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**WATER, SANITATION AND HYGIENE:
SUSTAINABLE DEVELOPMENT AND MULTISECTORAL APPROACHES**

**Household water treatment: Defluoridation of drinking
water by using bone char technology in Ethiopia**

Samuel Esayas, Michael Jon Mattle & Lema Feyisa, Ethiopia

REVIEWED - LOCAL

The first phase of a collaborative project aims at testing the acceptance and performance of bone char-based fluoride removal filters in Ethiopia. The filters were produced by the Catholic Diocese of Nakuru (CDN), Kenya and supplied to 121 households in two project sites in the Great East African Rift Valley. Each unit was regularly monitored, while providing technical support to all applicants. After a study period of one year, more than 80% of the filters in Meki (Weyo Gabriel) and 100% of the filters in Shashemene (Chalalaka) are in use. None of the users expressed any objections concerning the use of charred animal bones, independent of religious or cultural background. Fluoride removal efficiency of the filters was satisfactory, although lifespan is limited due to very high fluoride concentrations in some of the groundwater sources (up to 23 mg/L). Filter design requires modification for improved performance in Ethiopian communities.

Introduction

Fluoride is present in all natural water sources at different concentrations. Seawater typically contains about 1mg/L while rivers and lakes generally exhibit concentrations of less than 0.5mg/L. Groundwater may contain low or high concentrations of fluoride depending on the nature of the rocks. High concentrations are commonly associated with volcanic activity and fumarolic gases (Fawell et al, 2006) but may also occur in sedimentary or granitic aquifers (Amini et al, 2008). Fluoride ions have the same charge and nearly the same radius as hydroxide ions (OH⁻) and each can replace the other in mineral structures (Hem, 1989). The main mineral present in bones is hydroxyapatite (Ca₅(PO₄)₃OH) containing hydroxide ions and hence fluoride can easily get incorporated into bones by replacing the hydroxide ion to form fluorapatite (Ca₅(PO₄)₃F) (Bregenhøj, 1995). Low human intake may prevent against caries; however excess fluoride causes dental fluorosis and in more severe cases skeletal fluorosis (Fawell et al, 2006). Prevention is extremely important since there is no treatment for fluorosis. The main source of human fluoride intake is drinking water, especially in areas with elevated fluoride concentrations. Hence, fluoride removal for safe drinking water is the only way forward in mitigating fluorosis if no fluoride-low water source is available. The WHO (1993) has recommended a maximum concentration of fluoride in drinking water as 1.5 mg/L.

Fluoride occurrence and defluoridation in Ethiopia

Most groundwater sources in the Ethiopian Rift Valley are associated with high fluoride causing endemic fluorosis. According to Tekle-Haimanot (1990) Over 80% of the children in selected areas have developed varying degrees of dental fluorosis, while an increasing number of crippling skeletal fluorosis cases are being seen among people who have consumed high fluoride over a long period of time. It was predicted that over 80% of the total population in the Ethiopian Rift Valley are exposed and are likely to develop endemic fluorosis unless preventive measures are taken (Tekle-Haimanot, 2006).

In Ethiopia, defluoridation started as early as 1962 in Wonji sugar cane plantation by using activated alumina (AA) community filters. However, the community filters were not in continuous operation due to technical problems and limited supply of AA. In 2007, the sugar factory installed a piping system to provide low fluoride water from Adama/Nazareth and abandoned the use of the filters.

The other defluoridation method implemented in Ethiopia are aluminum-sulphate-based household and community filters, known as the Nalgonda Technique, implemented by the Water Resource Office of Oromiya financed by UNICEF and the Catholic Relief Services (CRS) respectively. Currently the filters are not in use due to various technical, financial and social challenges.

Pilot project with bone char filters in Ethiopia

Objective of the pilot project

The main objective of the pilot phase is to introduce bone char technology while studying social acceptability and filter performance in Ethiopian communities. From the international literature it is known that the use of bone char may not be universally acceptable due to religious and cultural beliefs (Fawell et al, 2006). Specifically in Ethiopia its acceptability is doubted (Tekle-Haimanot et al, 2006).

A multi-stakeholder partnership was established between implementer OSHO (Oromo Self-Help Organization), donor HEKS (Swiss Interchurch Aid) and Eawag (Swiss Federal Institute of Aquatic Science and Technology) and CDN WQ (Catholic Diocese of Nakuru Water Quality Unit) for technical and scientific support.

Selection of target area and households

Dental and skeletal fluorosis have been known in the operational areas of OSHO/ HEKS in Shashemene and Meki districts for several years. There are about 15 water sources in Meki (Weyo Gabriel) and two water sources in Shashemene (Chalalaka) with excess fluoride concentration ranging from 3 mg/L to 23 mg/L. The project was introduced after having assessed fluoride distribution and extent of health problems in the selected area. In a first step community trainings were carried out followed by an open debate on charred animal bones that are used as filter material. By November 2007, 101 households in Meki (Weyo Gabriel) and 20 households in Shashemene (Chalalaka) were selected for this pilot phase. The district administrators were closely involved in the selection, which included households with different ethnic and religious background.

Community training

Two people of each selected household were trained on health effects of excess fluoride and the operation and maintenance of the bone char filters. Self-contribution of the households amounted to 10% of the total cost of the filter. Each filter consists of a 20 litre plastic buckets equipped with lids and taps at the bottom, filled with 8 kg of bone char. The people were instructed to wait for a minimum of 20 minutes after having poured in the water before collecting the treated water.

Monitoring procedure

Different questionnaires were prepared for qualitative assessment of treatment acceptability, user friendliness and filter performance. Calculated percentages in the following chapter are based on the total response while the total amount of questioned users decreased with time.

Quantitative analysis of fluoride concentrations were carried out by potentiometric measurement (ion-selective electrode, Methrom 6.0502.150). A close monitoring system was put in place: Monthly visits were paid to both sites by OSHO and every two weeks by trained community facilitators. Treated water samples for fluoride measurement have been collected from each household every two months.

For simplicity only monitoring results for Meki (101 households) are presented in the following.

Monitoring results

Figure 1 - 4 show the monitoring results from the questionnaires 8, 10 and 12 months after implementation of the filters. In May 2008, only half of the selected households used the defluoridation filter for water treatment. Many users (33%) aired complaints of bad taste and/or odour in the treated water mainly at the beginning of filter usage. The investigations concluded that those filters with odour and taste problems were treating organic-rich, highly-turbid lake water (lake Ziway). The households were advised not to filter and ideally avoid usage of the lake water as the risk of microbiological contamination is high compared to groundwater usage. After organizing follow-up trainings with the selected households, filter usage could be revived to 88% and 92% in July and September respectively. During the second monitoring after two

months of filter usage only 8% of the users expressed negative experiences related to the quality of the treated water.

In Chalachaka, where the only water source is lake water (infiltrated or direct usage), testing of an adapted filter design for improved filter performance in reducing both fluoride and turbidity is currently ongoing.

Figure 3 shows that only 5% of the questioned people did not know about the origin of the filter material while two months later all the given answers were correct. Against the assumption often heard in Ethiopia that bone char will not be accepted due to religious or cultural reasons none of the questioned users expressed any constraints or rejections, neither after 10 months nor after 1 year of usage. The project area is inhabited by orthodox and protestant Christians as well as Muslims. Previously living as pastoralists, they still show close affection for cattle. Of major importance for this high acceptability of bone char is the support of all elders who declared bone char to be a harmless, non-living item that can even be applied during fasting periods at which consumption of meat for instance is avoided.

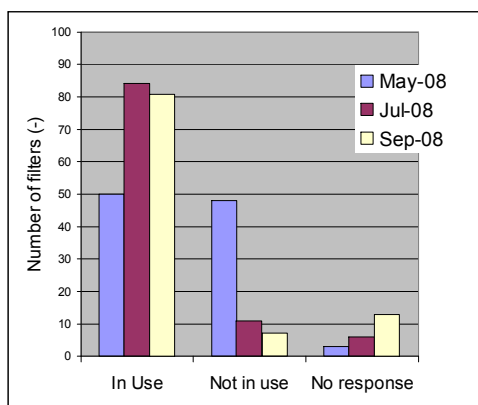


Figure 1. Usage of filter units

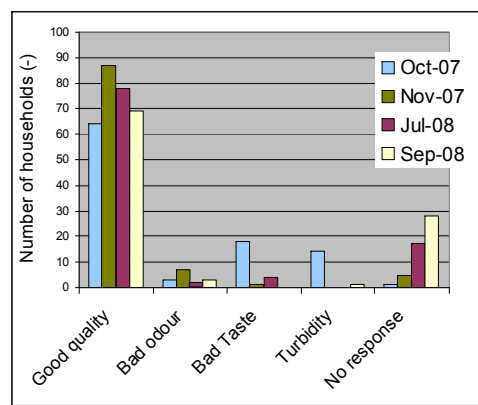


Figure 2. Quality of treated water

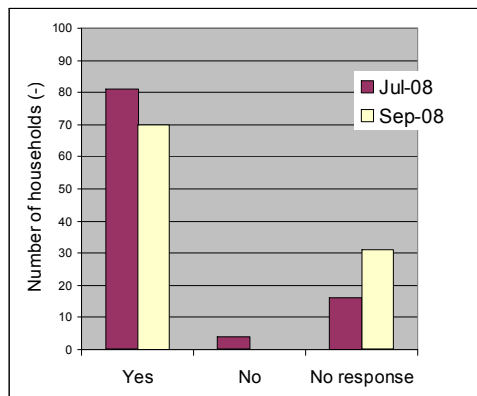


Figure 3. Awareness of the origin of the filter material (charred animal bones)

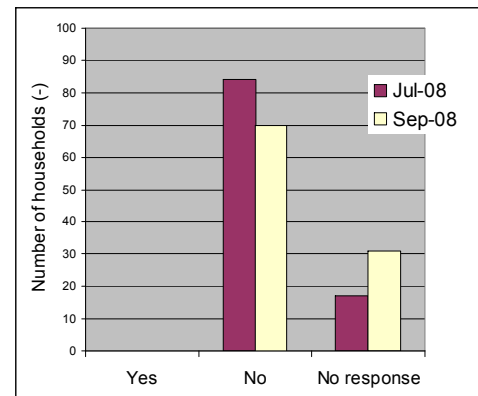
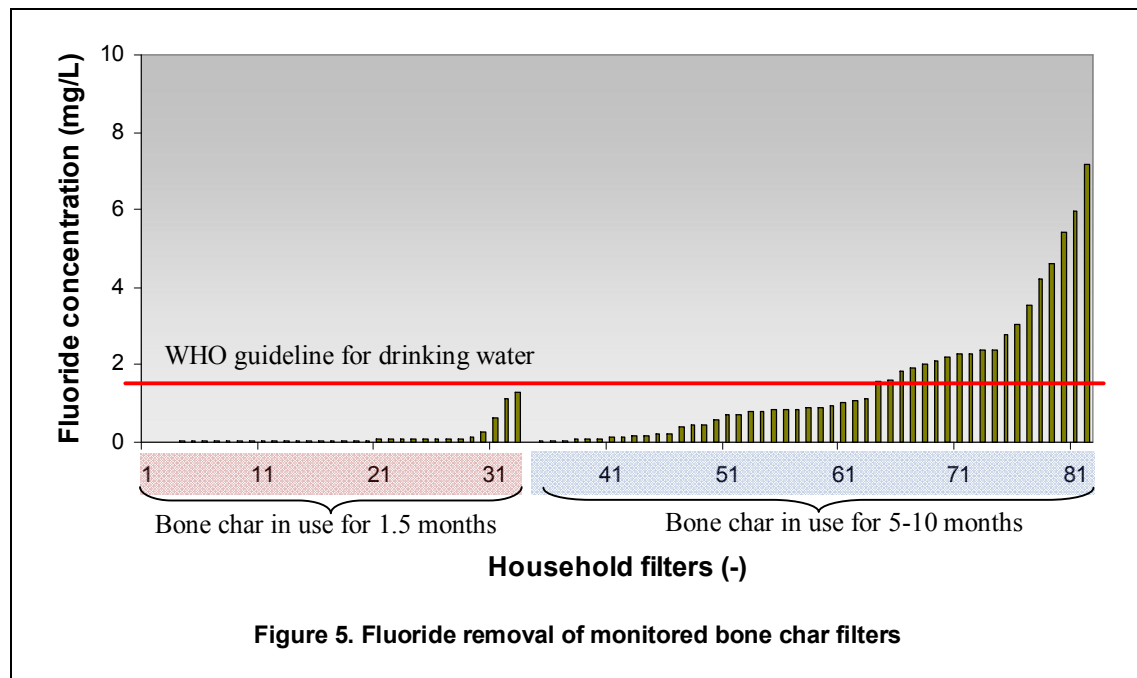


Figure 4. Constraints related to the origin of the filter material

Fluoride measurements

Figure 5 shows the fluoride concentration in the treated water of household filters in Meki. Initial attempts to assess the uptake capacity of the filters (mg F per g of filter material) showed that this is rather complex due to the variation in raw water source upon their availability. Through the questionnaires, a total of 15 water sources were identified as being available in Meki (Weyo Gabriel) with fluoride concentrations ranging from 3 to 23mg/L. However, Figure 5 shows that all filters with bone char in use for 1.5 months effectively remove fluoride independent on the raw water concentration. In June 2008, these households were supplied with fresh bone char as the old one was saturated. Even after the usage for more than 5 months, the majority

of the filters (61%) were still capable of reducing fluoride concentrations below the WHO guideline for drinking water (1.5 mg F/L). Variability of filter performance is big and increases with time. Possible reasons are different water consumption rates depending on the size of the households and different fluoride raw water concentrations that lead to the observed differences in filter performance. After having carried out the fluoride monitoring, saturated filter material of 19 household units was replaced by fresh bone char.



Conclusion and outlook

The one year testing phase of the bone char pilot project in the Rift Valley showed that the use of high-quality bone char is acceptable also in Ethiopian communities. The community members consisting of Ethiopia's main religious groups unanimously accepted the use of charred animal bone as a remedy to their public health problem. There is a strong demand of the communities living in the Ethiopian Rift Valley for sustainable defluoridation programmes. Filter efficiency is high and even fluoride concentrations >20 mg/L can be reduced to levels complying with the WHO guideline. However, lifespan of the filter is limited and saturated material has to be either replaced or regenerated. In order to carry out these maintenance requirements, awareness among all stakeholders has to be improved, hand in hand with close trainings and regular monitoring activities. Before promoting bone char as a viable defluoridation option for Ethiopia, OSHO, in collaboration with its partners is planning to test and evaluate a local production of bone char, profiting from the long-term experiences of CDN.

Aiming to reduce the frequency of filter material replacement, CDN and Eawag are currently investigating a modified treatment method known as contact precipitation (Dahi, 1996). CDN developed pellets containing calcium and phosphate that are added to the bone char filter and hence can extend its lifespan. Field testing in Kenya and recently also in Ethiopia is ongoing and will be enforced in future.

A close cooperation between OSHO, HEKS, Eawag and CDN and a strong learning orientation have led to the convincing success of the pilot intervention to remove fluoride from people's drinking water in Ethiopia's Rift Valley. However, the project team recognizes that many challenges lie ahead before being able to upscale the ingenious low-cost method in the region.

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