Nomograph for Defluoridation of Water in Batch using Fish Bone Char

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SUMMARY: Based on literature data on laboratory studies on batch defluoridation of water using fishbone charcoal, a nomograph is established. It concludes removal capacities between 0.05 and 0.65 mg/g.
The nomograph can be used for handy estimation of dose of fish bone char and stirring time required to defluoridate water containing up to 30 mgF/L down to acceptable level of 1.5 mg/L.

Key words: Defluoridation, nomograph, batch, fish bone char, removal capacity.

INTRODUCTION

In many parts of the world, particularly in the Indian and African regions, water contaminated with high concentrations of fluoride are the only source of drinking water. Internationally, a drinking water is not supposed to contain fluorides beyond a level of 1.5 mg/L. This limit is however, locally varied depending on the local situations, availability of alternatives, economy of the region, etc. For example, Indian standards limit a fluoride concentration of less than 1.0 mg/L, but in some African locations, a fluoride level of as high a concentration as 5 to 8 mg/L is forced upon the general public.

It is next to impossible to make treatment for fluoride removal at a municipal scale. It is however, possible to bring down a water's fluoride level to acceptable levels for the field, domestic or isolated situations. Several materials have been used as adsorbents for fluoride removal. The treatment modes could include systems such as the batch[1-20], column[21-22], counter-current[23-39], etc.

This paper presents nomographs for determining the adsorbent dose and time of contact required for bringing down the level of fluoride concentration to less than 1.5 mg/L. The stated nomographs have been prepared on the basis of laboratory data collected during a batch mode of study for fluoride removal using indigenously prepared fishbone charcoal as the adsorbent material. The handy nomographs are conveniently used for instantly evaluating the series of steps necessary to handle waters containing fluoride of concentrations as high as 30 mg/L.

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MATERIALS AND METHODS

Literature review. The methods for excess fluoride removal from waters include the adsorption, ion-exchange and precipitation methods employing various materials such as activated carbon, activated alumina, bone charcoals, phosphatic compounds, cation and anion exchangers, lime, alum, etc. The extensive works include those from Boruff [40], Smith and Smith [41], Maier [42-43], Savinelli and Black [44], Harmon and Kalichman [45], Rubel and Wooslay [46], Wu and Nitya [47], Hao and Huang [48], Weber [49], Dahi et al. [50], Bhargava [1-39], and many others. A comprehensive review was presented elsewhere [2, 3].

Charring of fishbone. The fishbone charcoal was prepared by carbonising the cleaned and pulverised fishbone in an electric furnace in a closed retort at 1000° C for 2 hours. The cooled material was sieved to get the required size(s). The bulk density and specific surface area of the material was determined to be 1.8 g/cm^3 and 85 m^2/g respectively. The material was thoroughly washed with distilled water, oven dried at 103° C, desiccated and stored in airtight containers.

Fluoride water. The test fluoride solutions of different initial fluoride concentrations were prepared by adding appropriate amounts of sodium fluoride to the tap water[9]. The various experimental runs were conducted at room temperature of 20 ^{0}C ± 2 ^{0}C with the test fluoride solution placed in glass beakers to which the different doses of the adsorbent material were added. The stirring in the beakers was done at 100 rpm (revolutions per minute) through the paddles of the jar test apparatus. The samples were collected at predetermined times and were analysed for residual fluoride concentration by Orion Ion Analyser Model 901 (M/S ORION Research Mfg. Co., USA) by using a specific ion electrode.

RESULTS

Observed data. For preparing the nomographs, the laboratory data [4, 7-9] has been selectively summarised in Table 1. The reported data pertain to the indicated values of temperature, pH, stirring rate, adsorbent size, and efficiency.

Preparation of nomograph. The batch treatment data available in Table 1 and the original sources of such data have been processed to establish relationships between the adsorbent dose and contact times in respect of the various initial fluoride concentration levels in the water that are reduced to a level of 1.5 mg/L or less. In situations where the initial fluoride concentration is extraordinarily high, similar relationships have been determined to bring down the fluoride level to indicated values, and the process can be repeated in one or more steps in series for achieving the final fluoride concentration at the desired acceptable level. The plots of these stated relationships in respect of the various initial fluoride concentrations make the nomograph as presented in Figure 1.

TABLE 1. The processed data showing the initial and final fluoride concentrations and resulting capacity of removal at the indicated adsorbent dose and contact time.

Adsorbent Dose (g/L)	Contact Time (min)	Initial conc. mg F/L	Final conc. mg F/L	Capacity mg F/g medium
32	5	3.0	1.5	0.05
16	7.5	3.0	1.5	0.09
8	22.5	3.0	1.5	0.19
4	25	3.0	1.5	0.38
2	240	3.0	1.5	0.75
32	30	6.5	1.5	0.16
16	120	6.5	1.5	0.31
8	120	6.5	2.6	0.49
4	120	6.5	3.9	0.65
2	60	6.5	5.2	0.65
32	300	10	1.5	0.27
16	960	10	-	-
32	5	10	5.0	0.16
16	30	10	-	-
8	90	10	-	-
32	15	20	10	0.31
16	30	20	-	-
8	80	20	-	-
32	30	30	15	0.47
16	60	30	-	-
8	270	30	-	-

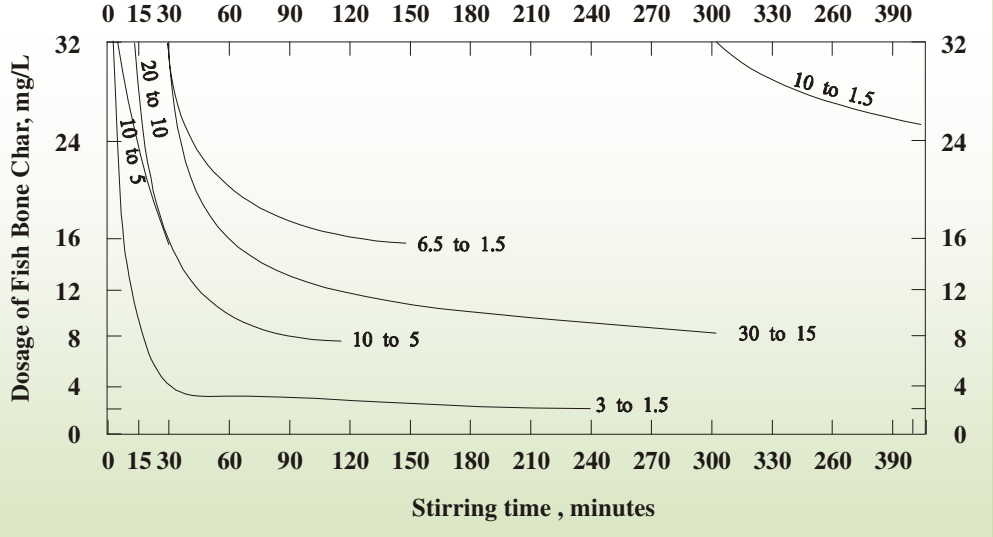

Figure 1: Nomograph for defluoridation in batch, indicating required stirring time and dosage of fish bone char and expected reduction in fluoride concentration in mgF/L . Stirring rate of 100 rpm, temperature of 20 °C, and pH of 8.0, using an adsorbent material size of 0.55 mm.

The nomograph have been constructed for an adsorbent material size of 0.55 mm (the geometric mean size of a mix varying between the sizes of 355 μ and 855μ) (the adsorption was found to increase with decreasing adsorbent sizes), temperature of 20 ^{0}C (the adsorption was found to increase with increasing temperatures), pH of 8.0 (the adsorption was found to increase with decreasing pH values) and the stirring rate of 100 rpm (revolutions per minute) (the adsorption was found to increase with increasing rates of stirring) [1-39].

DISCUSSION

Practical applicability. The nomograph can appropriately be manipulated (inter- or extrapolated) for initial fluoride concentration values other than the indicated ones. The adsorbent dose can be easily worked out for an assumed convenient contact time in a given situation of the initial fluoride concentration. Similarly, the contact time for treatment can be worked out for an assumed allowable dose of the adsorbent. The nomographs are thus most useful in both the situations, that is, when the allowable time at hand is limited and also when only a limited total amount of the adsorbent material is readily available.

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