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SOME RECENT INVESTIGATIONS CONCERNING BACTERIA IN DRINKING WATER.

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THE testing of drinking water as to its germ life, according to the method first suggested by R. Koch, has proved, in many cases, of great value in supplementing the chemical analysis. In fact, many of those prominent in matters pertaining to public hygiene are inclined to place more faith upon the estimation of the number of bacteria in a given quantity of water than upon the determination of chlorides and of those chemical elements, such as ammonia, nitrites and nitrates, which are usually looked upon as the products of bacterial life.

The German Imperial Health Office seems to be well aware that this method needs careful elaboration and abundant statistical material before it can be placed upon a firm basis, and before the interpretation of its results can be considered reliable. There are, moreover, many important collateral questions which must be solved before this point is reached. There are now published in the first volume of the *Arbeiten a. d. Kais. Gesundheitsamt*, three separate articles, extending and applying the gelatine plate method in endeavoring to get at the true signification of microörganisms in water. The first publication (p. 1) furnishes statistics of the chemical and bacteriological constituents of Berlin drinking water.

These tables point out very clearly the efficiency of filtration in removing the great majority of bacteria from the water, and in reducing the quantity of the chemical constituents. They also indicate the great variation which the number of bacteria may undergo in water derived from flowing streams and rivers. Thus the maximum number of bacteria contained in unfiltered water from the river Spree, in the month of March, was 5115, the minimum 936; in October, the maximum and minimum were respectively 8316 and 528.

In my own examinations of Potomac water, in part published elsewhere,[1] the number of bacteria would reach 3000 after heavy rains, and descend within a few weeks to about 300. In every case, the number of bacteria would grow *pari passu* with the turbidity of the water, indicating a washing into the stream, with the suspended matter, of the bacteria themselves, while the smaller number found in the settled water led me to infer the presence of a very small quantity of organic matter in solution. These facts force us not to rely upon one, or even a few examinations in estimating the average germ life of a given water, and from this deduce its healthfulness. Another fact brought out by these statistics, is the great value of Koch's method in determining the efficiency of filtration. This has been well shown by Frankland, and others. The method enables us to test, not merely the efficiency of a

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[1] American Monthly Micr. Journ., 1886, p. 61.

given filtering material or apparatus, but the length of time during which such a filter remains efficient. That this is a most important factor, is shown by the following statistics.[1] Water drawn in a Berlin kitchen, through a private filter, contained 3840 bacteria; the filter being removed, it contained only 35. A second examination furnished the same results, 4500 with the filter, 56 without it. To indicate the efficiency of sand filtration, used in Berlin, the following figures may be of interest. In July, 1884, about 75 per cent. of the bacteria were removed by filtration; in August, 80 per cent.; in September, 97 per cent.; in November, 42 per cent., etc.

Koch established, and made comparatively simple, the estimation of the number of microörganisms in water. But the signification of the number and kind of bacteria still remains to be determined. It may be safely assumed that the number of bacteria is a measure of organic contamination, and that the introduction of saprophytic bacteria into streams from polluted sources, may be taken as a broad indication that pathogenic bacteria, whenever present, will gain entrance through the same channels.

In order to see what relation subsists between the quality of drinking water, as indicated by taste, and by chemical analysis, another series of figures are published under the direction of Dr. Wolffhügel.[2] These statistics, collected from various cities in Germany and Austria, and compiled by various observers, do not indicate the perfect concordance between biological analysis and former estimation of quality which those would wish to see, who have

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[1] Arbeiten, etc., p. 562.
[2] Loc. cit., p. 546.

looked upon this method as more satisfactory than chemical analysis. Moreover, in the reports from some cities, the bacteriological estimates of the water from various pumps which have been condemned as unfit for use on the evidence furnished by chemical analysis, show in the main a low percentage of bacteria when compared with others regarded as fit for drinking water. Thus, on page 556, we find the water of two condemned pumps containing, respectively, 11 and 71 bacteria in 1 c.c., while that of another, not condemned, is put down as containing 1485 bacteria in 1 c. c.

These discrepancies may, however, be only apparent, when we consider that, in but a few cases, two or three examinations of water from the same source were made. These examinations, in most cases, show a close agreement in the figures; in a few, the difference is very marked. Thus (p. 554), two examinations, made about a month apart, describe the bacteria as too numerous to be counted in the first case, and but 63 in the second.

From these statistics, it would appear that, in the majority of the sources receiving their supply either from ground water or spring water, the bacteria number less than 200 in 1 c. c., a small proportion reach the number 500 to 600, while a few go as high as 2000 to 5000. In connection with these statistics, Dr. Wolffhügel reserves for himself some general deductions, to be published later. Meanwhile, in order to swell the material on which conclusions may be based, it would be advisable for those practically interested to confine their examinations to variations in the number of germs in a few sources of drinking water, rather than examine a large number but once or twice. In this way the effect of the seasons, of rainfall and drought may be watched. Nor is the effect on the number of bacteria of a prolonged exhaustion of water in ordinary pumps to be overlooked.

In a third article,[1] two questions are approached from the experimental side: To what extent do pathogenic bacteria multiply in water? To what extent do bacteria multiply in samples of water after collection and before examination? In regard to the second question, the authors conclude that bacteria do increase in number within certain limits of temperature, and that water packed in ice shows a gradual decrease in the number of bacteria capable of development. Hence the necessity of examining water immediately after it has been collected, in order to avoid any errors. The great increase in the number of bacteria of drinking water after collection is a fact coming under the observation of all who have paid any attention to the subject. I, at first, suspected that the biologically sterile tube might not be chemically clean, and hence exposed the tube to the Bunsen flame until all organic matter was carbonized or broken up. This, however, did not prevent a few thousand bacteria from increasing to over sixty thousand within twenty-four hours. The changed conditions are such as to make all other organisms a prey to bacteria. The authors have also found that the manner in which the collecting tube is closed affects the diminution of the number when exposed to cold, so that tubes with rubber stoppers contained, on the average, less than those plugged with cotton-wool. This, without doubt, depends on the oxygen supply. Experiments on the effect of mechanical disturbance, such as

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[1] Loc. cit., p. 455, Die Vermehrung d. Bakt. im Wasser, von Dr. Wolffhügel u. Dr. Riedel.

might occur in the transportation of samples, led to no uniform results.

In endeavoring to solve the first question stated above, how extensively pathogenic bacteria are capable of multiplication, the authors sterilized filtered and unfiltered water from various sources, including river, well water, and water from a contaminated stream. As a preliminary experiment, a number of bacilli isolated from water were tested in this way. All actively multiplied for ten or fifteen days after being sown. This multiplication was determined at stated intervals of one to five days, on gelatine plates. Among the pathogenic microorganisms, the anthrax bacilli multiplied, in some cases, to the fifteenth day after sowing. The bacilli of typhoid fever increased in number up to the third day, then diminished. Even when the contaminated water was greatly diluted with distilled water, there was a perceptible multiplication, or, at least, a preservation of the vitality of the bacilli for at least twenty days. In well water and drinking water from the river, the increase was not so marked, but the vitality was not destroyed after the twentieth day. In distilled water they were traceable after fifteen days. Cholera bacilli exhibited the peculiar property of quite disappearing during the first days, but multiplying later to a very marked degree. The authors explain this strange fact, by assuming preliminary adaptation of the bacilli to the medium in which they are placed, by which their multiplication is somewhat retarded. The enormous multiplication of typhoid and cholera bacilli in sterilized milk, points out the importance of keeping a strict supervision over this important article of food, and the absolute necessity of boiling all milk in times of epidemics.

Experiments designed to test the struggle for existence of pathogenic bacteria in unsterilized water, failed by reason of the rapid growth of the bacteria originally present. Immediately after sowing, the cholera bacilli were by far the most numerous, but, within a day, other bacteria multiplied so enormously as to crowd them out of sight or existence.

When first undertaking to analyze water by this method, it seemed to me that if the collected water were allowed to stand at a given temperature, and the maximum number of bacteria determined which the water was capable of sustaining, we might have an indicator of the relative quantity of organic matter present. This the authors have virtually done, only in a way which must be more accurate in some respects. If the water be sterilized by heat, and only one species of microörganisms sown, the conditions would be more uniform, since different bacteria would multiply with different rapidity. In such experiments the change in the water, effected by sterilization, must be taken into consideration.

From recent investigations, M. Bolton[1] determined in water the presence of certain bacteria, which multiply very rapidly for a number of days, and quite independently of the quality of the water used as a culture medium. The addition of nutrient substances, in quantities too small to be measured, was sufficient to cause active multiplication. They found nourishment enough in water repeatedly distilled. Pathogenic bacteria, added to water, regularly decreased in number, independently of the quality of the water. He therefore concludes that

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[1] Zeitschrift für Hygiene, I. Bd., I. Heft., Deutsche med. Wochenschr., 1886, p. 506.

the number of bacteria in a given sample does not furnish any safe basis for determining the chemical constitution, the degree of pollution, or the infectiousness. A knowledge of the various species of bacteria is a safer guide than their number, in estimating the quality of water.

Such researches aid in giving bacterial enumeration its proper place. They indicate the method to be pursued: a careful study of the biological properties, and the possible pathogenic effect of each species. The relation of bacteria to the processes in the alimentary canal is still an unexplored field. May not some of the speciesdaily introduced into the digestive organs, in the drinking water, give rise, under certain conditions, to fermentations and decompositions leading to catarrhal and other morbid changes?

Lines of research might be multiplied, if space permitted. They are comparable to clinical observations at the bedside, the value of which increases with the quantity. Since work of this nature is more laborious than intricate, and requires but little apparatus, its prosecution in every biological laboratory is to be highly recommended.