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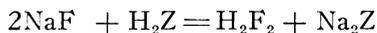
THE REMOVAL OF FLUORIDES FROM WATER BY IONIC EXCHANGE

R. E. BENSON, D. L. PORTH AND O. R. SWEENEY

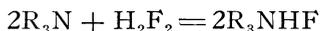
Mottled enamel is the term originated by McKay to describe the disfigurement of teeth which Smith and others discovered was caused by the presence of fluorides in drinking water. Since then considerable time, energy and money have been spent in an effort to find an economical method of removing fluorides from drinking water. At first the use of activated carbon and activated alumina were rather promising; but more recently the use of tricalcium phosphate to remove fluorides from water has been developed (2).

A patent by Adams and Holmes (1), wherein it was claimed that the sulphate ion concentration could be reduced nearly to zero, suggested that the fluoride content of water might be reduced to a permissible value by anionic exchange. Such a method of fluoride removal was investigated as a part of the research program concerning water treatment which has been in progress for many years at Iowa State College.

A fluoride solution of 10 p.p.m. of fluorine in tap water was passed in series through two beds of exchange material. The first bed of exchange material was Zeo-Karb H (furnished by the courtesy of the Permutit Company) and this substance replaced the alkali metals in the solution with hydrogen according to the equation:



The effluent was then passed through a bed of Nalcite B, an anionic exchange material furnished by the courtesy of the National Aluminate Corporation. This resin removed the hydrogen fluoride according to the equation:



As this method reduced the fluorine concentration to only 2 p.p.m., the procedure was further altered by passing the solution of sodium fluoride through four beds in series. The first and third beds consisted of 60 cc. each of Zeo-Karb H while the second and fourth beds each consisted of 60 cc. of Nalcite B.

The results obtained by the improved procedure are recorded in Table I. In determining the fluorine content, 100 cc. portions of

the effluent were analyzed by the colorimetric method described by Sanchis (3).

Table I. The Removal of Fluorine by Means of Zeo-Karb H and Nalcite B.

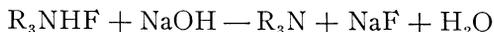
Run 1		Run 2	
CC. of Effluent	Fluorine Conc.	CC. of Effluent	Fluorine Conc.
	p.p.m.		p.p.m.
400	0.25	300	0.25
600	0.25	600	0.25
800	0.25	900	0.25
1000	0.25	1500	0.25
1200	0.25	2000	0.25
1400	0.25	2500	0.25
1600	0.25	3000	0.25
3200	1.0	3700	0.25
		4800	0.5

In the preceding tests a large excess of acid was used to regenerate the exhausted Zeo-Karb according to the equation:



In the following tests the amount of acid regenerating solution passing in series through both was reduced to approximately 200 cc. of 5 per cent hydrochloric acid solution. The time of contact of the regenerating solution with the Zeo-Karb was 20 to 30 minutes. After regeneration, the two beds of Zeo-Karb were washed with distilled water. The rate of flow of the wash water was 20 cc. per minute and the time of washing was 25 minutes.

The two beds of anionic exchange material were also regenerated in series; the caustic solution entered the fourth testing cylinder at the top and left the second testing cylinder at the bottom. Originally a five per cent caustic solution was used but this required an excessive amount of washing so the concentration was reduced to two per cent and then to 0.5 per cent. In the following tests, a 0.5 per cent solution of sodium hydroxide was passed through the two beds of anionic exchange material in series at the rate of 30 cc. per minute for a period of 30 minutes. This treatment regenerated the exhausted Nalcite B according to the following equation:



The method of washing the anionic exchange material was the same as previously stated for the Zeo-Karb.

In order to test the capability of the dual ionic exchange process for removing fluorine from concentrated solutions, a test was made in which the fluorine concentration was 2,000 p.p.m. The results are given in the following table:

CC. of Effluent	p.p.m. of Fluorine
500	0.5
800	0.5
1000	0.5
1200	5+

After the ionic exchange materials had been regenerated and washed, experiments were made in which a natural rather than a synthetic fluorine containing water was tested. Water from the former water supply of Ankeny, Iowa, was used in a series of tests. As the well had been capped for several weeks, the city having obtained another source of water with a much lower concentration of fluorides, the effluent from the first hour of pumping was discarded. The fluorine content of this water was 9 p.p.m. In Table II are recorded the results of one of several tests in which the rate of flow of effluent was 25 cc. per min. After this particular test the exhausted Nalcite B was regenerated with a 0.5 per cent caustic solution and the fluorine concentration of the resulting effluent was determined. These results are recorded in Table III.

Table II. Removal of Fluorides
Ankeny Water

Table III. Regeneration

CC. of Effluent	Fluorine ¹ Conc. p.p.m.	CC. of Effluent	Fluorine ¹ Conc. p.p.m.
600	0.25	160	very high
1200	0.25	320	very high
1800	0.25	500	very high
2400	0.25	660	very high
3000	0.25	830	5+
3600	0.25	1030	3+
4200	0.25	1190	1.7
4800	3+	1370	1.3
5400	5+		

* No attempt was made to determine the actual fluorine concentration of a sample that contained more than 5 p.p.m. of fluorine. The fluorine content was simply recorded at 5+.

The purpose of this investigation was to develop a method of removing fluorides from water. The results obtained clearly show that the fluorine content can be reduced by double ionic exchange to less than the permissible value of 1 p.p.m. which is allowed by many health authorities.

LITERATURE CITED

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