manganese and as this compound is the basic part of manganese permutit it was concluded that manganese dioxide was the principal factor in the removal of manganese in successful sand filtration.

Two filters were therefore prepared for experimental use. The apparatus (see Fig. 1) consisted of two gaswashing cylinders (A, A) connected at their tops by a siphon to a large carboy (B) holding the water to be treated. The rate of filtration could be so adjusted by two stopcocks (S, S) that both filters would deliver their effluents at the same rate. A glass tube (C) extending to the bottom of the carboy provided means for admitting compressed air for aeration.

Each filter was filled with one litre of clean high-grade filter sand, having an effective size of 0.50 millimetre and a uniformity coefficient of 1.32. One filter was treated successively with solutions of manganous sulphate, sodium hydroxide, and potassium permanganate. After two or three treatments a thin film of black oxide of manganese had formed on the grains of sand. The filter was then washed with water until an effluent free from manganese was obtained. The other filter was used without such treatment. The apparatus consisted, therefore, of two filters working in parallel, one containing sand only, and the other containing sand which had been slightly coated with manganese dioxide. As the depth of sand in each was 35 centimetres the filtering area of each was 28 square centimetres.

The removal of manganese in a manganese-removal filter, depends on the contact of the manganous compound with manganese dioxide; consequently, the rate of filtration should be expressed in terms of volume of water filtered per volume of filter medium and not per area of filter surface. The rate varied slightly in these experiments, but it was so adjusted that a volume of water equal to the volume of the filter medium was filtered in twenty minutes.

Filtration through sand removed iron, but did not detectibly decrease manganese. The content of dissolved oxygen was decreased throughout more than one part per million by passage through the filters, even in the experiment in which no removal of manganese apparently took place. Filtration through sand coated with manganese dioxide removed all manganese and iron, decreased alkalinity 14 parts per million, and decreased dissolved oxygen about the same extent to which it was decreased in the

in the sand filter. In order to determine the effect of adding a coagulant, <sup>2</sup> grains per gallon of alum was added, the water was then <sup>2</sup> grains per gallon of alum was added, the water was then <sup>2</sup> grains per gallon of alum was added, the water was then <sup>2</sup> gerated, and allowed to settle one hour as in the other series. The results obtained indicate that little change is caused by addition of the coagulant. Complete removal of manganese was obtained by filtration through sand coated with manganese dioxide but practically no removal by filtration is the send alone.

by filtration through sand alone. The action in presence of both iron and manganese was studied by treating a water in which to parts per million of manganese as  $MnSO_{1} \cdot 4H_2O$  and to parts per million of iron as FeSO.  $(NH_4)_2SO_4GH_2O$  had been dissolved. After this water had been aerated it had a high reddish-brown turbidity caused by precipitated ferric hydroxide. Treatment of this solution by filtration through sand alone resulted in complete removal of iron but no removal of manganese. Treatment of it by filtration through sand coated with manganese dioxide, however, completely removed manganese and iron. The alkalinity was not decreased by passage through either filter; this is not in accordance with the theory as the removal should have decreased the alkalinity by an amount equivalent to the manganese removed. This apparent discrepancy might be accounted for either by the presence of small amounts of substances capable of neutralizing free acid in the sand, or by oxidation of the manganous compound to a marked degree in the aeration and yet to a degree insufficient to form an insoluble compound.

Though no removal of manganese by filtration through sand could be detected by analysis the upper part of the sand became discolored by a slight deposit of manganese dioxide after the filter had been used for some time. This shows that there must have been some slight but continual removal of manganese by aeration and filtration. This slight deposit would rapidly aid in removal of more and more manganese until sufficient manganese dioxide would have been deposited to remove completely the manganese from water filtered through it; the process might be er;oneously considered to be simply one of aeration and filtration through sand when in reality it is a catalysis by manganese dioxide.

Manganese is efficiently removed from surface-water supplies by filtration through sand coated with manganese dioxide at two plants in Illinois. One of these filter plants was installed for removal of manganese as well as for hygienic purification of the water, and the other was installed for hygienic purification only, the presence of manganese in the water not being suspected. There was evidence of unsatisfactory removal of manganese for some time after the installation of these plants, but efficient removal resulted after a period had elapsed for the deposition of sufficient manganese dioxide in the filters. As no similar observations have been reported a description of these two plants with some of the operating results are presented.

## Summary

Manganese occurs normally in certain classes of water in Illinois, and amounts sufficient seriously to affect the quality have been found in several waters.

Little manganese is present in water from Potsdam sandstone, St. Peter sandstone, the overlying limestones, Lake Michigan, and the large rivers.

Manganese is usually present and often in very large amounts in coal-mine drainage.

Manganese is present in water from some impounding reservoirs on small streams in southern Illinois, and from some wells entering unconsolidated deposits near rivers.

No apparent relation exists between the content of manganese of a water and any of the other mineral constituents.

The persulphate method is the most convenient and accurate method for the colorimetric determination of manganese in water. Chloride does not interfere. Fivethousandths of a milligram of manganese in a volume of 50 cubic centimeters, equivalent to 0.1 part per million can be detected.

The standardized bismuthate method is accurate and reliable. The presence of chloride in amounts less than 5 milligrams does not interfere with this determination. By this method 0.01 milligram of manganese in a volume of 50 cubic centimetres, equivalent to 0.2 part per million can be detected.

The principle underlying all processes for the removal of manganese from water supplies, except those of direct chemical precipitation. is the reaction between manganous compounds and manganese dioxide to form a lower oxide.

The removal of manganese by the permutit process takes place according to this reaction, as the state of oxidation of manganese in the substance is not greater