Ward and Henderson¹⁴ in this country, Vervoort¹⁵ in Amsterdam, Seligmann¹⁶ and Frank¹⁷ in Germany and many others have shown the reality of school infection in definite instances. Frank, for example, in studying an epidemic of diphtheria in 1910-1911 among the pupils of a girls' school in Charlottenburg found that conveyance of infection must have taken place in the school since the children were recruited from all parts of the city, some of them coming from districts where at the time no diphtheria cases were known to exist. In 1909 the number of children in this school developing diphtheria amounted to only 0.7 per cent., which was about the average for the other schools of the city, while in 1910-1911 the number of diphtheria cases increased to 14 per cent. Detailed investigation of the school by classes showed in every instance a certain relation between the number of new cases and the number of diphtheria carriers; most of the cases occurred in the classes in which diphtheria carriers were detected. In those classes in which carriers were lacking there were only one or two cases or none at all. Among other recent writers Goldstein¹⁸ has laid stress on the importance of the healthy diphtheria carrier in spreading disease. Westenhoeffen¹⁹ points out that in the Berlin epidemic of 1911-12 the schools played the chief rôle in the dissemination of infection.

The discovery of the part played by the healthy germ-carrier throws light on the probable origin of certain obscure cases of infection. A child in a family in which a case of diphtheria exists may bear in its throat living diphtheria bacilli without manifesting any sign of disease. If this child is allowed to enter school a playmate may acquire the bacillus without in its turn becoming definitely ill. This second child, however, may take the germ home and pass it on to a non-school-going child in the same family who then may develop a typical case of diphtheria. In this and even more circuitous fashion a diphtheria bacillus may be handed around until the original source is difficult to trace. Variations in the virulence of the germ and in the favorableness of the soil in which it lodges determine the actual development of a "case." If a large number of children in a school happen to be in a susceptible state from climatic or other reasons, or if a diphtheria bacillus introduced into the school happens to have unusual infective power then a school epidemic will result.

Methods of control of school and institutional outbreaks of diphtheria are therefore coming to be focused on the detection and exclusion of the carrier. Summary disinfection of innocent chairs and tables and enforced school closure are in general found to be less effective than the discovery and isolation of the living bearer of diphtheria bacilli. When school attendance is regulated by bacteriologic findings school epidemics quickly subside.

Although we must freely admit that for diphtheria, at all events, evidence of infection through school attendance is entirely convincing we are as yet not in possession of sufficient information as to the relative importance of this source. Our knowledge of the mode of spread of scarlet fever and measles is in a still more imperfect condition. It would seem desirable if through the auspices of this Association an extensive and searching investigation under expert supervision might be

made of this question. To what extent and under what conditions are the infectious diseases of childhood spread by school attendance? At present in combating the spread of infectious disease without adequate knowledge of the channels of infection we are in danger of wasting our strength in misdirected effort, and the conservation of human effort is certainly one of the most desirable forms of conservation. Experience has shown us that not all theoretically possible methods of preventing infection are equally efficacious in practice. For each disease we should aim to adopt special methods carefully devised to produce the maximum effect with the smallest amount of injury or disturbance to the normal relations of human life. To this end it is essential to discover the ways in which infectious disease is commonly spread as well as the ways in which it might conceivably be spread. The abolition of the common drinking-cup is a highly desirable procedure even if only an occasional case of infectious disease is prevented, but has anyone ever put on record a measurable diminution in disease in a school after the introduction of bubbling fountains? In point of fact we do not know to what extent the various influences summed up under school attendance are factors in the dissemination of infectious diseases. The question should be investigated.

METHODS OF WATER PURIFICATION FOR LARGE CITIES

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All water supplied to cities originates in the rainfall. When rain-drops are formed by the cooling of air saturated with moisture, the water is free from mineral and organic matter and bacteria, and is therefore soft, colorless and pure. But as the drops fall through the air they take up its dust, which is both mineral and organic, and wash the air. If the rain is heavy enough, this washing makes the air clear and bright.

When the rain-drops strike the earth's surface, one part of the water is immediately evaporated, one is absorbed by vegetation, one runs off the surface into streams or open water courses, and one percolates into the ground until it reaches the ground water-table or level, which finally discharges subterraneously along lines of least resistance into the nearest open water-courses or at springs.

The portions of the rainfall which are available for city water-supplies are, first, the one which percolates into the ground to be temporarily stored before discharging into open watercourses or springs, and second, the one which enters the streams directly over the surface.

We may say, therefore, that the water-supplies for large cities must be obtained either from ground water through springs or wells, or from surface water in flowing streams.

SPRINGS AND WELLS

The quality of ground waters to be used for potable purposes depends on the character of the soils and rocks through which the water percolates after it has fallen on the surface as rain.

Some minerals can be readily dissolved and taken up by the water, and others are practically insoluble. Some waters may contain excessive quantities of salt, sulphur, manganese, iron or other objectionable minerals, which,

14. Ward and Henderson: California State Jour. Med., August, 1907.

15. Vervoort: Hyg. Rundsch., 1908, xviii, 1459.

16. Seligmann: Ztschr. f. Hyg., 1911, lxx, 35.

17. Frank: Hyg. Rundsch., 1912, xxii, 325.

18. Goldstein: Vrtlschr. f. gerichtl. Med., 1912, xliii, 136.

19. Westenhoeffen, M.: Berl. klin. Wchnschr., Jan. 8, 1912, p. 91.

if in large quantities and in solution, completely unfit these waters for potable purposes. Other waters may have large quantities of lime which make them appear very bright but also make them hard.

If these solutions are sufficient in quantity to make the waters objectionable for potable purposes, and if no better alternative supplies are available, they should be subjected to some system of purification. Not all mineral pollutions can as yet be economically removed. The only removals which are successfully carried out in the practice of to-day are chiefly those of the carbonates and sulphates of lime and magnesia, which make waters hard, and those of excessive quantities of iron, which unfit water chiefly for laundry use.

The hardness of waters is of two kinds, temporary and permanent. Temporary hardness is usually caused by the carbonates and the permanent hardness by the sulphates of lime and magnesia. The former can best be removed by a solution of freshly burnt lime, or lime-water. The bicarbonates are changed into monocarbonates by the hydrate of lime uniting with the half-bound carbon dioxide which is combined as a bicarbonate in the hard water. The resulting insoluble monocarbonates deposit as a fine powder.

Permanent hardness can be removed by adding sodium carbonate. The soda in this case unites with the sulphates dissolved in the water which results in the formation of neutral and inert sodium sulphate, and the insoluble carbonate, which is precipitated as a fine white powder. The largest water-softening plants on our continent are those in Columbus, Ohio, and Winnipeg, Manitoba.

The softest and most palatable ground waters are found in regions where the rocks are granite, gneiss, sandstones and slates. Limestone regions yield hard waters.

Waters containing much iron must be subjected to a process of deferrization before they can be used. The presence of iron in ground water is generally due to the presence of organic matter, which forms soluble ferrous carbonates. Alluvial plains are the usual sources of such waters. We find them on Cape Cod, Long Island and the Jersey shore. Northern Germany, including Berlin, has such waters. They are clear when first drawn, but soon become cloudy by the absorption of oxygen from the air and the consequent formation of ferric oxid.

The treatment of iron waters as at Rockaway, N. Y., at Berlin and a number of large North German cities, is simply by aeration, which causes oxidation and produces iron oxid, which is readily precipitated and removed by filtering the water through sand.

SURFACE STREAMS

The quality of surface waters furnished to large cities depends, first, on the condition of the air through which the rain has fallen; second, on the character of the surface over which it flows, and third, on the method of artificial purification which it may have received.

While Nature has purified the water issuing from springs, which are the overflows from the accumulated ground waters, it does not with equal thoroughness purify the water when it flows on the surface in open streams. On the contrary, much fresh and even more serious pollution may be added. Such pollution may be mineral or organic.

Mineral pollutions are chiefly from trade wastes. It is proper to prohibit the discharge of such wastes into streams which are to serve as water-supplies, because

it is sometimes exceedingly difficult to give them a proper treatment for that purpose.

Surface washings bring into the streams sometimes large quantities of clay and fine sand. Witness the alluvial streams in the Missouri and Colorado river valleys. But such pollutions can be readily removed by treatment.

The organic pollution is by far the more objectionable one. Not only does dead animal and vegetable matter give the water an objectionable taste and appearance, but it may harbor disease germs and may transport them to great distances. Objectionable tastes and odors are given waters by a number of low forms of life, constituting the plankton, the growth of which in rivers, ponds, or lake waters, is favored by a warm temperature, an abundance of food material, colloidal or dissolved, and other causes.

Water supplied to large cities must be free from objectionable mineral and organic pollution and, most of all, from pathogenic bacteria. It must be palatable and soft, clear and limpid.

WATER PURIFICATION

As surface waters available for large cities rarely have all of these qualities, it is necessary to purify them. Even mountain streams of excellent appearance and taste are no exception to this rule. While they may be free from objectionable mineral and crude organic pollution, there is no guarantee that even with policed watersheds there may not be pathogenic bacteria brought on them by beast or bird. We are therefore approaching the time, already reached in England and Germany, when it will be required to purify all surface waters and then to keep them from exposure to light, heat and dust and to conduct them by subsurface and enclosed channels to the points of consumption.

Four methods of water purification for large cities are now in successful use: (1) slow sand filtration; (2) rapid mechanical filtration; (3) coagulation with precipitation, and storage in large reservoirs, and (4) disinfection by hypochlorites of lime and soda, by ozone and by ultraviolet rays.

1. *Slow Sand Filtration*.—This method is the most common and, it may be added, also the best where it is available. Since first introduced in England it has been practiced for almost a century.

Sand filtration, if the works are properly designed and operated, removes substantially all bacteria and suspended matter from the water. The result is clear and limpid water free from disease germs. The essentials of the process are, first, a preparatory treatment, so that the filters can do their best, and second, the filtration process itself. In exceptional cases there may be some other adjunct to the treatment.

The preparatory treatment depends largely on the character of the water and of the filters to receive it. The water may be fairly clear, as generally in our Northern states and where sand and silicious rocks prevail; or it may be muddy, as in the lower parts of the Missouri and Mississippi valleys, and where the rain can wash clay and aluminous soils into the river. It may also be polluted from agricultural lands and by city sewage.

The preparatory treatments will accordingly differ. When plain sedimentation is sufficient this is the cheapest process. It allows the bulk of the suspended matter to deposit and the more or less clarified water to go to the filters for further treatment. When plain deposition is not sufficient, then it is practicable to add a small

amount of coagulant, particularly when the suspended matter is of a finely divided and colloidal nature. The effect of the coagulant is to draw together the fine particles into larger ones and thus produce a better precipitation and a clearer water.

When the water is more or less strongly polluted with sewage from agricultural or inhabited districts, the preparatory treatment should endeavor, if practicable, to destroy all pathogenic bacteria, so that they may not enter the filters, there perhaps to be nourished and propagated. For this purpose coagulation and precipitation are quite effective, because the descending and depositing solid particles carry with them to the bottom a high percentage of the bacteria, just as rain-drops clarify a dust-laden or hazy atmosphere.

A disinfectant added during the process of preliminary treatment is generally not advisable, because it destroys or injures in part the efficiency of the filter by reducing its bacterial life and activity. If a disinfectant is advisable, it is better to treat the water after filtration.

The preparatory treatment may also be a prefiltration, that is, a rapid coarse filtration. A coarse filter is added to take out the coarser material. To do this is particularly excellent for lake waters, where a large amount of the coarser suspended matter consists of plankton or small organic life, which would not be thrown down by precipitation. Plankton rapidly clogs the final filters.

The final filters are used both for bacterial removal and for clarification of the water. The work is done partly by bacterial activity and partly by straining. A bacterial slime is gradually formed on the upper surface of the sand filter, but to some extent on the surface of the sand grains for a short distance below. This slime acts partly as a strainer, through which the water must pass, which causes clarification, and partly as a nitrifier through the bacterial life which inhabits it and by which the dissolved organic matter is decomposed.

The bacterial slime further holds back by its straining action the suspended particles which gradually produce what has been called, here as well as in Germany, the *Schmutzdecke* or *Schlammdecke*, and by this accumulation the *Decke* increases in thickness and compactness until the water requires too much pressure or depth in order to pass through. At such times the filters must be cleaned. For ordinary or fairly clear raw waters this cleaning is required about once a month, and there are now in use several mechanical means for this cleaning.

In a few instances the attempt has been made to procure a higher purification, and also a further safeguard against the passage of bacteria through the filters, by having a double filtration through fine sand. It seems now that a greater economy and efficiency may just as well be secured by a system of preparatory prefiltration, properly adapted to final filters and connected with them. Each part of the plant has then a definite specific duty to perform, for which it can be specially designed and operated.

The rate of filtration through the slow sand-filters varies according to the character of the water and of the sand grains. The usual quantity of water which passes through a filter is equal to a depth of from 7 to 10 feet per day. In other words, it requires an acre of sand filter to purify from two and one-half to three million gallons per day. A well-prepared water can be passed through at greater velocities, varying from one and one-half to twice these rates.

2. *Rapid Mechanical Filtration.*—The large areas of sand-filters required for large cities, for which there is sometimes neither land nor money available, frequently

cause a not unnatural hesitancy to provide at all for filtration. It has also been found that the fine colloidal particles of a clay-polluted water are not sufficiently removed by the slow sand-filters to produce a clear and limpid water, nor was the color of some waters, caused by vegetable stain, such as occurs in timber regions, entirely removed by them.

These facts caused the rapid mechanical filters to be invented and introduced into America. They have been extensively and successfully used in a number of our cities, of which Cincinnati, Columbus and New Orleans, and the groups of small cities supplied by the East Jersey Water Company and the Hackensack Water Company near New York, are the largest and best examples.

The rapidity with which the water could pass through these filters was increased to a depth of 400 feet or less a day. The possibility of securing this greater speed without injuring efficiency was caused by artificially producing a deeper and stronger slimy coating to extend over the entire filter surface. This coating was not produced naturally by bacterial growth but artificially by a chemical coagulant, causing the formation of a flocculent suspended matter by the addition of a small quantity of aluminum sulphate (New Orleans, East Jersey and Hackensack), or of lime and iron (Cincinnati).

This flocculent matter covering the sand grains, which must be larger than in the slow sand-filters to permit of the greater speed of filtration, acts chiefly as a strainer. The rapidity of passage allows of a lesser bacterial activity and purification, and nitrates are therefore much less in amount than in the slow sand-filters.

With good design and construction, and with good operation, these two classes of filters can and do remove about equally well both pathogenic and ordinary bacteria.

The results in reducing typhoid fever have been found to be about the same. The filters in Cincinnati are equal in efficiency in this respect to any slow sand-filters in our country.

Owing to the speed with which the water passes through the filter, it will be evident that the amount of retained suspended matter in a given time will be correspondingly increased. As the speed is forty or fifty times as great as in the slow sand-filter, the *Schlammdecke* will be ready for removal, on the average, in at least one-fortieth or one-fiftieth of the time. These filters, therefore, require frequent cleaning, which is accomplished by a reversal of the current, and by efficient mechanical means of cleaning; also sometimes by air washing, by all of which the sand grains for the entire depth of the filter are turned over and over and in so doing clean each other by attrition.

A word should be entered here regarding the difference between the so-called gravity and pressure filters. The former permit the waters to pass by gravity and always with the same velocity. This conserves the integrity of the film produced by the coagulants and is far more efficient, as far as a removal of bacteria is concerned, than when the water passes through the filter under a high and particularly varying pressure, which is likely to cause a rupture of the film. Pressure filters, if economical, are satisfactory for obtaining clear water for manufacturing purposes. For potable water filtration they are not so good as the gravity filters and are now seldom used for that purpose.

The rapid filters as well as the slow filters require a preliminary treatment. But this refers more to the addition and thorough mixture of the coagulating material with the water than to the removal of coarse suspended matter.

It should also be added that, as in the former case, a disinfecting treatment is less effective and more costly as a preliminary than as a final treatment of the water after filtration.

In addition to the removal of bacterial and fine suspended matter the rapid filters have the advantage of removing also the usual stain found in many waters, by the use chiefly of alum and salts of iron.

The use of such coagulating materials was at first strongly objected to by the medical profession on account of the fear that they might enter the human body with the water in a raw state and produce objectionable pathologic conditions. Long experience, however, has shown that practically no evidence of such ill effects has been recorded wherever the filters have been properly designed and built, and afterward carefully operated.

It should be added that in a properly operated plant no raw alum is found in the water leaving the filter. This will be the case when the water has sufficient alkalinity, which allows the alum to be decomposed and thereafter disappear as such in the water. If the waters to be filtered are very soft, it is therefore customary to add some lime with the alum.

On the whole, rapid mechanical filters require a somewhat higher order of men for operation than the slow sand-filters, because they are somewhat more complex and the filter rate is greater, which therefore requires somewhat more skill and closer attention.

3. Coagulation with Precipitation, and Storage in Large Reservoirs.—It is sometimes preferable and more economical to postpone filtration of a surface water, when a sufficient security against disease conveyance can be obtained by a less complex and costly plant. This is the case, for instance, at St. Louis. The Missouri River water carries much fine clay in suspension and the bacteria contained in the water will by adhesive force approach and cling to the clay particles instead of remaining free in the water. Therefore by an effective precipitation of the clay particles it is practicable to obtain a water which may be quite healthful although previously perhaps dangerously polluted. By thus precipitating the solid matter the water will not always be made bright and limpid, because some fine colloidal matter is frequently still left in it. When a still better quality of water is desired, it always remains practicable to add a filtration plant by which to secure it.

The investigations of Dr. A. C. Houston, Director of Water Examination, Metropolitan Water Board, London, have shown that large storage reservoirs are quite efficient for the removal of bacteria. Not only do subsiding particles of suspended matter attract floating bacteria and carry them down for deposit, but it is asserted that in clear waters, not very much disturbed, the bacteria themselves will subside, and that therefore large reservoirs and long storage are a good sanitary measure.

I do not know whether or not similar observations have been made in the large reservoirs in our country. The Wachusett reservoir of the Boston supply has been available for such observations, and a still larger reservoir for the New York supply from the Catskills will be available.

It will be interesting to determine whether or not pathogenic bacteria die during the long retention in such reservoirs, whether they are deposited on the bottom or not, and further interesting to discover as to whether or not in such cases filtration may be omitted.

4. Disinfection by Hypochlorites of Lime and Soda, by Ozone and by Ultraviolet Rays.—As mentioned above,

the object of purifying the water-supply of large cities is to make it healthful, clear, limpid and palatable. Its healthfulness is controlled, in the cases under consideration, by its freedom from pathogenic organisms.

When waters are not and perhaps cannot be filtered, and even when filtered under perhaps abnormal conditions, the waters can be rendered healthful by destroying the dangerous bacteria through a separate treatment of the water for this purpose.

The disinfection of water has been under consideration for many years, and the last word has not yet been said. It has been proposed to utilize for this purpose the bactericidal effect of ozone, of the ultraviolet rays and of the hypochlorites of lime and soda.

It is clear that by any of these materials or processes bacteria will be killed. But a practical use for large water-supplies is possible only when the expense is reasonable and there is a satisfactory assurance of obtaining the desired effect.

As yet the applications of ozone and of the ultraviolet rays have not yet been developed sufficiently to secure economical processes.

The ozone process has been used in large cities, notably Wiesbaden, Germany, but has been abandoned after a year or two on account of cost and of not being sufficiently reliable. It is more difficult to obtain a thorough mixture of the water with ozone, which enters it as gas bubbles and soon loses its efficiency, than with a material entering either finely dispersed or as a solution, such as hypochlorite, which retains its efficiency for a much longer time.

The ultraviolet ray process is being studied and applied in Europe, but while its reliability appears to be greater than that of the ozone process, it appears at present that the cost may be too great.

For these reasons the hypochlorite treatments, being more economical at present, are now much more extensively used. Within the last few years, since the process was first practically developed for the water-supply of Boonton, N. J., more than a hundred cities in our country use it. Its efficiency has been successfully demonstrated in several cities, where it was rapidly installed at the outbreak of typhoid epidemics. Allowing for the lapse of the period of incubation, it was found that new cases, if not traceable to secondary infection, did not occur (Minneapolis and other cities). In still other cities where the treatment was introduced, the usual slight autumnal rise in the typhoid curve was practically eliminated (Montreal).

CONCLUSION

This brief account of the methods of water purification for large cities should give us the comfortable assurance that we have reached a stage of development in this branch of public service at which it becomes possible to furnish healthful water-supplies at reasonable cost, whether they are obtained from subterranean or from surface sources.

170 Broadway.

Clinical vs. Pathologic Diagnosis.—Diagnosis, however, is half the victory in the battle with disease, and from the point of view of the patient is of more importance than some piece of fragmentary tissue or rare microscopic specimen preserved for exhibition with a report on its pathology if she survive, or, be she ever so philanthropic, the chance of its being added to a museum for the inspection of others when she is dead.—H. Macnaughton Jones in *Clin. Jour.*