Improving Fluoride Removal Efficiency

Bone char is a highly efficient fluoride removal material, however, its lifespan is rather limited. Laboratory experiments reveal that the addition of pellets containing phosphate and calcium can extend the lifespan of bone char filters. Kim Müller, Francis Kage, Esther Wanja, Michael Mattle, Lars Osterwalder, Annette Johnson

According to UNESCO estimates, more than 200 million people worldwide rely on drinking water with fluoride concentrations exceeding the international WHO guideline of 1.5 mg/L [1]. While industrialised countries commonly use activated alumina or membrane technology to remove fluoride from drinking water, defluoridation is still uncommon in low and middle-income countries. A survey of defluoridation treatment in Eastern Africa reveals that bone char filtration is an efficient and viable fluoride removal method. Increasing the uptake capacity of bone char and thus prolonging the lifespan of the filters can, however, reduce maintenance requirements and improve treatment sustainability, especially for remote areas.

Improving bone char filters

In the 1990s, research experiments were conducted to extend the lifespan of bone char filters by adding calcium and phosphate to the water [2]. This new method was then referred to as co- or contact precipitation. Fluoride concentrations are reduced by both precipitation and sorption reactions in contact with hydroxyapatites ($Ca_5(PO_4)_3OH$), the main component of bone char. In 1995, this method was field tested in a community pilot plant in Tanzania [3]. Though filter lifespan was increased, high maintenance requirements due to continuous calcium and phosphate supplies hindered large-scale implementation. To overcome this drawback, the Catholic Diocese of Nakuru (CDN), a Kenyan faith-based organisation, took on the challenge of developing pellets that contain calcium and phosphate mixed with the bone char filter material. These pellets slowly release the required chemicals for fluoride precipitation into the water without creating additional maintenance efforts to the user. According to preliminary, unpublished lab investigations at CDN, this method prolongs the lifespan of the filters compared to filtration by bone char alone.

In-depth lab investigations

Eawag and CDN are currently conducting comprehensive lab analyses to acquire an improved understanding and to optimise contact precipitation for enhanced filter performance. The potential of contact precipitation can best be assessed in fixed-bed experiments carried out both at Eawag and CDN, using PVC columns filled with 260 mL of filter material (hereafter referred to as one empty bedvolume, eBV). For column experiments at Eawag, distilled water spiked with 6 mg F/L was used. CDN's columns were fed with natural Kenyan groundwater containing 6.0–6.3 mg F/L. The columns were run at a constant flow rate of 10 eBV/d (gravity flow with clamps for flow rate regulation at CDN, peristaltic pumps for flow rate regulation at Eawag).

Fig. 1 shows fluoride breakthrough curves for bone char and contact precipitation columns conducted at Eawag and CDN. Addition of pellets significantly prolongs the filter's lifespan, i. e. by a factor 6 in the case of synthetic water and 3 with natural Kenyan groundwater. The results obtained from the contact precipitation experiments at Eawag correlate well with those of CDN, as breakthrough of bone char was increased by a factor 2 under natural groundwater conditions compared to distilled water spiked with fluoride. Higher pH-buffering capacity in natural groundwater and possible precipitation processes with naturally occurring calcium (3 mg/L) and phosphate (0.3 mg/L) may enhance fluoride removal with bone char.

Uptake capacity in the case of distilled water spiked with fluoride increases from 0.6 mg F/g to 3.7 mg F/g filter material for bone char and contact precipitation, respectively. Removal efficiency is generally higher than 98 % for the first few eBV. The contact precipitation experiment at CDN revealed slightly lower removal efficiencies, averaging 90 % for the first 300 eBV. The steeper breakthrough curves for bone char columns indicate faster removal processes compared to contact precipitation, where the outlet fluoride concentration only rises slowly.

Only the beginning…

These lab findings reveal that contact precipitation can improve filter performance, however, far more experiments will have to be conducted to scientifically describe and optimise this method. A PhD study is currently determining and quantifying the different fluoride removal mechanisms of the contact precipitation method. In parallel, ongoing testing and monitoring of pilot implementation in Kenya and Ethiopia will complement the lab findings with field data.

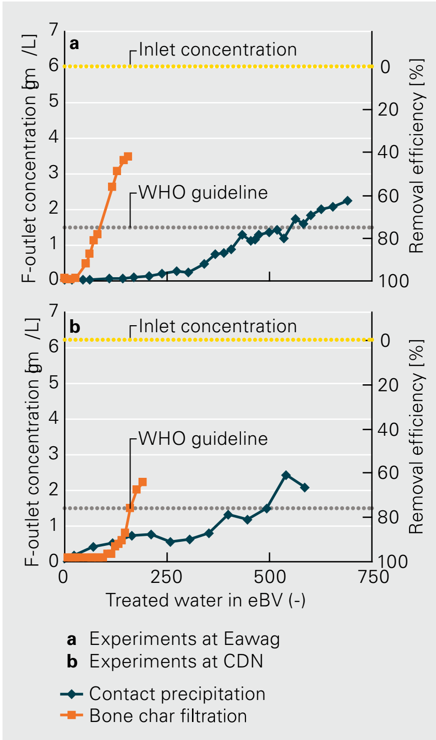

Figure 1: Fluoride breakthrough curves as a function of treated water in empty bedvolumes (eBV).

In 2006, Eawag and CDN initiated a collaboration to: i) further develop and optimise low-cost defluoridation methods applicable in low and middle-income countries and ii) facilitate its implementation.
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[1] UNESCO Ground water briefing: Trace elements in groundwater and public health, http://www.unesco.org/water/third_wwf/groundwater_health.pdf (status 29.2.2008)

[2] Larsen, M.J., Pearce, E.I.F. (1999): Partial Defluoridation of Drinking Water Using Fluorapatite Precipitation. Caries Res. 26 (1), 22–28.

[3] Dahi, E. (1996): Contact precipitation for defluoridation of water. In: Proceedings, 22nd WEDC Conference, New Delhi, 262–265.