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FLUORIDE BINDING CAPACITY OF BONE CHARCOAL AND ITS EFFECTS ON SELECTED MICRO-ORGANISMS

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FLUORIDE BINDING CAPACITY OF BONE CHARCOAL AND ITS EFFECTS ON SELECTED MICRO-ORGANISMS

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SUMMARY

Water is a major source of fluoride ions in areas where skeletal and dental fluorosis are endemic. We investigated the capacity of bone char to remove fluoride from water and its effects on selected bio-indicator organisms. Under static and dynamic conditions, the capacity of bone char was in the order of 2.5 mg of fluoride per g of bone char. Bone charcoal did not appear to support growth of *yeast* and *S. aureus*. *E. coli* and *S. faecalis* counts in the filtrate decreased with time but there was substantive growth in the bone charcoal.

INTRODUCTION

Considerable efforts have been made in the area of materials and methods concerning drinking water defluoridation. These have been reviewed by Fejerskov *et al*(1). Because of cost, availability and to a certain extent efficacy considerations, application of many of these technologies is yet to be effected in Third World nations where skeletal and dental fluorosis are endemic. Recently, application of bone meal(2,3) and bone char (charcoal)(1,3,4) in defluoridation of domestic water has been recommended. Already a standard bone char based defluoridator(4) is being tried in at least 6 countries in Africa and Asia. In view of variations in fluoride levels and in water usage in different places, fluoride sorption characteristics by bone char are required for effective application. The objective of this paper is to report on the capacity of bone char to remove fluoride and investigate its effects on growth of selected bio-indicator organisms.

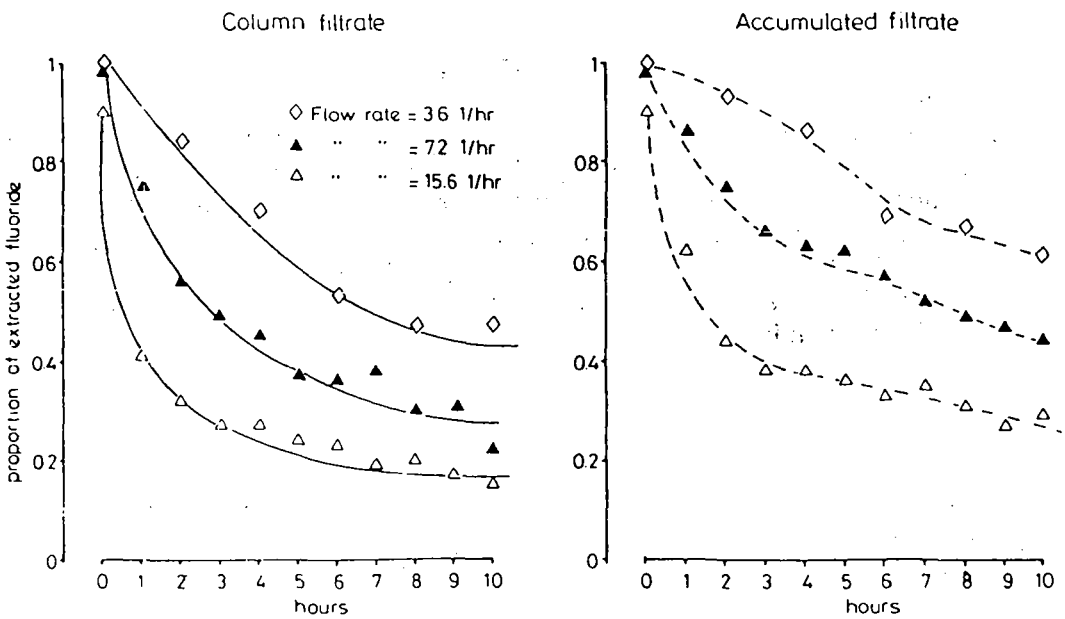
MATERIALS AND METHODS

Defluoridation tests were carried out under static and dynamic conditions. Under static conditions, 10 g of bone char was added to 100 ml of distilled water containing 50 mg of fluoride in a plastic bottle. A roller mixer was used to mix the two phases for 3 minutes. The mixed constituents were then allowed to stand on the bench ($23 \pm 2^{o}C$) for either 1 hour or 8 hours. 2 ml were then drawn and prepared for fluoride analysis. These tests were done in triplicate.

In dyanamic tests, columns made from poly(vinyl chloride) (PVC) water pipes measuring 3.3 cm diameter and 58 cm long were sealed on the lower end with nylon mesh. The latter was fixed with a polymeric cement (Pattex contact cement — Henkel Ltd). Into these columns 200 g of bone char granules of different sizes were transfered. They consisted of a blend of 20% fine particles (< 500 µm), 50% medium sized particles (500-1000 um) and 30% coarse particles (1001-1500 µm). A sprinkler and cotton gauze were fitted above the level of bone char to facilitate filtration and dispersion of water. Borehole water containing 10.76 mg/l of fluoride

Figure 1

Changes in filtrate and accumulated filtrate fluoride concentration with time.



was allowed to flow from a constant head tank through the bone char beds at flow rates of 3.6 l/hr, 7.2 l/hr and 15.6 l/hr. Samples were collected from the end of the column and accumulated filtrate. 4 test runs were done for each flow rate. A pH/ion meter (HACH model 19200 — Cambridge Massachusetts), fluoride eletrode, and fluoride adjustment buffer (TISAB II) were used in fluoride determinations.

PVC columns of similar dimensions were also used in microbiological investigations. To ensure, hermetic seals, column ends were fitted with adaptors and self threading caps. The junctions were subsequently sealed with a PVC adhesive (Tangit — Henkel Ltd). The columns were sterilized using lysol (Phenesal, Kiwi Home Industries Ltd) and then rinsed using sterile distilled water. The columns were packed with 100 g sterile bone char sandwiched between 10 g of wood charcoal that consisted of medium size particles. Sterility was confirmed by observing no growth from saline filtrate after flushing the beds daily for 7 days. The columns were then inoculated with inoculi containing 1.2×10^6 colony forming units (cfu) of *E. coli*, 1.6×10^6 cfu of *S. aureus* 1.8×10^6 cfu of *S. faecalis* and 0.25×10^6 cfu of *yeast*. The columns were flushed weekly for 6 weeks with sterile saline and the filtrates cultured using specific growth media for the indicator organisms(5). Columns that had been inoculated with saline was used as control. After 8 weeks column contents were emptied and samples of bone char cultured.

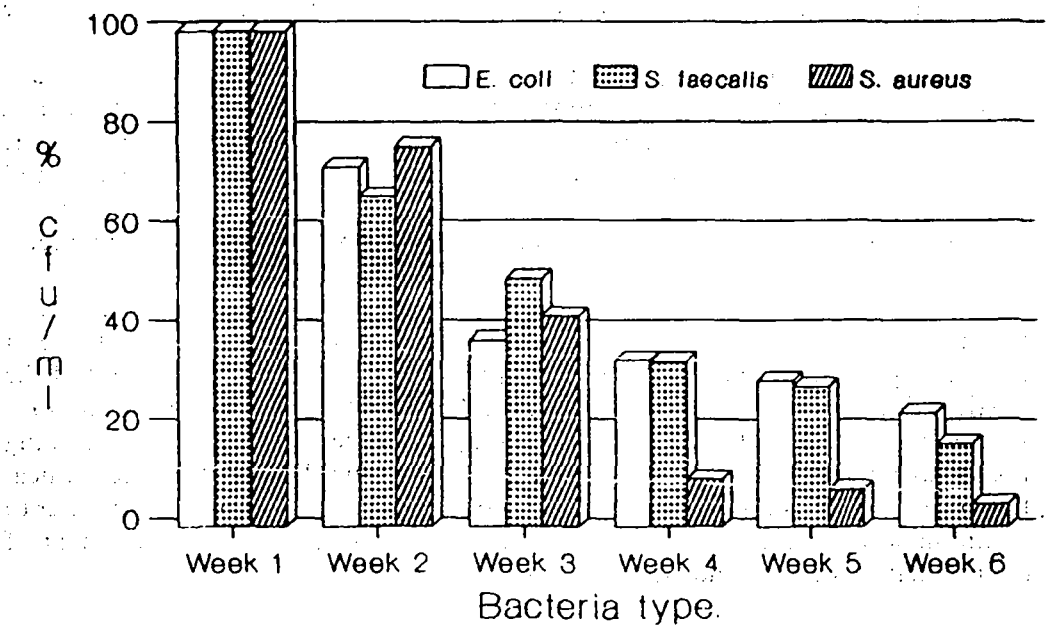
RESULTS

The mean amount of fluoride taken up by bone char under static conditions was 19.73 mg after detention for 1 hour and 20.25 mg of after detention for 8 hours. The rate of fluoride uptake in the columns decreased by 50% after passage of 25.2 l of filtrate at flow rate of 3.6 l/hr. A comparable decrease was observed after passage of 19.4 l and 12.5 l at filtrate flow rates of 7.2 l/hr and 15.6 l/hr respectively (Figure 1). The amount of fluoride removed from accumulated filtrate were comparable after filtration of 36 l at flow rates of 3.6 l/hr and 7.2 l/hr. Under these conditions, the capacity of bone char was in the order of 1.93 mg fluoride per g of bone char.

Using cfu count in the filtrate at the end of the first week as denominator, a decrease in filtrate cfu of between 100% in the case of *yeast* and 50% in the case of *S. faecalis* by the end of 3 weeks was noted (Figure 2). Quantative determination of *yeast* colonies within the first 2 weeks was not possible because of confluencing of yeast colonies. Substantive growth of *E. coli* and *S. faecalis* were noted from the cultured bone char. The haviest growth was observed from contents in the upper part of the columns. Growth of *S. aureus* was lighter and more uniformly distributed. There was no detectable growth from bone char that had been inoculated with yeast or that from the control columns.

Figure 2

Changes in bacteria count in the filtrate with time.



Note: cfu/ml after 1 week incubation were 8.4x10^4 for E.coli, 1.2x10^6 for S. faecalis and 2.4x10^5 for S aureus

DISCUSSION

Since the difference in the amount of fluoride taken up after 1 hour and 8 hours contact time was small, it appears that the rate of fluoride uptake by bone char is a relatively rapid process. This observation was also apparent in column filtrates. Under dynamic conditions, the rate of fluoride uptake decreased remarkably after passage of about 20 l (Figure 1). Thus to a large extent, the rate of fluoride uptake appeared to depend on the amount of contacting water and not the detention time. However, at flow rate of 15.6 l/hr, the rate of fluoride uptake was significantly reduced after passage of less than 20.1. It would appear that, flow rates of 15.6 l/hr cannot allow optimal fluoride removal but extending bone char-water contact time by use of slow flow rates enhanced utilisation of the fluoride binding capacity of bone char. Such improved utilisation of fluoride binding capacity can be achieved by using a multi-stage defluoridator. Our findings indicate that the capacity of bone char for fluoride is in the order of 2.5 mg of fluoride per g of bone char. Besides filtration of other water contaminants and probably ease of application where piped water is available, dynamic defluoridation did not appear to offer major advantages over the static method. In this regard it is noteworthy that, the ICOH household bone char defluoridator(1,4) is estimated to cost about US$ 20 (excluding the cost of bone char) in Kenya, a price that may be relatively high for some rural communities. Furthermore, in view of variations in factors such as water supply and methods of water storage for domestic use, the effectiveness of such a defluoridator versus simpler dosing methods are worthy considering when implementing defluoridation using bone char.

In communities where water treatment plants are not available, provision of a device that provides microbial decontamination of drinking water would be desirable. The bone char/wood charcoal environment probably had repressor effects on *yeast* and to a lesser extent on *S. aureus* and probably non on *S. faecalis* or *E. coli*. This confirmed other reports that activated carbon allows growth of certain bacteria species(8). Therefore, the decline in colony forming units in the filtrate was probably due to increased adsorption(6,7) of bacteria to carbon and ripening(8) of the bone char columns in case of the 3 bacteria species. Regarding other electrolytes, bone char lowered water hardness but had insignificant effects on magnesium, calcium, iron and phosphates(9).

Our findings confirmed those of Fejerskov *et al*(1) and Phantumvanit *et al*(4) that bone char has significant fluoride binding capacity. Given the rapid rate of fluoride uptake by bone char, it would appear that with some refinement of the particle sizes and retention time, dosing methods may be considered in situations where application of defluoridators is not appropriate. Investigations regarding regenerating and disposal of spent bone char are required. Except for mechanical filtration, there was no obvious indication of antibacterial activity of bone char to common water contaminants, namely *E. coli* and *S. faecalis* and treatment of contaminated water would still be necessary.

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