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AFFORDABLE WATER SUPPLY AND SANITATION

Defluoridation technology based on activated alumina

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IN THIS PAPER the experiments related to the development of defluoridation unit at domestic level for a 3 mg/1 flouride water, using activated alumina are presented in detail. The design and other specifications of the defluoridation unit are given. Details regarding the field studies in a fluorosis-affected village nearby Gandhigram are also discussed.

Materials and methods

Several grades of activated alumina with different particle sizes were first taken up for the study. After trial and error experiments, taking into consideration the defluoridation capacity of the material and the rate of flow of water through the bed of activated alumina, three different particle sizes were selected for further investigation with an aim to select the most suitable one among them for use in the defluoridation unit. The particle sizes of the three different grades of activated alumina studied, are: Grade I: >300 <355, Grade II: >150<300 and Grade III: >125<150 microns.

Column experiments were carried out in order to find out the variation of the rate of flow of water through the packed bed of activated alumina with a change in the height of the bed keeping the height of the water column above the bed as constant. These experiments were performed (with each of the three grades of alumina) at three different heights viz. 20, 25 and 30 cm of the activated alumina column. The diameter of the column used was 3.7 cm and perfectly dried alumina of each grade was used in the experiments.

The defluoridation capacities of the three grades of activated alumina were determined by column experiments, fixing the height of the column of alumina as 25 cm. the input water with 3 mg/1 fluoride and with an alkalinity of 432 mg/1 was actually selected from a fluorosis-affected village, Kolinjipatty, situated nearby Gandhigram after carefully analysing various drinking water sources of that village for fluoride concentration by the fluoride electrode method (Fluoride electrode manual, 1977).

The concentration of fluoride in output water was monitored periodically and defluoridation experiments were continued till the output water fluoride did not exceed 1 mg/1 which is the tolerance limit as prescribed by the Bureau of Indian Standards. The defluoridation capacity of activated alumina was then calculated (S. Meenakshi, 1992).

Regeneration of exhausted alumina was carried out with two different regenerant solutions, viz., 2% sodium bydroxide and 2% hydrochloric acid.

Table 1.
Rate of flow of water through activated alumina

Grade	Particle size (microns)	Height of the column (cm)	Rate of flow of water (lit./hr.)
I	>300<355	20	4.6
	25	4.2	
	30	3.7	
II	>150<300	20	1.6
	25	1.3	
	30	0.8	
III	>125<150	20	0.9
	25	0.7	
	30	0.5	

Results and discussion

Results of the experiments on determination of rate of flow of water through the activated alumina column, at various heights of the column, at various heights of the column are given in Table 1.

These results indicate that there is a significant change in the rate of flow of water with a change in particle size as well as in the height of the column. The rate of flow is found to increase in the order with an increase in particle size because, the pore volume of the bed increases with increasing particle size. There is a decrease in rate of flow with increasin the height of the bed because the resistance offered by the bed itself itself increases with the increase in the height. Selection of a suitable height of the absorbent column is essential before we design any defluoridation unit because of two reasons:

(i) A minimum contact time is necessary between the fluoride and activated alumina particles.

(ii) On the other hand, the rate of flow should not be too low in which case there will be problem of acceptability of the design by the users.

The results of defluoridation capacities of the three grades of activated alumina are given in table 2.

These results indicate that there is increase in defluoridation capacity in the order, grade I < grade II < grade III as expected. Out of the three grades, grade III

Table 2.
Defluoridation capacity of activated alumina

Grade (microns)	Particle size (microns)	Defluoridation capacity
I	>300<355	960
II	>150<300	1140
III	>125<150	1220

showed somewhat higher defluoridation capacity but with this grade the rate of flow of water is lowest. On the other hand, for the grade I the rate of flow of water is highest but it suffers from the disadvantage of having lowest defluoridation capacity among the three. As both the factors viz., defluoridation capacity and rate of flow of water are equally important (none of the two can be given preferential treatment over other), it was felt reasonable to select the grade II which has good defluoridation capacity as well as good pore volume to give the necessary rate of flow of water.

The results of regeneration experiments showed that 2% HC1 is a better regenerant with a regeneration capacity of $2.2 \times 10m^{-2}$ m^3 of alumina / Kg of HC1.

Based on the results obtained activated alumina grade II with the particle size > 150 < 300 microns was finally selected. Using this material the height of the column has to be finalised. Secondly, the quantity of the activated alumina to be taken in the unit is to be decided taking into account the cost factor also. Several trials were made with different quantities of activated alumina in stainless steel cylindrical columns of diffeerent dimensions. The most optimum dimensions of the column were found to be as follows.

i) Radius of the column = 5 cm

ii) Height of the column = 25 cm

With these dimensions of the column, the volume of the activated alumina bed comes to be 1.964 litres which accommodates about 2 kg of the material.

Using this stainless steel cylindrical column with the dimensions of 5cm radius and 25 cm height, attempts were then made to develop a suitable design of the unit with the provision for the input water reservoir at the top and the treated water collector at the bottom.

The radius of the column is such that a vertical three container design keeping the column in the middle, reservoir for input water at the top and the collector for treated water at the bottom is not easily acceptable by the users. Acceptability of any model by the users is the most important criterion for the success of any technology. Being conscious of this point, we surveyed the various water filters available in the market which are already accepted by the people. The objective of the survey is whether we can fit in our design into the already accepted model. After several attempts, it was possible to attach the column to the input reservoir of the existing filter itself. The design and the specifications of the defluoridation unit developed are shown in Fig.1.

The capacities of the various components of the unit are as follows.

Input reservoir capacity	=	12 lit
Column capacity	=	2 lit
Capacity of treated water	=	13 lit

Details regarding defluoridation of water with this unit are as follows.

Rate of flow of water	=	3 lit / hr
Input water fluoride	=	3 mg / 1
Output water fluoride	=	1 mg / 1
Defluoridation capacity of the material	=	1140 mg F / Kg
Frequency of regeneration	=	3 months

At the rate of consumption of 12 litres per day, for a family of three to five, exclusively for drinking and cooking purposes, the material gets exhausted only after 95 days that is, approximately 3 months. The total cost of the defluoridation unit including activated alumina = Rs. 650.00. The recurring cost of defluoridation / annum for a family of three to five persons = Rs. 30.00.

Figure 1. Defluoridation unit using activated alumina

Field trials

Field trials were carried out in a village Kolinjipatti, Nilakkottai block, Dindigul Anna District of Tamilnadu in South India. This unit was used by the members of the selected family continuously for a period of three months. Periodically (once in a week) the treated water samples

Table 3.
Fluoride & pH levels of water samples during field trial

S.No.	Raw water		Treated water	
	Fluoride (mg/1)	pH	Fluoride (mg/1)	pH
1.	3.0	7.6	0.70	7.7
2.	3.0	7.7	0.72	7.9
3.	2.9	7.6	0.70	7.7
4.	3.0	7.8	0.75	8.0
5.	3.0	7.7	0.79	7.8
6.	3.0	7.5	0.81	7.8
7.	3.0	7.6	0.83	7.8
8.	3.0	7.7	0.85	8.0
9.	3.0	7.8	0.87	8.0
10.	3.0	7.6	0.88	7.9
11.	3.0	7.6	0.92	7.9
12.	3.0	7.7	0.93	7.9

were analysed for fluoride and pH in the laboratory and the results are given in the table 3.

Acceptability by the family

After just one week of using this defluoridation unit, the family got adapted to it and they have used the unit for a period of three months without anycomplaints. The fluorosis affected families in the village, out of curiosity, visited the unit and got convinced of the ease of operation of the unit. The point that for the same cost of an ordinary water filter, they can get defluoridated water, impressed the people very much.

References

Fluoride Electrode Instruction manual, Orion Res.Inc., U.S.A., 1977.

A. Meenakshi, Ph.D. Thesis, Gandhigram Rural Institute, Gandhigram, 1992.