LOW COST DOMESTIC DEFLUORIDATION

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SUMMARY: A simple household defluoridator is designed as a column, provided with a funnel attached to a down pipe arrangement, in order to allow for upflow filtration of fluoride water through a medium of locally available brick pieces. The unit is made of PVC-pipes of 1 m length and 20 cm diameter. Alternatively of brick/cement concrete of larger diameter in order to obtain sufficient removal when treating water of relatively high fluoride content (1.4 - 8 mg/L). Removal efficiencies observed are between 85 at the start of the operation period and 25 % at the end of it. The operation periods are between 90 and 250 days, after which the medium is replaced. Awareness programmes were conducted for school children, health staff, pre-school teachers and government officers at grass root level. The beneficiaries themselves were trained to change the filter medium in time in order to get optimum operation and maintenance. Eight hundred defluoridators were distributed in stages after the awareness programmes and they are in operation in different villages. A survey showed that nearly 85 per cent of the defluoridators are in working order, indicating the sustainability of the developed technique.

Key words: Fluoride; Defluoridation; Fluorosis; Bricks; Clay; Upflow filtration; Sri Lanka.

INTRODUCTION

Dental and skeletal fluorosis is an endemic problem in certain parts of the world such as China,[1] India,[2] and the Rift Valley of Africa. In recent studies it was shown that more than forty per cent of the wells in the North Central Province of Sri Lanka has fluoride rich water. Fluoride content of more than 1 mg/L was considered as fluoride rich water. Dental fluorosis had been identified as an endemic problem in the dry zone areas of Sri Lanka. The unsightly brown discoloration of the teeth had led young children affected in villages to a severe psychological impact. In addition medical reports revealed that skeletal fluorosis patients have been identified especially in certain dry zone areas in Sri Lanka.

Presently several methods have been practised to defluoridate water but in developing countries, the application of these techniques has certain drawbacks at the time of implementation. In Sri Lanka several methods are available, using filter media such as Serpentine, activated Alumina, Alum, and Charred bone meal. In all these methods the main disadvantage is that the filter media used is not readily available for the affected community.

In contrast the filter medium used in this study is freshly burnt bricks, which is freely available in affected localities. In addition replacing the filter medium upon saturation in the proposed unit is a low cost easy operation, which can be carried out at domestic level with negligible maintenance cost and absence of negative impacts on the environment.

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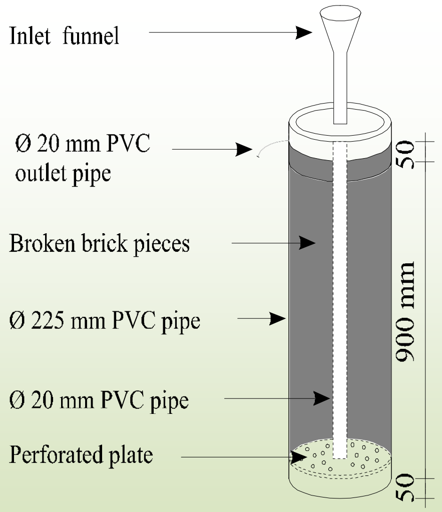

FIGURE 1. Low cost Defluoridator

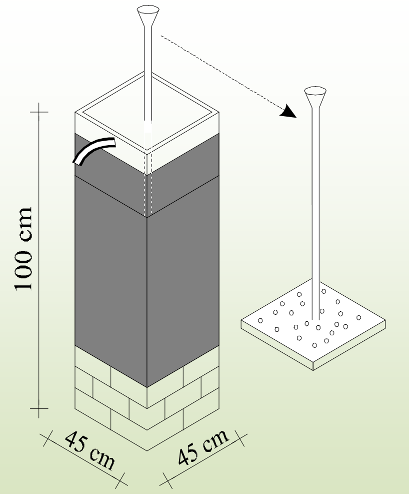

FIGURE 2 Defluoridator made of cement and bricks

MATERIALS AND METHODS

PVC-defluoridator. The newly designed household defluoridator is made of a PVC pipe, 100 cm in height and 20 cm in diameter. The inner diameter is 2 cm. The filter has a circular perforated plate fixed at 5 cm from the bottom. The outlet is fixed 5 cm below the top of the filter. The filter unit is packed up to a height of 75 cm with broken pieces of freshly burnt bricks, grain size 8-16 mm. The filter medium used for the removal of fluoride is low temperature burnt clay pieces. The fluoride rich water is fed through a funnel like inlet pipe at the top (Figure 1).

Before the start of operation the filter unit is filled with fluoride rich water and kept for at least 12 hours. Thereafter, when fresh fluoride rich water is fed through the inlet pipe, an equal volume of defluoridated water comes out automatically through the outlet. The efficiency of the defluoridator was tested by analysing the fluoride contents in the inlet and outlet at various time intervals.[3]

Brick/cement defluoridator. In an alternative design, the defluoridator is made out of cement and bricks (Figure 2).

Programme strategies. The strategies worked out in the pilot defluoridation programme in Sri Lanka may be listed as follows:

Awareness programmes were carried out in Village Schools. The students were requested to bring water samples of their wells. Analysis of these samples helped in the identification of fluoride rich wells.

With the help of public health officers, families with children less than 5 years of age using high fluoride drinking water were selected.

Thereafter awareness programmes were carried out to the beneficiary families and the defluoridators were distributed with special emphasis made on the change of filter media at appropriate time intervals.

TABLE 1. Fluoride removal percentages of the defluoridators

Unit No.	Period of the tested cycle	Cycle length, Days	Well * mg F^{-}/L	Outlet ** mg F^{-}/L	Fluoride removal, %
06	94.09.08 - 95.05.15	250	1.74	0.83	65.5 - 21.7
09	94.11.17 - 95.10.05	326	1.42	1.26	29.1 - 11.3
11	95.03.20 - 95.08.30	160	1.86	1.23	76.2 - 35.3
12	94.09.10 - 94.04.15	220	1.45	0.87	49.3 - 33.0
13	94.11.17 - 95.03.20	124	1.60	0.77	82.7 - 40.3
26	95.05.10 - 96.12.30	235	2.35	1.43	77.6 - 31.3
41	95.01.02 - 95.03.28	87	3.68	2.30	76.7 - 29.2
10	94.09.26 - 95.02.20	155	2.85	0.65	72.6 - 22.6
14	95.05.21 - 96.02.07	270	2.43	1.47	? - 39.5
29	95.04.21 - 95.08.25	120	2.30	1.40	53.9 - 37.2

* Average value. ** At the end of cycle

Several visits to these beneficiaries were done in the first year to guide them in operation and maintenance. During these visits water sampling and testing were done to evaluate the efficiency of the defluoridators.

A visit at least once in six months thereafter for a period of 5 years is planned to check the functioning of the defluoridators and to encourage the continuous use.

RESULTS

The removal efficiency of the defluoridator is determined to be between about 85 % at the start of an operation period and down to 25 % at the end of it. In a survey, it was found that about 80 % of the defluoridators were in operation by the beneficiaries. Table 1 shows the percentage of fluoride removal in defluoridators run by beneficiaries in one village. All the beneficiaries had changed their filter medium on time, showing that the beneficiaries could manage these defluoridators on their own. The life span of the brick medium depends upon the fluoride content of the well water. It also depends on the daily consumption pattern of the household and the size of the brick pieces packed in the defluoridator. Column 4 in table 1 gives the fluoride

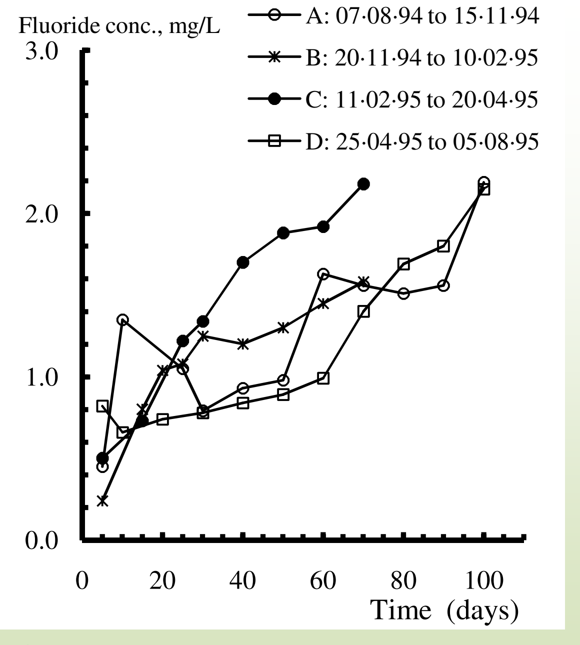

FIGURE 3. Effluent fluoride conc. vs. time in defluoridator No. 42, (Volume 24 L. Dia.= 280 mm. Average inlet F = 5.0 mg/L).

content of the defluoridated water at the time of changing the filter medium. It was observed

that the fluoride content of the defluoridator No. 41 was high in spite of changing the medium within 87 days. This is because of the relatively high content of fluoride (3.68 mg/L) in the well.

Figure 3 shows data of a defluoridator, unit 42, with a large diameter of 280 mm, thereby increasing the capacity of the defluoridator. This facilitates the treatment of water containing higher content of fluoride (5 mg/L). The beneficiary was provided with this unit and instructions were given on its usage. The consumption rate of this household was 8 litres of defluoridated water per day. Accordingly after every 70 to 100 days of operation the filter medium had to be changed to obtain the best efficiency as shown in Table 2 and Figure 3, graphs A,B,C, & D.

TABLE 2. Defluoridator no. 42.

Inlet fluoride (mg/L)	Period	Graphs	F^- content treated water (mg/L) Start	End
5.0	7.8.94 – 15.11.94 (100 days)	A	1.00	2.00
5.0	20.11.94 - 10.2.94 (70 days)	B	0.24	1.24
5.0	11.2.95 – 20.4.95 (100 days)	C	0.50	1.85
5.0	25.4.95 – 5.8.95 (70 days)	D	0.66	1.75

DISCUSSION

A larger defluoridator of capacity 50 x 50 x 100 cm^3 was built with cement mortar and bricks by a village mason in a household. The water samples were collected periodically. In this defluoridator high levels of fluoride can be defluoridated as indicated in Table 4. The average fluoride content of the water used in this defluoridator was 8.0 mg/L. The consumption rate of defluoridated water in this household was 15 litres per day. Table 4 gives the fluoride content of defluoridated water up to 100th day of operation of the unit.

TABLE 3. Performance of a brick/cement defluoridator. Volume=250 L F_{inlet} = 8 mg/L.

Time, days	Effluent, mgF/L
01	2.95
07	1.30
15	1.20
30	1.06
50	1.24
60	1.46
70	1.44
80	1.50
100	1.70

This domestic defluoridator, Figure 1, was compared with the bone char method[4] practised in Sri Lanka. The salient features of the two methods are given in Table 4.

The burnt clay brick have silicates, aluminates and hematites as main components. When brick chips are soaked in water for several hours, these oxides get converted to oxyhydroxides of iron, aluminium and silica. The Si-O Al-O bonds are much stronger than Fe-O bonds. The geochemistry of fluoride ion (ionic radius 0.136 nm) is similar to that of the hydroxyl ion (ionic radius 0.14 nm) and these can be easily exchanged between them. As it takes minimum of 4 hours for the ion-exchange to take place, it is advocated to draw the water in the morning and evening. The upward flow technique used, prevented the sand particles mixing with water.

TABLE 4. Comparison of the brick chips defluoridation with conventional bone char method.

Description	Bone char method	Brick pieces method
Methodology	Adaptation form Thailand	Locally developed
Flow Direction	Downward flow	Upward flow
Filter medium	Medium has to be fabricated and supplied to the community	Broken brick is already available in the localities
Cost of replacement	US$ 5.0	US$ 1.0

The results show that the developed defluoridators do not remove fluoride from the completely. It is a known fact that certain amount of fluoride in the range 0.5 to 0.8 mg/L is required for human body.

The fluoride removal efficiency, as observed, varies in the range of 80 to 30 per cent. For an inlet concentration of 4 mg/L this corresponds to an average residual concentration of 2.2 mg/L. It is therefore inferred that even a high fluoride level of 8 mg/L could be brought down to less than 2 mg/L by increasing the unit diameter and thereby its efficiency and capacity (Table 3).

Thus the important feature of the developed filter unit is the low cost of replacement of filter medium and its availability in the localities. This probable explains why the survey carried out indicated that the adopted technique is acceptable and sustainable technique for use at domestic level. With the help of awareness programmes and in collaboration with health staff, the developed technique may alleviate fluorosis in Sri Lanka.

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