to the unaided eye. Only the vinegar eels and large parasites can be so discerned. A multiplicity of vegetable and animal forms of life have been developed from ice that is clear as crystal.

The examination of ice water as to its fitness for use must be chemical as well as microscopical. The chemical analysis includes examinations for solids, ashes, oxidation, nitrous acid, nitric, sulphuric, and phosphorous acids, chlorine, and ammonia. The *Euglea viridis,* which swarms in water containing decomposed matter, and is a hotbed for growing cholera or diphtheria bacilli, is always present where these are found. *Chilomas* in living form, which is plentiful where decomposing matter is in the water, and assists the growth of cholera and diphtheria bacilli, was found by Scheelee in his examination of the ice water used in New York restaurants and hotels. He also found the *Monas vivipera* in living form. The latter takes its nourishment from decomposing organic matter only, and it is this germ that gives to stagnant water its green appearance. A micrococcus of a suggestive type was likewise very noticeable. The above are but a few of the organisms isolated from melted ice. They all indicate impurities, and some of them are dangerous.

Bacteria can maintain their vitality in water for weeks, months, and even years. Water serves as a culture medium for many, in which they thrive. Tests by Cramer showed that Zurich hydrant water increased 17,000 times in its bacterial contents after standing for twenty-four hours. Leon ascertained that the water supply of Munich, which contained only five bacteria to each cubic centimeter, contained 500 bacteria per cubic centimeter after standing for twenty-four hours. With reference to the rapidity of the multiplication of bacteria in general, Cohn states that a germ divides into two in the space of an hour, these into four at the end of the second hour, and these into eight at the end of three hours; in twenty-four hours the number will amount to more than 16,500,000. At the end of two days, this bacterium will have multiplied to the incredible number of 281,500,000,000. Certain bacteria grow best in water, and here come to luxuriant development. Only a small amount of organic pabulum is required for the indefinite life of many of the water bacteria, and the cholera spirillum will live for a year or more in water, although usually it dies in less time than this.

Naturally it is not so much the number as the *character* of the bacteria present in water that makes the latter dangerous; a few cholera, typhoid, or virulent coli germs are more hazardous than great numbers of the so-called saprophytic bacteria. Even the latter, however, when present in large quantities, arouse suspicion as indicating contamination with organic material which affords a pabulum upon which these low organisms better thrive.

As a rule, it may be stated that water containing more than 500 bacteria per cubic centimeter is likely to be contaminated; this would be 160,000 to a tumblerful of ten ounces. Water containing 1,000 or more bacteria per cubic centimeter is in all probability contaminated by sewage or surface drainage, and should be rejected.

The typhoid bacillus. To give a concise description of the chief disease-producing organisms found in water, the bacillus of typhoid fever was discovered in 1880 within the human body, and four years later it was grown or cultivated externally. It is a rod-shaped organism with rounded ends, and is three times as long as broad. Its length is from one to three micromillimeters.[1] Projecting from its sides are numerous hair-like processes known as flagella, by means of which it is able to propel itself very rapidly through water. These are $\frac{1}{200000}$ of an inch in diameter. It glides along in an artistic way, making serpentine windings and curves. A drop of water under the microscope in which typhoid bacilli are suspended presents a most impressive picture.

[1] A micromillimeter is 1/2500 of an inch.

We have here what might be likened to a swarm of dancing gnats. Millions of these minute microbes in a very small part, even, of this hanging drop, constituting a "field" under the microscope, will be seen darting to and fro in every direction, knocking into and gliding by one another, but for the most part tending to rush to the edge of the drop to get air. The typhoid bacilli dried upon small and thin pieces of glass, stain very readily with the aniline dyes, and then they may be seen even more distinctly, although under any circumstances they must be magnified by powerful lenses (preferably a $\frac{1}{12}$ oil immersion), so extremely minute are they. This germ grows very readily outside the body upon the ordinary artificial culture media used by bacteriologists. Its growth upon the surface of cooked potato is quite characteristic, and was thought early in its history to be absolutely distinctive. As shown by recent investigations, however, a number of other organisms occurring in water very closely resemble the typhoid bacillus in its growth upon potato. These are quite common, and are thought to be modified forms of the true typhoid-fever bacillus. It grows upon gelatin, thrives well in milk, and multiplies rapidly in beef tea, causing a cloudiness. Upon agar-agar, a material imported from Japan, it also develops freely, giving rise within twenty-four hours to a growth perceptible to the unaided eye. In a case of typhoid fever, these bacilli will be found in myriads in the intestines, where they produce the ulceration that characterizes this disease. They are also found in large numbers in the surrounding glands of the abdominal cavity, and in the spleen and other organs, and to some extent also in the blood.

The fact of the typhoid-fever bacillus not being found more often in water supplies is no decisive argument against its presence. Messrs. Andrewes and Laws, after extensive researches in London, England, estimate that even though the typhoid bacillus be intimately mixed with the city's sewage from typhoid-fever cases direct, there will be only one typhoid-fever bacillus in one-tenth of a cubic centimeter of the sewage at the outfall. So numerous were the failures of these observers in their attempts to find the typhoid bacillus in London sewage that they finally became oppressed by a sense of mathematical improbability. The average amount of sewage produced in London is 200,000,000 gallons per day; calculating that two hundred cases of typhoid fever prevailed during the time when the above observations were made, it is estimated that the amount of typhoid sewage was one two hundred and fifty thousandth of the whole. The investigators found it possible to work on only $\frac{1}{5000}$ of a cubic centimeter of sewage at a time, and this only when ninety per cent of the organisms were inhibited by the addition of 0.05 carbolic acid, and incubated at 37° centigrade. Under these circumstances they were able to isolate pure cultures of the typhoid bacillus directly from sewage, a thing which had never previously been done.

The colon bacillus. The colon bacillus, being present at all times in the human intestines in large numbers, and consequently in the excreta, is ever liable to be present in water; and this organism, with the virulence which it is capable of taking on, may give rise to serious intestinal disturbances, and in fact to a train of symptoms closely simulating typhoid fever. This colon bacillus much resembles the typhoid-fever germ, and most experts now regard them as intimately related. Frequently in epidemics resembling typhoid fever, examinations of the water supply will show the presence of an organism that is pathogenic for animals, as revealed by inoculation, but which is not the true typhoid-fever bacillus. The animals fall sick and die, and pure cultures of the colon bacillus may be recovered from their viscera.

Beef-tea cultures, to which the suspicious water has been added, are first incubated at 40° centigrade for twenty-four hours. A few drops of a diluted solution of carbolic acid are also added to the culture. This, with the heat, retards the development of the common water bacteria, which grow best at 22° centigrade, but favors the growth of the disease-producing germs.

The cholera spirillum. The term "bacillus," as often applied to this organism, is a misnomer. The cholera germ is not rod- but spiral-shaped, and is properly known as the cholera spirillum. It was first discovered by Koch in India in 1894, being found in a tank from which the natives drank water. Cholera is almost always endemic in India. In 1894 it had extended to other parts of Asia, and threatened to invade continental Europe. The German government, fearing its approach and consequent disaster, equipped a scientific commission, at the head of which was placed the illustrious Robert Koch, and sent them to India to investigate the cause of that dreadful disease. The cholera spirillum is a very motile organism, and has a terminal flagellum. Its somewhat oval body, with the flagellum, gives it a comma appearance. Hence it is often called "the comma bacillus." It develops freely at the ordinary atmospheric temperature in all nutrient substances that have a slightly alkaline or neutral reaction. In case of cholera it is found in incalculable myriads in the intestinal canal, and therefore occurs in the dejections. It multiplies rapidly upon soiled linen, from which source pure cultures may be obtained. As found in the slimy flakes in the intestinal canal of cholera patients, Koch likens its mode of grouping to that of a school of fish when swimming up stream; that is, the individuals all point in nearly the same direction, and lie in irregular parallel linear groups that are formed by one comma being located behind the other without being attached. The colonies of the cholera spirillum upon gelatin, in which it grows freely, have a frosted appearance, with irregular-shaped points. These, with the indol reaction, the wrinkled film upon the surface of bouillon cultures, and its morphological characters, serve to distinguish it from other water bacteria.

Koch found the cholera spirillum in a water tank at Calcutta during a period of fourteen days, and his experiments showed that it preserved its vitality in well water for thirty days and in Berlin sewer water for from six to seven days. In the experiments of Nicati and Rietsch, the cholera spirillum preserved its vitality in diluted water for twenty days, in sewer water (of Marseilles) thirty-eight days, in water of the harbor for eighty-one days. The numerous experiments recorded by the observers named, and by Bolton, Hueppe, Hochstetter, Maschek, Kraus, and others, show that, while the cholera spirillum may sometimes quickly die in distilled water, in other instances it preserves its vitality for several weeks (Maschek), and that it lives still longer in water of bad quality, such as is found in sewers, harbors, etc. Bolton found that for its multiplication water should contain at least forty parts in one thousand of organic material, while the typhoid bacillus grew when the proportion was considerably less than this, namely, 6.7 parts in 100,000.

Organisms resembling the cholera spirillum. A number of bacteria found in water, although not identical with it, closely resemble the germ of Asiatic cholera discovered by Koch, and now conceded to be the specific cause of cholera, occurring in man. The organisms here referred to are not uncommon in water, and several of them have been studied quite accurately, and photographed. They are of particular interest in this connection. The first of the organisms of this group to which we will refer is the Spirillum Dunbar. This organism was described in 1893 by Dunbar and Oergel, who secured it from the water of the Elbe. It much resembles the cholera spirillum, but it never exhibits signoid forms. It liquefies gelatin even more quickly than the cholera spirillum. The colonies upon gelatin plates and the puncture-cultures in gelatin are identical with those of the cholera spirillum.

Another organism of this group is the Spirillum Danubicus. It was isolated by Heiler in 1892. In appearance it is rather delicate and decidedly curved. It is often united in signoid and semicircular forms, and exhibits long spirals in old cultures. It is actively motile, and the growth upon gelatin is rapid. Several light-gray-colored colonies, resembling those of the cholera spirillum, but exhibiting a dentate margin, have been observed. The growth of gelatin punctures also much resembles that of the cholera spirillum.

The spirillum Bonhoffi was found in water by a Berlin bacteriologist of the name of Bonhoff. It has a decided resemblance to the cholera spirillum, but is rather stouter and less curved. Curved forms, that is, semicircles, signoids, and spirals, do occur in old cultures.

The Spirillum Weibeli was found in 1892, by Weibel, in spring water which had a long time before been infected by cholera. It is short, rather thick, and bent, often forming S-shaped figures.

The Spirillum aquatilis was found by Günther in 1892 in the water of the river Spree. It is similar to the cholera spirillum in shape, has a long terminal flagellum, and is motile. The colonies which form upon gelatin are circular, have smooth borders, and look very much as if bored out with a tool. They have a brown color, and are mildly granular. In gelatin puncture-culture, growth occurs almost exclusively at the surface.

The malaria germ. Concerning the probable presence of the plasmodium, the parasite which is the cause of malaria, in drinking water that is charged with vegetable matter from low, marshy districts, we have important evidence from the lower Mississippi Valley. So extensively did this disease prevail in the large tract between the Mississippi and Yazoo rivers, that population of the region seemed for a time to be impossible; the very atmosphere seemed infected. The use of artesian wells, however, has brought a wonderful change. Formerly the residents of the delta drank the water from small surface streams, shallow wells, and sluggish bayous. As a result of the use of water free from surface contamination, the region has been robbed of many of its terrors and has proved to be exceedingly healthy.

For hundreds of years the Roman Campagna was the home of the deadly "Roman fever." The water supply of the "Eternal City" was very poor, and the fever made great ravages. But since improvement in the above conditions the death rate of Rome has been lower than that of Naples, Florence, Turin, or Milan, and there occurs scarcely a death in Rome from malaria contracted within the city. While we in the North do not have the extensive swamps of the Mississippi region, still there is in the above experiences an important lesson for us and for all who live where impure water, laden with vegetable refuse, is drunk. Whether it be on the banks of the Ohio, the Schuylkill, the Hudson, or any other river, there malaria may occur.

The septicæmia bacillus. One of the organisms producing the most disastrous of the septicæmias (blood poisoning) of animals, namely, the bacillus of rabbit septicæmia, was first discovered by Koch and Gaffgy in a tributary of the Spree river flowing through Berlin. Mori has isolated from canal water three disease-producing organisms. According to Lortet and Despeignes, the Rhone river water of Lyons scarcely contains anything except bacteria that are pathogenic. The filtered residue and precipitate injected into guinea-pigs rapidly lead to their destruction. Disease-producing organisms have been frequently detected in the examination of river and well water. With a knowledge of the very dangerous character of these germs, such water would be drunk with much hesitation. The hydrant water of Freiburg, Germany, frequently contains the bacillus of green pus.

The number of bacteria in drinking waters fluctuates greatly. Upwards of fifty per cubic centimeter will be found in ordinary hydrant water; in good pump water, 100 to 500; in filtered river water, according to Günther, 50 to 200 are present; in unfiltered river water, 6,000 to 20,000. According to the pollution of the water the number may reach 50,000. In densely populated and manufacturing districts the rivers and brooks are to the highest degree contaminated, and the color, consistency, and odor of many waters indicate that they deserve the name polluted, rather than water unqualified. The number of germs in a single drop of a heavily decomposed fluid, such as may gain access to rivers in the form of sewage, often amounts to millions.

In the Spree river at Berlin, according to investigation made in the Hygienic Institute of that city, there are from 3,200 to 150,000 bacteria per cubic centimeter, the average number being 37,525. At the Stralau waterworks, the number was four hundred. The water of the Oder, collected within the limits of the city of Stettin, was found by Link to contain from 5,240 to 15,000 bacteria per cubic centimeter; that of the Limmat, at Zurich, 346 in one specimen, and 508 in another (Cramer). Adametz (1888) has described eighty-seven species of bacteria obtained by him from water in the vicinity of Vienna; Maschek found fifty-five different species in the drinking water used at Leitmeritz; and Tils (1890) has described fifty-nine species obtained by himself from the city water used at Freiburg.

As showing the influence of locality on the number of bacteria present in different parts of a river, the following observations are of value. The water of the Seine at Choisy, before reaching Paris, was found to contain 300 bacteria; at Bercy, 1,200; at St. Denis, after receiving sewer water from the city, 200,000 germs per cubic centimeter (Miquel).

Let us now examine into some of the conditions surrounding domestic wells and springs in the larger towns and villages, conditions which also prevail sometimes even about rural homes. We shall then be better able to understand how a well, like a Nevada silver mine, may have "millions in it," and how "the old oaken bucket" may bring from the depths elements of disease with the same draught that refreshes the thirsty throat. For convenience a well is situated in the back yard, perhaps a rod away from the house, or it may even be nearer. Certain other things, also for convenience sake, are grouped close about the backdoor. Here is a cesspool but a short distance, perhaps only a few feet from the well; there is a vault, a filthy institution which is an open disgrace to civilization. A little further away is the garbage heap. In other adjacent localities are the chicken coop, the pig-pen, and the stable, with their accumulations of decomposing filth. It may be that in a corner a dead animal has been buried to save the trouble of conveying it to a distance. A damp and reeking spot near the backdoor marks the place where the slops have been deposited since the drain to the cesspool became stopped up with the accumulated refuse of half-a-dozen years.

Every one of the sources of contamination mentioned is a contributor to the well. A part of the putrid material floats upon the ground and is disposed of by evaporation, but the greater portion of it soaks into the ground. It is a common error to suppose that whatever has disappeared into the ground is destroyed. The filth which has disappeared from the surface may be out of sight, but it is not out of existence. If the soil is filled with refuse of various kinds, the well will be contaminated. Every rain washes the filth a little deeper down until it reaches the well proper or one of the underground veins of water by which it is fed. It may not be generally known that a well will draw water a distance of 60 feet.

As showing the danger of soil pollution and the length of time during which the same will last, the following, from Dr. Lanciani's work on "Ancient Rome," will be of interest:

> While a system of garbage collection existed under Roman rule, the disposal of refuse was as crude as it is in many modern towns and cities. That this disposal method was regarded as a nuisance at a very early period is made evident by the fact that sanitary laws were passed 2000 years ago that were intended to at least mitigate the trouble.

Some of these laws, graven on stone, were unearthed by Dr. Lanciani in his excavations, and the text of one of them reads:

> C. Centius, son of Caius, the prætor, by order of the Senate, has set up this line of terminal stones to mark the extent of ground that must be kept absolutely free from dirt and from carcasses and from corpses.

On the bottom of this stone, in red letters, some probably near resident had written, "Do carry the dirt a little farther; otherwise you will be fined."

The long and active survival of disease germs in soil was also made manifest by excavations made inside a coffer-dam uncovering the bed of the Tiber, alongside the bridge leading to the Castle of St. Angelo, in Rome. Here, in successive strata, were found coins and other relics fixing the age of the deposit down to the fourth century A. D.

The soil, as it was slowly removed, was piled upon an adjoining wharf, and then taken away. When the very lowest and oldest of all the strata disturbed was so disposed of, an epidemic of typhoid fever broke out among the workmen and those living in the immediate vicinity. The result of careful examination is said to have shown that the trouble came from the lowest strata, and that the disease germs that had been lying dormant at the bottom of the Tiber for nearly 1500 years were still active for evil, and proved their vitality.

Roth examined the water of sixteen surface wells in Belgard, which has a very porous subsoil, and he found from 4,500 to 5,000 bacteria in three, from 7,800 to 15,000 in six, from 18,000 to 35,000 in six, and 130,000 per cubic centimeter in one. Forty-seven wells of Stettin, the water of which was examined by Link, gave the following results: less than 100 bacteria in six, 100 to 500 in twenty-one, and in the remainder (sixteen) from 1,000 to 18,000. Bolton examined the water of thirteen wells in Göttingen, and found but one in which the number of colonies from one cubic centimeter was less than 100; in twelve the number varied from 180 to 4,940. Sixty-four wells in Mainz, examined by Agre, and fifty-three in Gotha, by Becker, gave similar results.

It might be well to say something here about the best method of disinfecting a well once contaminated, so that it may again be used without danger. In case of a tubular well, it should first be pumped dry; the pipes should then be removed and placed for two hours in a two-per-cent carbolic-acid solution. Afterward they should be brushed, and several gallons of a five-per-cent solution of carbolic and sulphuric acids poured in. The pipes are then reinserted, and pumping is resumed until no trace of the carbolic acid can be detected in the water. This is determined by the phenol test on the addition of perchloride of iron. The common method of putting chalk into a well as a means of purifying it is of little value (Fränkel).