Domestic Defluoridation of Water Using Locally Produced Activated Alumina

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SUMMARY: A low-cost defluoridator for domestic use is developed, based on activated alumina as a sorption medium. The filter column is 11.4 cm in diameter and 1 m in height. It is designed to contain about 8 L or about 3 kg of alumina. The alumina is prepared by using aluminium sulphate and sodium hydroxide to precipitate aluminium hydroxide at 60-70 °C. The precipitate is settled, washed, granulated and calcined at 550 - 600 °C for 4 hours. A column test in the laboratory revealed that the fresh alumina could remove fluoride from 5 mg/L to < 0.7 mg/L at a capacity of 1.2 g/kg. The developed filter allows for monthly regeneration of the medium by the users themselves. A quantity of 0.4 kg of aluminium sulphate is used in the regeneration. The filter operates upwards, while the regeneration operates downwards in the filter column.
Field-testing data show that the filters could treat water containing about 2 mgF/L down to 0.15 - 0.46 mg/L, thus an average removal efficiency of 85 %. Monitoring of a filter through 5 operation periods shows that the regenerated alumina loaded with water containing 2.6 mgF/L could treat the water at an efficiency of 89 %. The medium capacity is estimated to be 0.7 gF/kg regenerated alumina.
Field experiences show that the villagers very well accept the filter; it is easy to operate and to maintain and the filter costs are affordable to the families, about 45 USD for purchase and 20 US Cents for the monthly regeneration.

Key words: Activated alumina, domestic defluoridation filter, Vietnam, regeneration, aluminium sulphate, field experiences, medium capacity.

INTRODUCTION

Various methods and techniques have been applied and used for the treatment of access fluoride in drinking water. Each of them has certain advantages and disadvantages and their individual appropriateness would always depend on the actual local conditions, the most important factor being the community's acceptance [1,5]. This article briefly presents the technique of preparation of activated alumina from Aluminium sulphate or Alum, $Al_2(SO_4)_3.18H_2O$. Furthermore it describes a device for fluoride removal on household scale using the produced activated alumina. Tests of the filter were carried out in Ninh Hoa district, Khanh Hoa province (Vietnam), an area with emerged fluorosis related to the excess fluoride in drinking water. A local area is known as "an area without smile" due to the damage and the very clear appearance of black and "dead" teeth.

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MATERIALS AND METHODS

Preparation of activated alumina: The activated alumina commercially available in Viet Nam is imported in grades that only fit to the industrial use. Hence the activated alumina for the use by the rural family had to be specially prepared. The raw materials utilised are aluminium sulphate, $Al_2(SO_4)_3.18H_2O$, and sodium hydroxide, NaOH, chemicals that are normally used in water treatment [2]. The activated alumina is prepared as a precipitation product obtained by neutralization of 150 litres of a 15 % solution of the aluminium sulphate with about 10 litres of a 20 % solution of sodium hydroxide at 70 ^oC with an average pH value of 7.0. The solution mix is kept at 60 ^oC about 8-10 h. The collected precipitate is then washed with warm drinking water to remove the excess of sulphate ions. Hereafter, the supernatant water is removed by decanting, leaving the precipitate in suspension as a paste. The paste is then formatted as a granulate product by an extruder with screen hole diameter of 5.0 mm. The granulate product is then dried naturally and calcined at 550-600 ^0C for 4 h, the yield being about 5 kg and the bulk volume about 14 L.

Medium specifications: The granular activated alumina prepared as described above meets the following six specifications [2, 3]. 1) Main crystallite phase, γ-Al_2O_3. 2) Granular size is 3-5 mm. 3) Bulk density is 0.35 kg/L. 4) Specific surface area (BET) is 250 m^2/g. 5) Fluoride removal capacity of 1.2-1.5 gF/kg alumina and 6) Compression tolerance 50 kg/cm^2.

Capacity testing: The capacity of the freshly produced activated alumina is determined through the following column experiment: The filter bed is 50 cm in height and 2 cm in diameter thus containing 157 mL medium. Its dry weigh is 55 g. The column is fed with raw water containing 5.0 mgF/L, at a flow rate of 942 mL/h, i.e. 6 Empty-Bed-Volumes/h or flow velocity of 3 m/h. The cumulative volume of water that could be treated to an effluent concentration less than 0.7 mg/L is 16 L. Thus capacity of fresh activated alumina is 1.2 gF/kg.

Experiments showed that at the flow rates 5-7 EBV/h and the initial fluoride concentration in the raw waters of 5-10 mg/L, the capacity of the alumina is in the ranges 1.2 – 1.5 g/kg alumina.

Design of the household defluoridator: Given the above mentioned characteristics of activated alumina a special domestic filter was developed and designated as "FLOWAT". The diagram of the FLOWAT filter is presented in Figure 1.

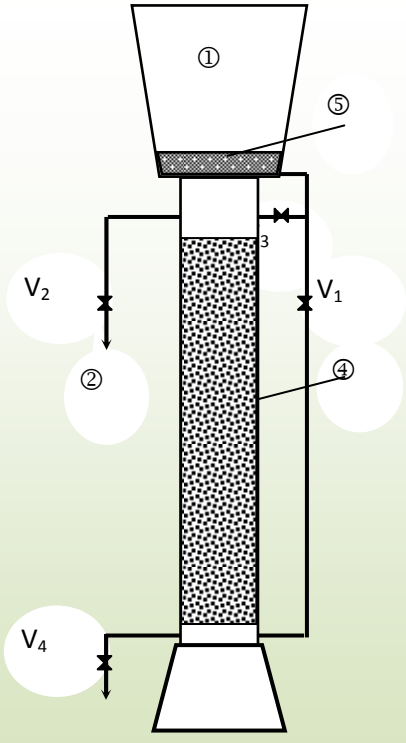

FIGURE 1. A diagram and a picture of the FLOWAT filter
① Bucket for raw water. ② Tap to collect treated water. ③ Tap for washing
④ Bed of activated alumina. ⑤ Polyethylene spongy plate for pre-filtration

The filter body is made of PVC material normally used in the water supply works. The column inner diameter is 114 mm. Its height is 1000 mm height, allowing for a filter bed height of 800 mm. A water bucket of 13 L volume is installed over the column, functioning as a raw water container. The bucket is supplied with a piece of polyethylene spongy plate in order to retain any suspended solid that might be in the raw water. The water bucket connects to the filter column through valve V_1 at the bottom below the filter medium and through valve V_3 at the top above the filter medium. All connecting pipes are made of PVC, inner diameter 21 mm. During operation the water is taped through valve V_2 above the filter medium. A fourth Valve

V_4 is fitted below the medium to allow for drain during regeneration and backwashing.

Filter operation: Under normal filter operation valves V_3 and V_4 would remain closed, while valve V_1 remains open. Raw water is poured into the bucket and the treated water is taped through V_2.

Medium regeneration: At the end of each filter period 10 L of a 4 % solution of aluminium sulphate in fluoride free water is poured to the bucket. The solution is allowed to flow through the bed of activated alumina and drained through V_4. Then 10 litres of fluoride free water is poured for wash of bed before the start of the new filter period.

Filter performance: For areas where the raw water up to 4.4 mgF/L, the filter is capable to treat about 900 litres for a month, i.e. 30 litres/family-day, before the treated water concentration reaches 0.7 mg/L and the regeneration is required. This is normally sufficient for a family's use for drinking and cooking, including final washing the food. Thus regeneration is needed once a month. For areas where the fluoride concentration is higher, usually 4 - 9 mg/L, the regeneration it would be needed to regenerate the filter 2 times per month. It takes about 2 hours to regenerate the filter.

Field-testing: Since 1999, a number of 1,200 filters have been used by villagers in Khanh Hoa province. In this study, 40 FLOWAT filters were tested in the field. Thirty filters were installed in Ninh Quang commune, Ninh Hoa district, Khanh Hoa province for treatment of well water containing 1.7 to 4.1 mgF/L. Ten filters were installed in Ninh Xuan commune, Ninh Hoa district, Khanh Hoa for treatment of well water containing 4.1 - 6.3 mgF/L. All filters were monitored continuously for 6 months.

Attention was also paid to the effect of aluminium sulphate or alumina particles on the treated water. The aluminium tests carried out shows that there is no aluminium in the treated water.[4]

RESULTS AND DISCUSSION

The obtained results are shown in Figure 2 & 3.

Figure 2 shows that the 10 filters have been loaded with water containing 1.7 – 2.3 mgF/L, 2 mg/L on an average. On average the filters could remove the fluoride down to 0.15 mg/L at the start of the filter periods. The removal efficiency decreased to 77 % at the end of the filter periods where the treated water had an average concentration of 0.46 mg/L.

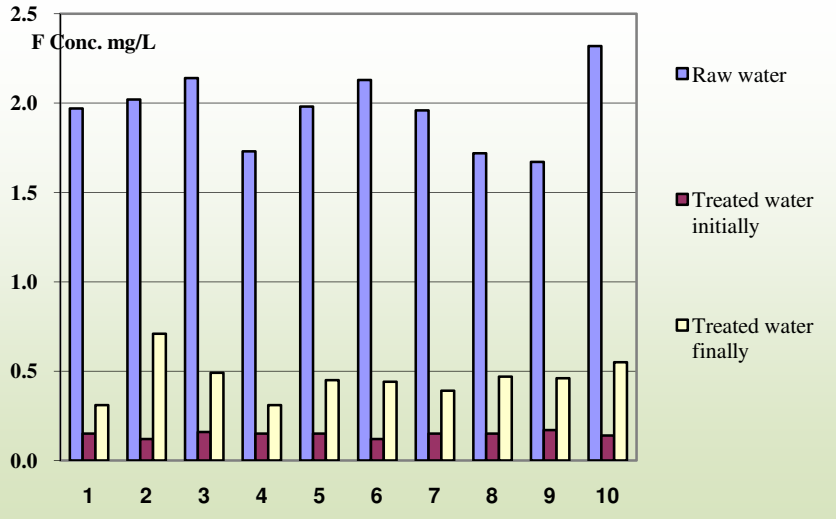

FIGURE 2. Monitoring data from 10 FLOWAT filters during 5th operation period.

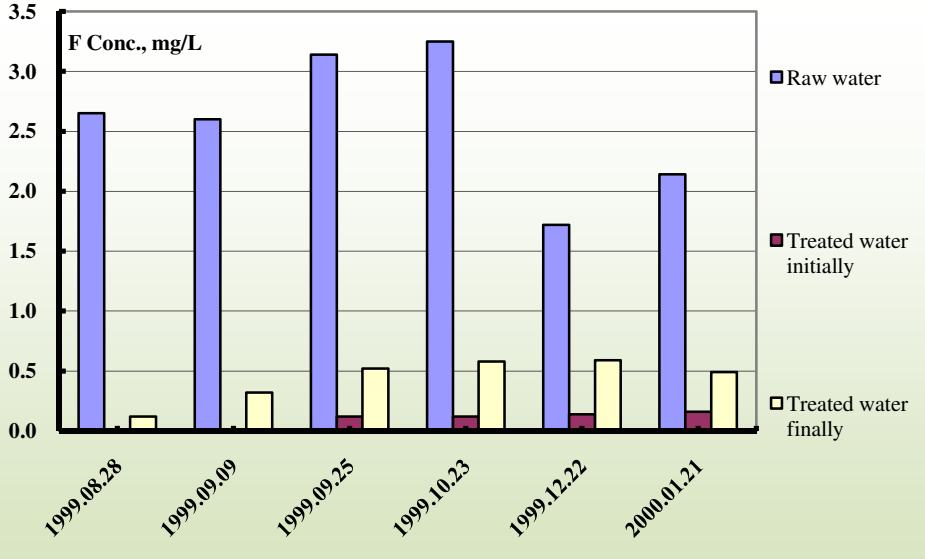

FIGURE 3. Monitoring data of a FLOWAT filter during 5 operation periods including 5 regenerations (no data available for November, 2000).

Figure 3 shows that one filter was operated for 147 days, during which the filter was regenerated five times. On an average, the raw water had a fluoride content of 2.6 mg/L and the treated water was between 0.1 and 0.4 mg/L, indicating an average removal efficiency of 89 %. Assuming a daily consumption of 30 L of water per family per day, the fluoride removal capacity of activated alumina in this filter is calculated to be 0.7 g/kg. This figure is very close to what is recommended by Dahi 2000 as a design parameter for activated alumina [5].

The field experiences have shown that FLOWAT is easy to operate and to maintain. The cost of the filter is 650,000 VND, equivalent to about 45 USD. The monthly regeneration requires only 0.4 kg of aluminium sulphate, which is considered affordable to the beneficiaries, as 1 kg of alum is 3,000 VND, equivalent to 20 US Cents. Furthermore, the filters seem to be highly accepted by the communities in the tested communes. The villagers there considered the filters as a necessary facility in their households and were ready to pay for them.

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