SLOW SAND FILTRATION OF WATER.

By Joseph Race, F.I.C.,
City Bacteriologist and Chemist, Ottawa.

FILTRATION through sand as a means of purifying water has been used for a large number of years, but it is only comparatively recently that the principles which are the foundation of this method, have been investigated in a scientific manner and thoroughly recognized. It cannot be claimed that perfection has been arrived at in this respect, but it is undeniable that great advances have been made and that water filtration is now a specialized science. Sand filtration was primarily introduced for the purpose of removal of suspended organic and mineral matter and it was not until many years had passed that it was found that bacteria, pathogenic and otherwise, were also removed in this process. It is now generally accepted that the action of filters is a combination of mechanical, physical, and biochemical functions and although these functions are interdependent and proceed simultaneously it is convenient to discuss them separately.

Mechanical.—When turbid water, *i.e.*, water containing matter in suspension, is passed slowly through a bed of fine sand the coarser suspended particles are intercepted by the sand grains on the surface and gradually a coating is built up in which the interstices become smaller and smaller. This coating is composed of finely divided mineral matter together with any micro-organisms (algae, etc.) that were present in the unfiltered water and is generally known as the blanket layer or "schmutzdecke." This layer performs the sole mechanical function of the sand filter and becomes denser as the period of service increases, until finally the resistance produced by it interferes with the operation of the filter. The resistance, measured as loss of head of water, is nil for properly designed filters when new and it is generally found convenient to operate a filter until the loss of head becomes so great that the full capacity of the bed cannot be obtained. The loss of head, under normal conditions, usually increases slowly for some time but finally a point is reached when the loss of head increases rapidly with a constantly decreasing capacity. It is not advisable to allow such conditions to continue as they prolong unduly the time required for draining a bed preparatory to scraping and washing.

The flora of the raw water lying comparatively stagnant on the filter tends to multiply, and by increasing the schmutzdecke reduces the filter-run. Covering the filters has been found beneficial in this respect, especially in tropical regions. In Canada, the covers are necessary as a protection against frost, but in summer they are also an advantage.

It was formerly believed that the "schmutzdecke" was the only purifying agent in a sand filter, but now it is regarded as merely incidental and as a disadvantage rather than otherwise. Schmutzdecke formation governs the length of the run and modern improvements in filtration are in the direction of processes tending to reduce its formation. Sedimentation reservoirs, coagulation basins, and roughing filters are being employed for this purpose. When the raw water is run directly onto the sand filters the suspended matter is almost entirely arrested in the top layer, such turbidity as escapes from a matured bed being often ultra microscopical in size and of a colloidal nature.

Hazen (Trans. Am. Soc. C.E., Vol. LIII., p. 59) has suggested that for very small particles of suspended matter the time of subsidence is controlled by the viscosity which will vary as $\frac{T+10}{60}$, in which T, the temperature, is expressed in degrees Fahrenheit. Longely (Trans. Am. Soc. C.E., Vol. LXXII., p. 398) found that the results obtained during the operation of the Washington filters supported this theory, the turbidity of the effluent being approximately twice as great at temperatures less than 40° than at 70° when the initial turbidity was the same.

The tendency in modern practice is to reduce to a minimum the turbidity of the water supplied to the filter. In the Puesch-Chabal process the degrossiseurs also remove about 60% of the bacteria in addition to reducing the turbidity and a similar action is found in Washington where sedimentation has been supplemented by coagulation. In the latter case an endeavor is made to keep the turbidity of the water supplied to the filters under 20 parts per million.

Physical and Biochemical Action.—When a bed of clean sand is used for water filtration, the purification effected is at first small and it has been found that increased efficiency is coincident with the formation of a slimy, gelatinous covering over the surfaces of the sand particles. These masses or zooglea contain large numbers of bacteria and algae and are responsible for the bacteriological and chemical purification of the water. The bacteria of the water whilst passing over these gelatinous coatings adhere and unless the momentum of the particle is greater than the adhesive power of the sand envelope it remains and is digested. Dunbar, in his "Principles of Sewage Treatment," points out that this film is the active principle in the changes taking place in sewage filters and that, when freshly removed from a submerged bed, has the property of absorbing large quantities of oxygen. When sewage is poured onto a mature bed purification is effected much too quickly to be accounted for by bacterial action, and Dunbar therefore assumed that the action was a physical one, *viz.*, that of absorption of the organic impurities in the water with a simultaneous loss of the oxidized nitrogenous products produced during the previous period of aeration and rest. The Massachusetts Board of Health experiments at Lawrence have shown, that with sewage filters constructed of fine sand, a given volume of material is capable of oxidizing a constant weight of carbon and nitrogen in a given unit of time. This purification is much larger than sand filters are usually required to perform for water purification purposes and, as in the latter case, the operation is continuous and the sand submerged, the oxygen required for the aerobic processes must be obtained from the dissolved oxygen of the water. Non-submerged filters have been employed for water purification purposes, but as the capacity is strictly limited to very low rates this type is not likely to become at all general. In the process of purification the albuminous substances dissolved in the water are absorbed by the film and afterwards decomposed and oxidized; dialysis and osmotic pressure being, according to Dunbar, of minor effect.

The reduction of organic matter by a filter is generally of secondary importance, as organic matter, per se, is not objectionable from a sanitary standpoint. When this organic matter is of such a nature as to produce discoloration its removal is of some importance but in this respect the sand filter is comparatively inert. The usual removal is about 20% to 25% but the amount, as might be anticipated, varies with the nature of the discoloring material.