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Original Article

The Effects of Charred Cattle Bones on the Treatment of Fluoride in Water using Ceramic Filters

Ebele Ayibuofu Erhuanga
Industrial Design Department, Federal University of Technology, Akure, Nigeria

Abstract
Filtration is a process wherein a medium (the filter) removes or strains something from whatever is passed through it. Ceramic water filters make use of micro pores in a fired ceramic medium to filter out microbes and other contaminants from water by size elimination. The traditional ceramic water filters remove particles and solids from water by trapping them as the water takes its natural flow through the pores of the ceramic. While the ceramic filter is known to basically treat water by excluding whatever is larger in size than the pores of the ceramic medium; other variants of the filter have been developed to enhance water purification by coating the filter elements with silver solution. However, in some locations around the world, excessive levels of mineral contamination in ground waters have raised issues as regards the potability of such waters. In this light, the research sought to study the effect of using cattle bones as a constituent material in developing a ceramic filter which can treat excess fluoride in water, amongst others. The methodology applied involved, the collection of cattle bones charred to temperatures of about 500-600^{o}C in open air. The bones were crushed and milled with clay materials and combustible material into clay slip which was used to shape the ceramic filters. The filter samples were fired to bisque ware at a temperature of between 850-900^{o}C. Physio-chemical analysis was carried out on the filter-treated water samples and compared vis-à-vis the raw water samples for certain parameters including fluoride. The results indicated that the developed filters were effective in the reduction of fluoride concentration levels as detected in the raw water samples; with greater reductions with increasing bone char ratio in the filter compositions. There were also indications of inclusions of traces of calcium ions in the filtered water samples.
Keywords: Ceramic filter, Fluoride, Cattle bones.

Introduction

Filtration is the passage of a liquid or material through a filter, utilizing gravity, pressure or vacuum (suction). Therefore, a filter is a device, instrument or material, which removes something from whatever passes through it (Rittner and Bailey, 2005). On this premise,

Corresponding Author: Ebele Ayibuofu Erhuanga < ebeleerhuanga@gmail.com >
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ceramic water filtration as defined by Brown, Sobsey and Proum (2007), is the process that makes use of a porous ceramic (fired clay) medium to filter microbes or other contaminants from water. The pore size of the ceramic medium is what determines the effectiveness of any ceramic filter, as it is designed to be small enough to strain off anything bigger than a water molecule by size exclusion. Further developments in the ceramic water filter technology, has led to the treatment of ceramic filters with a silver solution which acts as a microbicide to inactivate any bacteria in water, that pass into the filter. This has contributed to the increased performance of ceramic water filters (National Academy of Sciences, 2008). The contemporary ceramic water filters, as several studies have shown, are highly effective in the removal of microbiological contaminants, however, the capacity of the ceramic filter to treat all classes of contaminants in water is still limited. This research therefore, sought to explore the possibility of expanding the efficacy of the ceramic water filter to include the removal of fluoride from water. This involved the study of the effect of the inclusion of charred cattle bones in the ceramic filter body composition. Therefore, bone char was added to the ceramic filter's composition to assess its ability (in composition) to remove fluoride from water, seeking to answer the question - Will the incorporation of bone char into the ceramic body composition facilitate the filter's efficiency to remove fluoride in water? And what would be the resultant effect?

Materials and Methods

The materials employed in this study comprised;

1.) the clay body, which was a mixture of kaolin and laterite,
2.) the combustible, pore-creating material, which in this case was charcoal, and
3.) The bone char prepared from charred cattle bones.

Clay bodies are mixtures of clays and other materials in varying proportion designed to accomplish specific goals like plasticity (to aid shaping), stability (in large scale work), increased porosity, thermal shock resistance, dry and fired strength or vitrification and density (Pitelka, 2007). In this study, a porous clay/ceramic body was formulated for the purpose of adjusting its chemical properties, by the inclusion of additional materials, to achieve certain reactions under controlled systems. The clay body used in this study comprised a mixture of kaolin clay and laterite to improve strength and plasticity in the resulting ceramic body.

Bone char, which was produced by calcining cattle bones, consists basically of apatite II (hydroxyapatite) and about 11% elemental carbon. Heat treatment of cattle bones removes the organic matter that could add taste and colour to the filtered water. Calcination temperature for specific bone char used for defluoridation is between 400-600^{o}C. Temperatures higher than 600^{o}C may damage the apatite structure, resulting in poor fluoride removal capability, while temperatures below 400^{o}C may result in bad taste and odour in treated water (Posner, 1987). Previous studies indicate that Bone char is a cost effective and efficient means of removing trace impurities and found useful in sugar and water purification industries. It is believed to have a high absorption capacity for a wide range of inorganic and organic contaminants. Therefore, the effect of the incorporation of powdered bone char media into a ceramic filter body for the removal of fluoride from water, was the aim of this research.

The combustible materials added to clay in the production of ceramic water filters are often organic and combustible in nature. This material, when added to the ceramic body mix, combusts when the body is fired to high temperatures, leaving greater number of cavities in the fired clay. These cavities allow for easier flow of water through the filter than the naturally occurring pores in the fired clay. Charcoal derived from the burning of a tree stem was used as combustible material in this study.

Methods

The methods engaged in carrying out the research included the following;

Firstly, the raw materials needed were sourced and collected from various locations within Akure in south-west Nigeria. They included clays, charred cattle bones and charcoal. The clays formed the base material in the ceramic body; the bone char culled from cattle bones was added to test its ability to remove fluoride from water. While the charcoal was used as the combustible material to create more pores in the ceramic.

The materials were pulverized and processed to dry powdered forms. The processing of the materials included, air-drying to reduce the moisture content in them and facilitate pulverization, burning of the wood stem for charcoal, crushing and grinding to reduce particle size, sieving using fine mesh (60 micrometer), and bagging of the materials to keep the moisture out.

Plate 1: Charred bones

Plate 2: Processed bonechar

Ceramic body compositions were formulated by varying the blend of materials using the quadaxial blend formulae. They were weighed and batched using the formulated compositions and milled into ceramic slips using the ballmill for an hour each. The slips were used in making the sample ceramic filters by the slipcasting technique using plaster of paris moulds and sodium silicate was used as deflocculant. The sample ceramic pot filters were air dried in a chamber and fired at bisque temperature (850 - 900˚C).

Plate 3: Three-piece mould

Plate 4: Slip-casting of filter samples

Plate 5: Demoulding

Plate 6: Demoulded filter sample

Plate 7: Drying process

Plate 8: Firing process

Plate 9: Fired filter sample

Finally, the effectiveness' of the developed filters were assessed by carrying out physio-chemical analysis on raw and filter-treated water samples. This was achieved by collecting raw water samples from water sources which were common to the study area, which are the shallow wells. The raw water samples were passed through the filters to obtain the treated water samples (filtrate). The raw and the treated water samples were tested at the laboratory for such parameters as, pH, turbidity, Total Solids (TS), Total Dissolved Solids (TDS) and fluoride.

Plate 10: Test filtration

In an attempt to improve the chances of determining fluoride concentration in the water samples, the raw water sample was doped with little quantity of toothpaste which contains Sodium Fluoride (1450 ppm) as an active ingredient. The fluoridated raw water was then passed through the three filter samples to get the treated water samples. Thereafter, both the raw and the treated water samples were sent to the laboratory and analyzed to determine the fluoride concentrations in the samples using photometry procedure.

Results and Discussion

The results of the laboratory analysis on the raw and the treated water samples show that all the filter samples improved pH and treated TS, TDS and fluoride in the water samples. While all the filter samples treated fluoride, with up to 75% reduction in filter sample S2, the results also indicated increased Calcium (Ca) ion concentration in the treated water samples. This may however be traceable to the action of the bone char in the removal of fluoride from water, whereby the contaminant species in some cases substitute Ca^{+} in the hydroxyapatite lattice by incorporation, releasing free calcium ions into the water.

The results indicate that filter sample S2, which has the highest bonechar content in composition (20%), gave the best fluoride treatment (75% reduction) and the highest increase in calcium (54%). See Table 1 below.

Table 1: Results comparing fluoride and calcium ion concentrations in the treated water samples

	Water Samples			
Parameters	**Raw**	**Sample S2**	**Sample S5**	**Sample S24**
Fluoride (cfu/ml)	1.25	0.31	0.38	0.83
Calcium	3.50	5.40	4.65	4.40

The chart presented below (Fig 1) depicts the relationship between the bonechar content in each filter sample and the resultant reduction of fluoride and increase in calcium in filter-treated water samples. The values are given percentage. It shows that concentration of calcium ions increased with increasing fluoride reductions, which was greater in higher bonechar content.

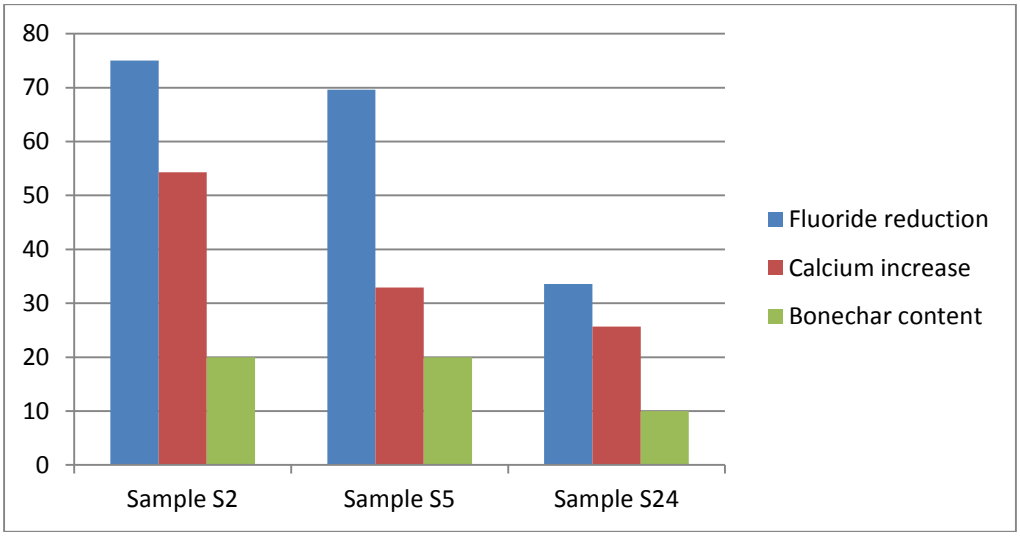

Fig 1: Chart representing relationship between fluoride reduction, calcium increase and bonechar content in treated water and sample filters

The results also showed that the filter samples with higher ratios of bonechar in composition gave greater reduction of fluoride in the treated water. Sample S2 with 20% bone char content gave a reduction in fluoride concentration of 75% as compared to S24 with 10% bonechar which gave a fluoride reduction of 33.6%. However it was observed that though filter samples S2 and S5 have same bonechar ratios (20%), S2 with higher laterite content gave greater fluoride reductions. This may corroborate the claims that lateritic soils also show capacity to remove fluoride (Chidambaram *et al,* 2003). See Table 2.

Table 2: Percentage reduction values of some parameters analyzed

`	TDS (%)	Fluoride (%)	Bacteria count (%)
S2 (20% bonechar)	52.63	75	41
S5 (20% bonechar)	51.32	69.6	81
S24 (10% bonechar)	8.33	33.6	91

Key: TDS= total dissolved solids, S2= Sample 2, S5= Sample 5, S24= Sample 24

Summary of Findings

The findings are summarized below:

1) Increasing ratio of Bone char in the ceramic filter composition indicated increasing ability of the sample filter to reduce fluoride concentration in the treated water sample

2) In all the filter-treated water samples assessed, improved pH values were recorded as well as reduction in Total Solids, Total Dissolved Solids and bacterial count values present in the raw water.

3) All the filter samples reduced the fluoride concentration in water in a range of between 33.6% - 75% reduction.

4) Increased Calcium concentration levels were indicated in all the treated water samples.

Conclusion

The study has shown that the incorporation of bone char as an additional material in the making of ceramic water filters improves the filter's ability to remove fluoride from water.

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