Field Trial of Fluoride Removal by Phosphoric Acid-Crushed Limestone Treatment

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Abstract

This paper describes the results of a field trial of our recently reported technique of fluoride removal from groundwater having potential for rural application in developing countries. The technique is based on phosphoric acid-crushed limestone treatment and capable of removing fluoride to as low as 0.001mg/L. The field trial was conducted with a small community unit and five domestic units having batch capacities of 220 L and 15 L, respectively. The results have been excellent and even better than that of the reported laboratory scale pilot study reducing the [F^-] to 0.58-0.81 mg/L from initial 2.8 to 20 mg/L consistently up to 250 cycles with an adjusted dose of only 0.68 mM phosphoric acid (PA). The fluoride removal was independent of the initial [F^-] but strongly depend on the dose of PA. The slight variations in the effluent [F^-] have been attributed to difference in alkalinity of the water and possible dissolution of CaO impurities of limestone rather. All relevant water quality parameters of the treated water, including Ca, PO_4 and heavy metals, meet the requirements of the WHO for drinking water. The effluent pH remains in the range 7.45-7.90. The field trial has proven this highly efficient, extremely low-cost, safe and environment-friendly method, which has been being operated by laymen without needing electricity as a very good rural fluoride removal technology for developing countries.

Keywords

Fluoride removal; limestone defluoridation; phosphoric acid; hydroxyapatite

INTRODUCTION

Presence of excess fluoride in groundwater is a worldwide problem affecting millions of people, particularly in the developing countries. Some developing countries like India have set a maximum limit of 1 mg/L of fluoride in drinking water against 1.5 mg/L advised by WHO. However, a fluoride removal method which is low-cost, safe, environment-friendly and can be used by a layman without requiring power is still not available. We recently reported a fluoride removal technique based on phosphoric acid-crushed limestone treatment (PACLT), which meets most of the above-mentioned requirements (Gogoi, 2015). Here we report the results of a field trial of the PACLT method conducted at small community and household level at some fluoride affected villages of Karbi Anglong district of Assam, India.

MATERIAL AND METHODS

The crude limestone obtained from Bokajan Cement Factory, Assam, India, was a high purity calcite (Nath, 2010). PA (AR, Merck, Mumbai) was used as such. [F^-] and pH were determined by using Orion 5 Star Benchtop Multiparameter Kits with a fluoride ion selective electrode and a pH electrode, respectively, following standard procedure (Gogoi, 2015).

Each field unit consisted of a plug-flow reactor, a mixing container and a filter. We used a small community unit made of a 500 L plastic container reactor, filled with 5-20 mm crushed limestone, giving a void volume (batch capacity) of 220L (Figure 1). An additional 500 L plastic tank was used for mixing PA with raw water before feeding the reactor. We also used five household units made of 40 L bucket as reactor giving a batch capacity of 15L. A 15 L bucket was used for mixing PA. A four layered sand-crushed limestone-sand-gravel filter cum pH corrector was used for both types of units. The simple procedure is:

(i) The raw water was mixed with the specified dose of PA and put into the reactor.
(ii) After 3h of residence time, the water was transferred to the filter to get fluoride-free water.

RESULTS AND DISCUSSION

The PA dose was optimised which gives an initial [PA] of. Though the method was found to be capable of removing fluoride to as low as 0.001mg/L, the effluent [F^-] was maintained at ≈ 0.7 mg/L by adjusting the dose of PA as 0.68mM needing 0.47mL of 8.5% PA per litre of water. The fluoride removal results along with pH obtained up to 250 cycles from the field units with sources [F^-] between 2.8 and 20 mg/L, which are better than even than that of the reported laboratory pilot test, are shown in Figure 1. All relevant water quality parameters including pH, Ca and PO_4 were consistent with WHO guidelines. The method is not affected by coexisting ions. The observed excellent performance of the PACLT has been attributed to a strong and highly selective sorption of F^- by in-situ formed hydroxyapatite in addition to precipitation of fluorite and adsorption by limestone. The capacity of limestone and the total cost of the method have been estimated as 160 L per kg of limestone and 0.28 USD per m^3 of treated water. The users express satisfaction with the simplicity of the method.

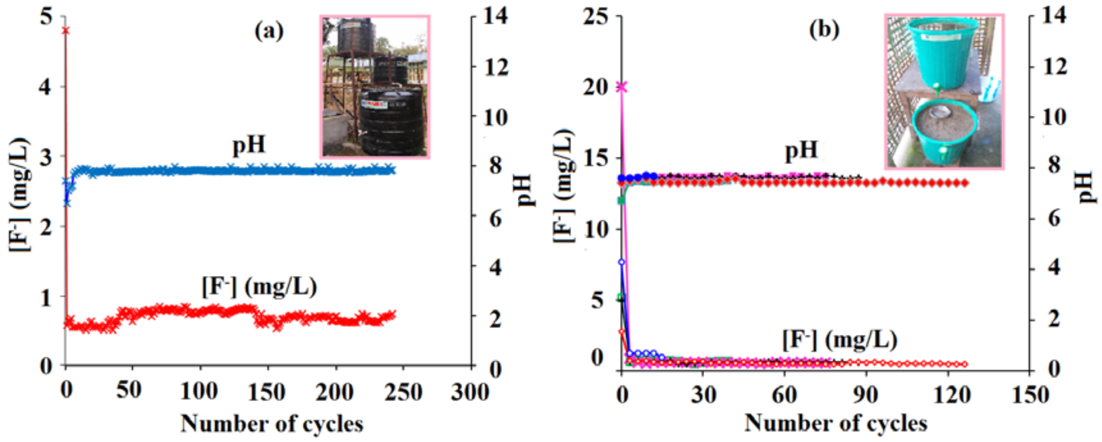

Figure1. [F^-] and pH of water before and after treatment in the small community unit (a) and the five domestic units (b) with picture of the representative systems in the respective insets.

CONCLUSIONS

The field application has proven PACLT as an excellent fluoride removal method with very high efficiency, extremely low cost, high capacity of limestone, no residual contamination, non-requirement of power, environmental-friendliness with small solid non-leaching sludge, simplicity and ease of operation, and suitable for rural application.

REFERENCES

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