

Alumina Hydrate in Mechanically Filtered Water

Some Observations on the Passage of Colloidal Alumina Through Water Filtration Plants—Research Work at Toronto Plant Indicates Impossibility of Removing Residual Alumina from Filtered Water—Alumina Becomes an Aluminate?

By NORMAN J. HOWARD* and FRANK HANNAN†

Toronto Filtration Plant Laboratories

PRESENCE of aluminum hydrate in the effluents of mechanical filtration plants has recently caused considerable differences of opinion amongst those directly concerned in the purification of public water supplies. In Toronto, where the new drifting sand system is in commission, an alumina reaction has always been obtained in the filtered water, and in view of the fact that this is an entirely new system, it has been claimed by some to be caused by the direct application of aluminum sulphate to the filters without a preliminary period of coagulation and sedimentation. The exponents of the standard mechanical gravity filter, claim that the filtered water from mechanical plants, if properly operated, would yield an effluent entirely free from aluminum sulphate or aluminum hydrate.

Correspondence has passed between numerous engineers, sanitarians and the writers, as to the conditions existing principally in the states of New York, Maryland and Rhode Island, and the province of Ontario. The consensus of opinion was that the presence of aluminum hydrate in the effluents of many mechanical plants was not an unusual condition, and was frequently met with, and the reason why such cases had not appeared in the experiences of some water works authorities, might well be due to the fact that a number of consulting engineers have little or no routine relation with the daily operating details or results in filtration plants.

Investigation Confirms Previous Opinions

In view of the importance of the question, it was thought desirable to investigate further the conditions with the object of throwing light, if possible, on a subject involving a study of some of the colloidal properties of aluminium about which so little is known. It is yet too early to form any definite conclusion, and the opinions expressed hereafter are only based upon conditions as actually found to exist in Toronto.

Investigation in the laboratories of the filtration plant have confirmed previously expressed opinions that the removal of aluminum hydrate in treated Lake Ontario water is an impossibility. It is not proposed even to consider the question of aluminum sulphate occurring in the effluents of the Toronto plant, as with a normal alkalinity in the raw water of nearly 100 parts per million estimated as CaCO_3 , the presence of undecomposed alum would be a chemical impossibility.

The initial laboratory experiments were made with mechanically filtered water, and with water treated in the laboratory with aluminum sulphate. The quantity of chemical applied ranged between one-half and two and one-half grains per imperial gallon. A period of four hours' sedimentation was allowed the laboratory samples before filtering through small rapid sand filters. The samples were then tested for a positive or negative alumina reaction. The reagents used were fresh solutions of extract of logwood (1%), hæmatoxylin (0.3%), and $\text{N} \times 6$ acetic acid. The presence of alumina was determined by the formation of a blue to purple color which after acidification turned to pink or brown. In the absence of alumina a deep pink color resulted, which turned to yellow on addition of the acid. It was found that control tubes were always necessary on account of the extremely sensitive nature of some of the reactions.

Throughout the whole series of a large number of tests, not a single sample that had been mechanically filtered or

artificially treated with alum in the laboratory, failed to give a positive reaction. Further experiments were made to determine if six thicknesses of very fine paper would retain the hydrate. The filter paper used was Whatman's No. 5. In order to get water through the filter a suction pump was used.

The results of these tests were extremely interesting, as it was found that the first 50 c.c. of water which had passed through, showed a considerable decrease in the intensity of the reaction. The next 50 c.c. gave an increase over the first 50, while after the passage of 200 c.c. little change could be seen in the filtered and unfiltered solutions.

This clearly pointed to adsorption and the explanation of this would seem to point to the action being electrostatic. When positive hydrosols are passed through filter papers which are negatively charged in contact with pure water, adsorption of the positively charged hydrosols (colloidal alumina) and the neutralization of the negative charge of the filter paper result. When sufficient of the hydrosols have passed through to render the filter paper neutral, adsorption no longer takes place and alumina passes through freely in colloidal form. This explanation is supported by the fact that a filter paper which has had its negative charge neutralized by the adsorption of Al ions has much less action than a fresh paper.

A similar experiment was made with the positive colloid methylene blue (0.5 p.p.m., or a 0.00005% solution). This was passed through six thicknesses of filter paper and the color was retained until 1,115 c.c. had passed, after which a gradual and progressive increase was noted. The experiment was continued until 10,065 c.c. (approximately ten litres) had been filtered, after which it was impossible to distinguish between the filtered and unfiltered solutions.

Experiments were next made to determine the effect of variation in the rate of filtration. Water treated with 1 grain per gallon, and mechanically filtered at the rate of 75, 100, 125 and 150,000 gallons per acre per day, showed little change in the alumina reaction. It should be pointed out here that our observations showed the sand to retain alum for a considerable period after the application of alum had ceased, and that frequent backwashing was necessary to free the sand particles from the hydrate. This experiment was duplicated using the small laboratory filters, when similar results were obtained.

Effect of Lime

Further tests were made to determine the effect of the addition of Ca(OH)_2 to water treated with aluminum sulphate. To each sample of raw water one grain of alum was added plus the molecular equivalent of lime water [1.5 c.c. of $\text{N} \times 0.04524 \text{ Ca(OH)}_2$ solution] necessary for exact precipitation. The application was in the following order:—

- Series 1.—Water+Lime+Alum.
- " 2.—Water+Alum+Lime.
- " 3.—(Alum+Lime)+Water.
- " 4.—Water+Alum.
- " 5.—Control: Water+Lime.

The physical effects were first observed and it was seen that numbers 1, 2, and 4 generally flocced in a similar manner, but that number 3 produced a heavier floc which precipitated rapidly. The principal reason for making these tests was to determine if the addition of lime would decrease the residual hydrate after filtration. After standing 30 minutes, all samples were filtered through fine filter

*Bacteriologist in charge. †Chemist.