Method of excessive fluoride removal from potable water: A fluorosis preventive measure

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Abstract

Fluoride removal capability on heat treated bone was studied both in batch and filter column in the laboratory. Field studies of filter column were carried out with 30 defluoridation units installation in 30 randomly selected households in Kitefu village where fluorosis is a major problem. Laboratory results gave fluoride removal capacity of 3.8 mg fluoride per gram heat treated bone at a residual fluoride concentration of 7.88 mg/L using a filter column. On batch experiments capacities ranged between 3.5 to 4.6 mg fluoride per gram heat treated bones. In both cases the initial fluoride content of the raw water was 8.5 mg/L and a contact time of 30 minutes. Field results gave a fluoride removal capacity of 12.41 mg fluoride per gram heat treated bones. The total cumulative fluoride removed was 21,102.3 mg at a residual fluoride content of 0.31 mg/L from an initial fluoride level of 2.8 to 3.2 mg/L. The total volume of water treated was 8,250 litres. Palatability parameters are within the acceptable limits, pH value less than 8.5 apparent colour less than 50 PtCo/L and turbidity less than 5 NTU. Taste and odour were not displeasing. Bacteriological quality gave nil count total coliforms per 100 mL.

Introduction

Tanzania has problems of high fluoride in some of its surface and groundwater sources. In some places of the amounts of fluoride in drinking water exceeds the general World Health Organization (WHO) guideline of 1.5 mg/L (1). The regions severely affected by excess fluoride in their water sources are Arusha, Kilimanjaro, Mwanza, Shinyanga and Singida. This has been well established by the Soil and Water Laboratory of the Ministry of Water at Ubungo Dar es Salaam, as well as by Brokonsult AB a Swedish firm which was commissioned in 1978 to undertake a study for the Rural Water Quality Programme in Tanzania (2). When executing the Water Master Plan Programmes, more water samples were collected and analysed for physical and chemical parameters in which fluoride was one of them (3).

In Shinyanga region water samples from shallow wells have recorded concentrations as high as 60 mg/L, while for drilled boreholes a figure of 49 mg/L fluoride was recorded (4). In Singida values of up to 67 mg/L fluoride were observed in shallow and deep aquifers (5). In Arusha Region, Arumeru District is the most affected where values of fluoride up to 80 mg/L were recorded from a borehole. Springs gave values as high as 15 - 63 mg/L (6, 7). As a result people in these regions using water sources with fluoride above 1.5 mg/L suffer from dental, skeletal and in some cases crippling fluorosis.

Defluoridation has been considered to be one the possible methods of reducing excessive fluoride in potable water, but due to lack of appropriate technolgy and unavailability of resources to support research on appropriate defluoridation methods no proper defluoridation programme was laid down to solve the problem of excessive fluoride in potable water. As a result the country adopted a temporary standard for rural water supplies of 8.0 mg/L fluoride (8). If the guideline set by the WHO was adopted, then Tanzania would have 30% of its water sources as unsuitable for domestic consumption (9).

The problem of excessive fluoride in potable water was realized by the Government as early as 1950. However it is only in 1980's that the Ministries of Water and Health, took concrete steps towards solving this problem and as a result various defluoridation methods were considered for use in Tanzania.

Amongst the solutions was the development and testing of household defluoridation device which is appropriate, affordable and acceptable to Tanzanian conditions.

This paper reports on the results a defluoridation unit which used heat treated bone media. Thirty defluoridation units were field tested for a period of nine months in Kitefu village Arusha region Tanzania.

Materials and methods

Heat activation of raw bones. The cattle bones collected were sorted, cleaned and heat treated for fluoride removal process. The activation was done by using a locally developed kiln packed with a kilogram of wood charcoal into 10 kilograms of raw bones. With this method combustion took place all the time within the aerated kiln. Smoke and vapour escaped through the chimney fixed at the top and this slow process of extracting and burning of the remaining organic matter from the bones allowed the bones to be dry and to be organic free. When dry bones were put in the enclosed compartment the maximum temperature of 558°C to 559°C was reached within 6 to 8 hours depending on the type of bones put in the kiln for activation. Air entered the kiln by a suction process and temperature was monitored after every 30 minutes. The burning was carried out in an aerate kiln. To improve the aeration, two pipes of 12.5 mm diameter were incorporated. The smoke and vapour escaped through a chimney at the the top. Once the charcoal had ignited, the bones were fed into the kiln. The kiln was capable of handling about 10 kg of unbroken raw bones. The burning of the bones was carried out for about 18 hours. The material was unpacked from the kiln chamber the following morning. The set up of the organic removal kiln is as indicated in Figure 1.

Milling and Sieving. The burnt bones were crushed after unpacking. This was achieved by manually pounding and sieving using standard sieve sizes. The particle size diameters ranges used in the columns are 0.5-1.4 mm and greater than to 4 mm.

Analysis of Samples. Water samples were collected from the treatment unit in clean plastic botties for physical and chemical analysis. The analysis was done using field Hach test kit spectrophotometer DR 2000 and digital titrator. Analysis of fluoride in the water samples collected was carried out at room temperature with Orion Research Model 701A/digital ion analyzer fixed with combined fluoride electrode. Interpretation of the fluoride results after the analysis was based on a standard curve. The analysis methods follow the international recommended "Standard methods of the examination of water and wastewater" (10).

Packing of the defluoridation unit and testing in household.
Total amount of media packed into the column was 1.7 kg. The filter column was of 54 cm long PVC pipe of a diameter 80 mm. This was packed with heat activated cattle bones, bottom layer 300 grams particle size greater than 4 mm, middle layer 1,200 grams diameter 0.5 - 1,4 mm and top layer diameter greater than 4 mm. Bottom layer was meant to hold the media and the top layer for energy dispersion and some fluoride uptake. Flow rate in the column was 4.5 litres/hours for a retention time of 30 minutes. Thirty household defluoridation units packed with heat activated bones were installed in Kitefu village in December 1995.

Results and discussion

The fluoride removal process taking place in the defluoridation units was based on filtration and adsorption. Fluoride was adsorbed on the surface of the heat treated bones.
For the first 3 months the treated water gave a residual fluoride concentration of 0.13 to 0.22 mg/L from an initial fluoride content of 2.8 to 3.2 mg/L. The amount of water treated was 20 to 30 litres/day for the period of nine months. This water was used for drinking and cooking purposes only.

The media used had a capacity of 3.8 mg fluoride per gram heat treated cattle bones based on batch tests in the laboratory. Flow rate used in the operation of the devices was 4.5 litres/hr. Dimensions of the unit were 54 cm long and a diameter of 80 mm. The retention time was 30 minutes. The quality of the water produced by the devices gave a pH value of less than 8.5 and apparent colour of less than 50 PtCo/L. Taste and odour were not displeasing and no complains were registered from the people using the defluoridators. The water quality parameters were recorded in August, 1996 after nine months of continous operation of the units in the households were as follows, residual fluoride concentration of 0.31 mg/L, pH values 7.8 to 8.4, colour 0 to 50 PtCo/L and turbidity 0 to 5 NTU. Bacteriological analysis gave nil count total coliform per 100 mL.

It has been reported that the media can remain active for more than three months before replacement is considered but no confirmative information has been given. The same period has been noted in Thailand (11) with no data to confirm the period the defluoridators operated in the communities.

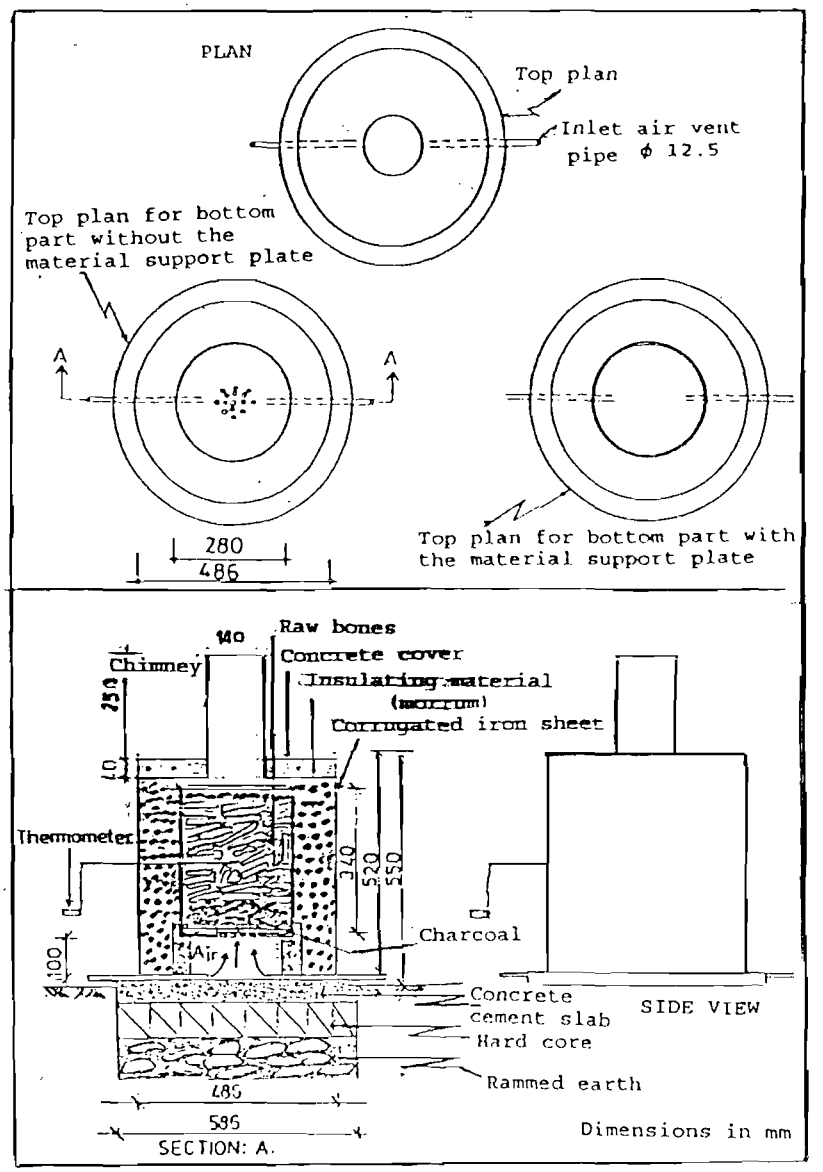

Figure 1: Low cost kiln for bones activation by heat treatment.

The device fluoride removal capacity was at its peak in the first two months after which it slightly dropped and fluctuated between 2250 and 2400 mg for the rest of the seven months (Feb. to Aug. 1996) which was still considered to be a high removal capacity (Figure 2). The monthly and cumulative fluoride removed during the operational period were as shown in Figure 3 whereas the amount of fluoride removed and accumulated in the filter column and the quantity of water treated by the unit as a function of operating time are as presented in Figure 4. The average monthly fluoride removal capacity [by weight of heat treated bone (HTB)] in relation to average monthly residual fluoride is as presented in figure 5. The fluoride removal rate was observed to decreaseproportional to the utilization time as presented in Figure 6.

Bacteriological Quality

Random treated water samples were collected from 10 out of the 30 units being filed tested and were analyzed for coliform bacteria. The results obtained showed that water from 6 households gave nil count and 4 gave some counts as indicated in table 1. After a month the same houses were revisited and sampled for the same. All the samples gave nil count total coliforms per 100 mL.

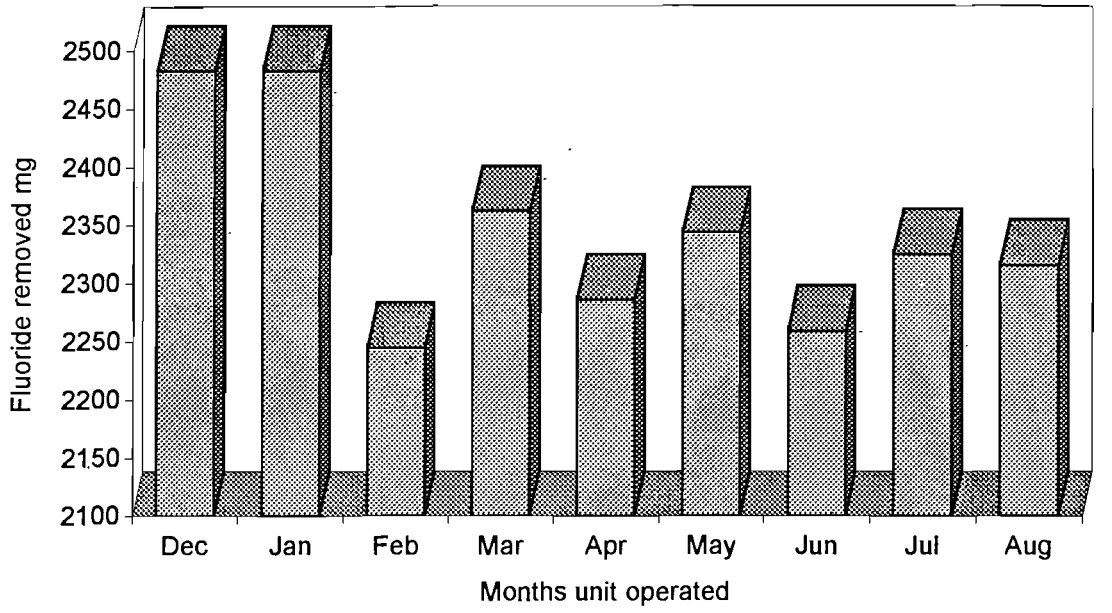

Figure 2 Monthly fluoride removed plotted against the unit operating time .

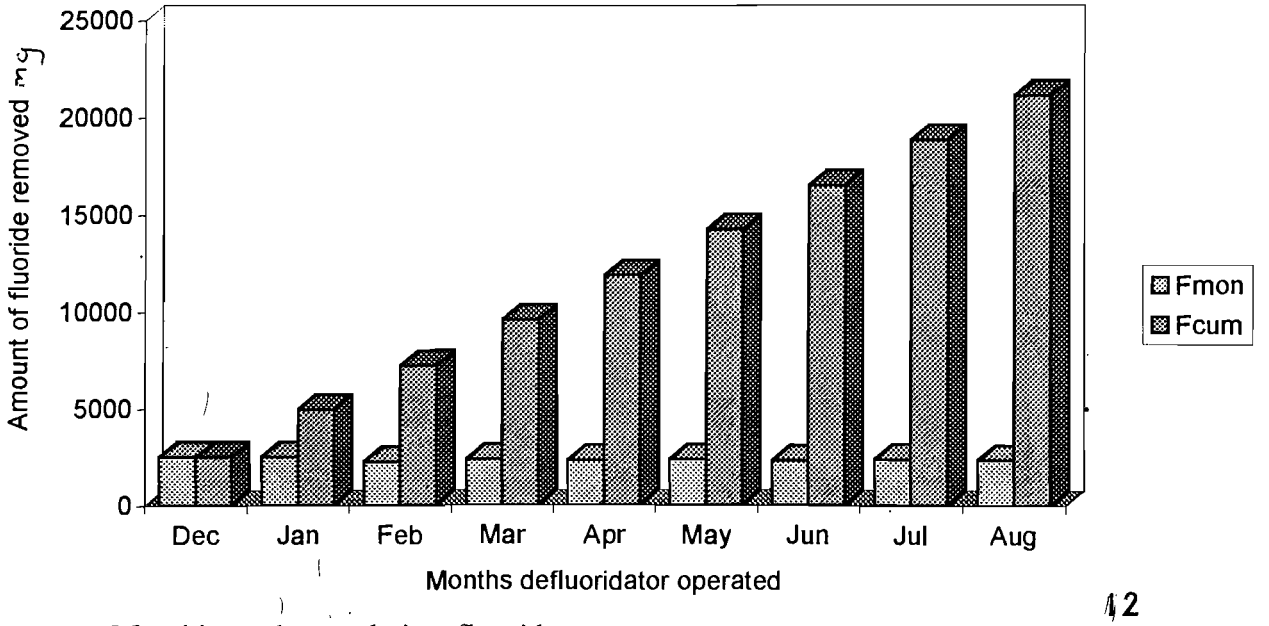

Figure 3: Monthly and cumulative fluoride removed as function of operating time.

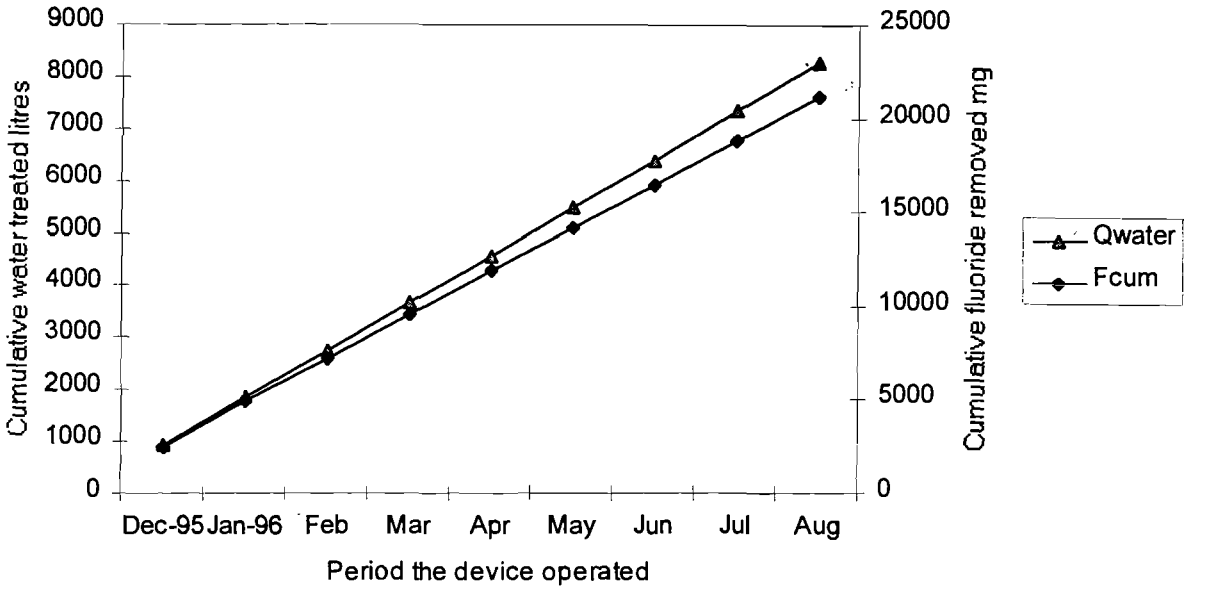

Figure 4: The amount of fluoride removed land accumulated in the filter column and quantity of water treated by the unit as function of operating time.

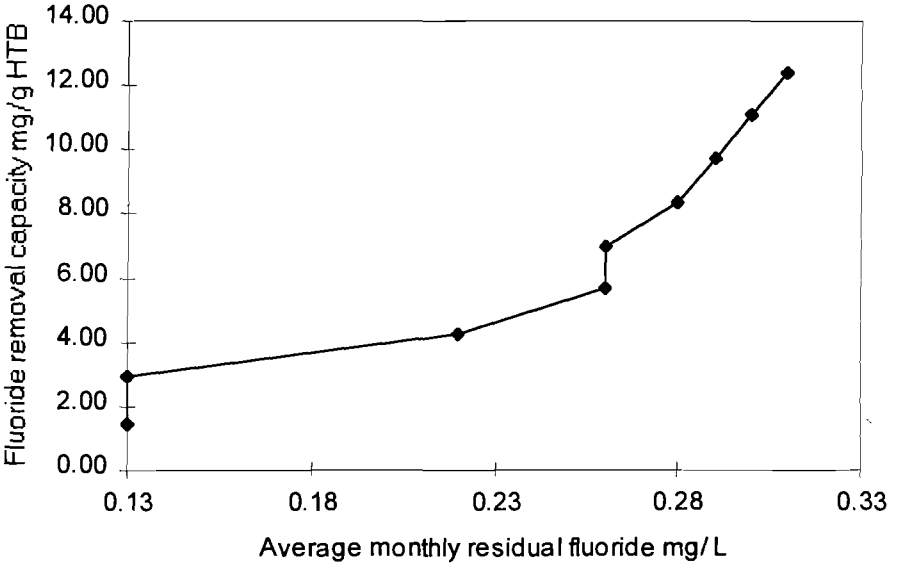

Figure 5: Fluoride removal rate plotted against number of months the unit operated

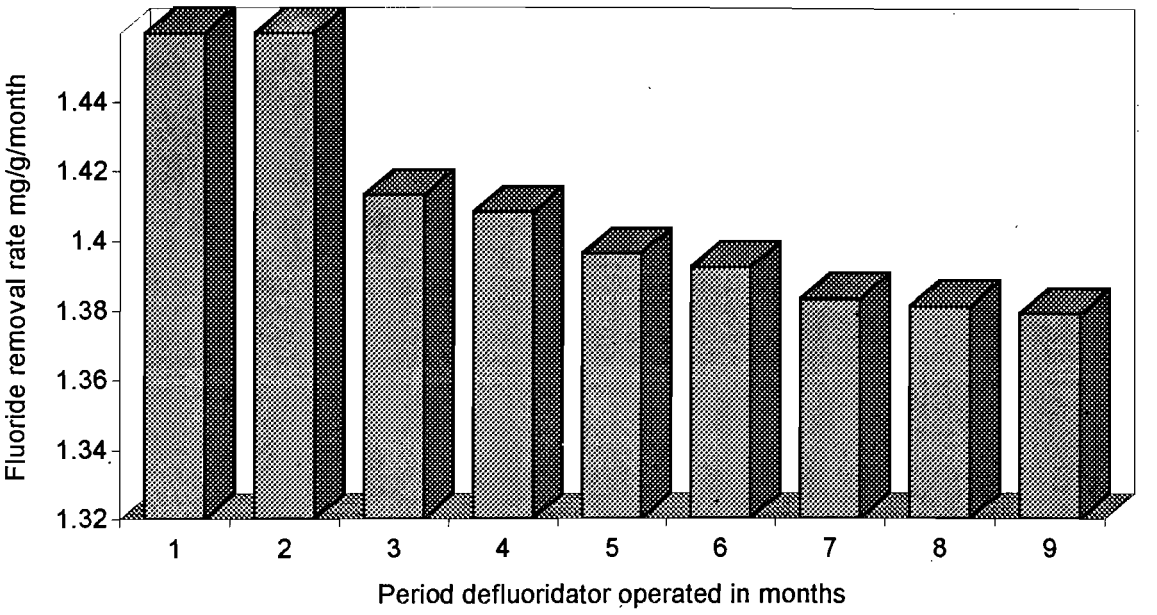

Figure 6: Fluoride removal rate plotted against number of months the unit operated

Table 1: Households checked for bacteriological quality of the water treated by the units.

Name of household	Total coliforms count per 100 mL	
	9 March 1996	13 April 1996
Village Chairman	14	0
Moses Urio	0	0
Eliopokea Nicodem	13	0
Senyaeli Ndewario	19	0
Tuwati	1	0
Joseph	0	0
Lokeli Akyoo	0	0
Elishila Sarakikya	0	0
Waryaeli Urio	0	0
Sangito Ayo	0	0
Tap Water	0	0

Conclusions

Presented in this paper are the latest results obtained following a nine months period of testing the household defluoridation unit. Even at the nineth month of opreration in field condition the units were still able to reduce excessive fluoride and the residual fluoride was 0.31 mg/L. Based on the results obtained by this study it can be concluded that at low fluoride concentration the rate of fluoride uptake by heat activated bones is good and can last longer than what has so far been reported in the literature.

The recorded fluoride removal capacity of 12.41 mg fluoride per gram heat activated bone at a residual fluoride content of 0.31 mg/L is one of the highest values ever reported from field operating units. This is 32.7% of the theoretical fluoride removal capacity of 38 mg/g heat activated bone. The initial fluoride concentration of the treated water ranged from 2.8-3.2 mg/L. But

all calculations were done using the minimum value of 2.8 mg/L.

No bacteriological quality problems were observed. The incidence reported in the paper originated from house to mouth contamination. This has been overcome by health education to beneficiaries on cleanness. It is concluded that the media preparation method is perfected.

The defluoridation method is simple, acceptable, appropriate and affordable. It works better with water that has low fluoride concentrations. While additional studies are required to check the efficacy of the defluoridation unit with high fluoride concentration waters this unit is considered to be appropriate and can be recommended for use in endemic fluorosis populations.

Acknowledgement

We gratefully acknowledge the financial support by DANIDA through its ENRECA Programme and the material and technical support given by Central Oral Health Unit, Ministry of Health, Tanzania.

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