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Water Purification Using Electrocoagulation as a Viable Solution for Upgrading Rural Water Supply Schemes

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ABSTRACT

Nearly 30 percent of the rural water supply schemes implemented in Sri Lanka is not used as drinking water sources due to high hardness, alkalinity and fluoride. The community has rejected these schemes because the surrounding wells in these areas have low hardness levels although their microbiological quality is very poor. Thus the community has gone back to the contaminated sources for drinking water in spite of heavy investment in these rural water schemes.

This paper highlights a pilot study done at Asokamalagama, Pemaduwa in North Central Province to upgrade the water quality of their rural water supply scheme. In this study, fluoride level of 5.5 mg/l and hardness of 220 mg/l $CaCO_3$ has been reduced to less than 1.0 mg/l and 90 mg/l $CaCO_3$ respectively. Thus the water quality is adhering to SLS 614 : 1983 for fluoride and hardness content. The methodology used is Electorcoagulation coupled up with sedimentation, sand filtration and activated carbon filtration.

In this study fluoride distribution in the Electorcoagulation defluoridation process and the hardness deposition in the cathodes were investigated to get the optimum condition of the removal. The bench scale model was attempted in a five litre vessel using water with high fluoride and hardness content and the trials carried out showed a reduction of fluoride by 80 – 90 % and the hardness by 40 – 50 %. The pilot plant was constructed in Asokamalagama using tube reactors initially and later converted to plate reactors but with the same removal efficiency achieved as in the bench model. The plant is operated by female operators in the village thus empowering the village women.

This one year implementation study shows that this methodology could be applied to other problematic rural water supply schemes if budgetary provisions are available.

INTRODUCTION

It has been identified ten problematic rural water supply schemes in Anuradhapura, five schemes in Vanathavillu Divistion in Puttlam District, seven schemes in Kobeigane DS Divisiton in Kurunegala District and six schemes in Galgamuwa DS Division in Kurunegala District. In both Anuradhapura and Kurunegala rural water supply schemes, the main areas of concern are hardness, alkalinity and fluoride while that of Puttlam is high hardness and alkalinity only. The methodologies available to treat the above issues in water are Reverse Osmosis, water softening and Electorcoagulation. The Electorcoagulation methodology is selected for this study because of the availability of purchasing electrical and mechanical components in Sri Lanka and the low cost of installation. In addition, the sustainability has been proved by operating this unit for more than one year.

MATERIALS AND METHODS

A bench scale trial was carried out using 6 Aluminum electrodes of size 10 X 30 cm^2, 5 mm apart in 1.5 liter vessel of Asokamalagama tube well water (Figure 01). One A current was passed through it for a period of one hour. The flocs were allowed to settle and filtered through a 0.45 micron filter paper and the samples were analyzed. Efficiency of removal of hardness and fluoride verified using different type of waters in other parts of Sri Lanka.

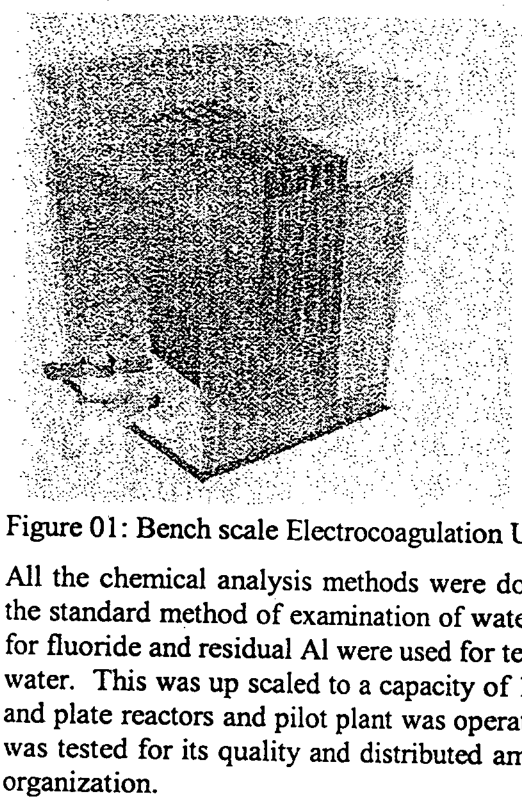

Figure 01: Bench scale Electrocoagulation Unit

All the chemical analysis methods were done according to the procedure given in the standard method of examination of water (APHA, 2005). Pocket spectrometers for fluoride and residual Al were used for testing the raw water as well as processed water. This was up scaled to a capacity of 100 l/hr and 200 l/hr using tube reactors and plate reactors and pilot plant was operated in this village. The processed water was tested for its quality and distributed among villagers, by the community based organization.

RESULTS AND DISCUSSION

The main cathodic and anodic reactions for hardness and fluoride using aluminum electrodes are given in the following (Behbari *et al.*, 2011, Ghosh *et al.*, 2008).

At the anode: $Al \longrightarrow Al^{+3} + 3e$

At the cathode: $2H_2O + 2e \xrightarrow{H_2} 2OH^-$

When the anode potential is sufficiently high, secondary reactions may occur, especially, oxygen evaluation.

At the anode: $2H_2O \longrightarrow O_2 + 4H^+ + 4e$

Aluminum ions produced by electrolytic dissolution of the anode, immediately undergo spontaneous hydrolysis reactions which are pH dependent. They are Al $(OH)^{+2}$, $Al(OH)_2^+$, Al $(OH)_3$ and $Al(OH)_4^-$. At pH between 6 to 8 fluoride adsorption takes place and forms $AL(OH)_{3-x}$ Fx (Hu *et al.*, 2003). On the other hand calcium carbonate deposition takes place at the cathode thus reducing hardness.

At the Cathode : $HCO_3^- + OH^- \longrightarrow CO_3^{-} + H_2O$

$CO_3^{--} + Ca^{++} \longrightarrow CaCO_3$

The initial trial was up scaled to produce 100 l/hr unit using tube reactors. In this unit circular tube of length 1.5 m and diameter 60 mm were used.

The first few trials could only achieve and average fluoride level of 1.7 mg/l with the source level of 5.5mg/l. This is a reduction of 66% of the fluoride content in water (Padmasiri and Jayawardana, 2010). The resultant processed water of fluoride 1.7 mg/l was recycled through the unit and it was possible to reach the target of less than 1.0 mg/l fluoride in the processed water. The electricity consumption of the unit is 0.36 KWH thus the electricity cost is negligible. However, in the operational point of view the female operators found it difficult to fix the end caps, also there were other short comings in the fabricated unit. Subsequently, trials were carried out using plate reactors.

Using a electrical current of 2 A each for all these tubes, the lowest average fluoride in the processed water was 1.20 mg/l. Figure 02 presents 15 sets of tube reactors in which each reactor was supplied with increasing current with a flow of 100 l/hr. Then the total charge coulombs were increased with the each reactor and the removal efficiency of fluoride was obtained as 92% and fluoride in the processed water was less than 1.0 mg/l. (Figure 03). Figure 04 shows the removal efficiency of hardness and it was in the range of 70% reduction.

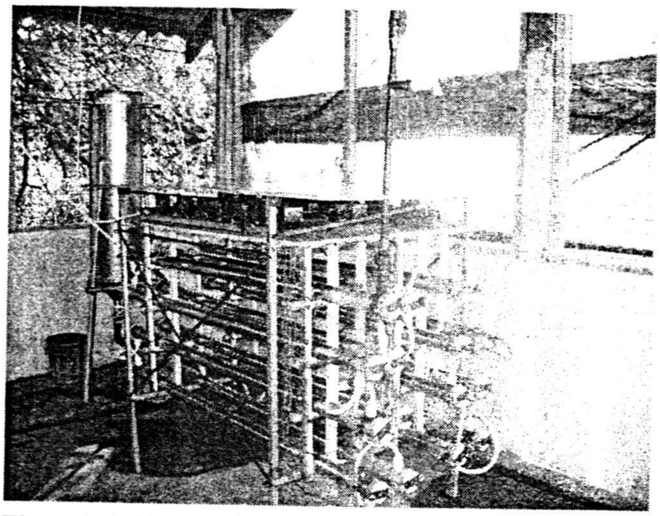

Figure 02: 15 sets of tube reactors

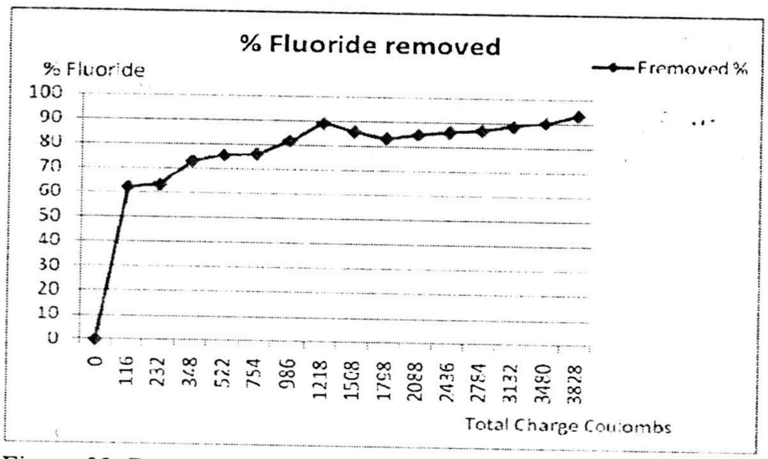

Figure 03: Removal of Fluoride at Asokamalagama reactor at flow rate of 100 l/hr

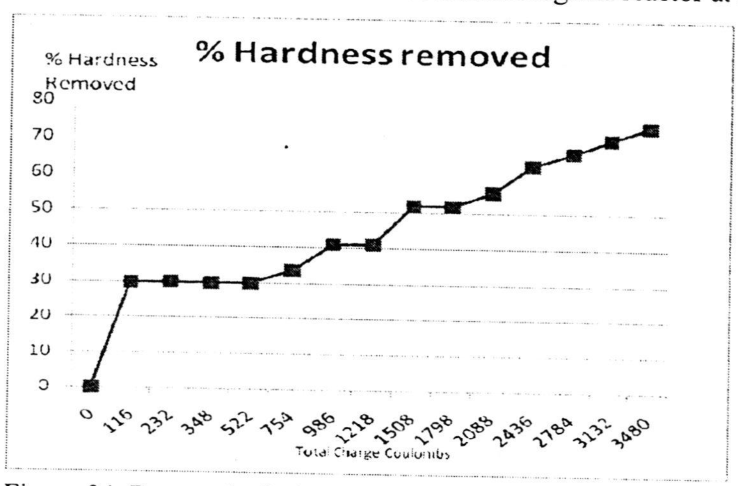

Figure 04: Removal of Fluoride at Asokamalagama reactor at flow rate of 100 l/hr.

Figure 05 presents three plate reactors with vessel capacity of 20L with the aluminum plates where the current in reactors 1, 2 and 3 were 2, 4 and 6 Amp respectively. Several trials were carried out and samples were collected from each reactor at half an hour intervals. The collected sample was allowed to settle and then filtered through 0.47 micron filter paper using a vacuum hand pump. The filtered water was subjected to fluoride and hardness tests.

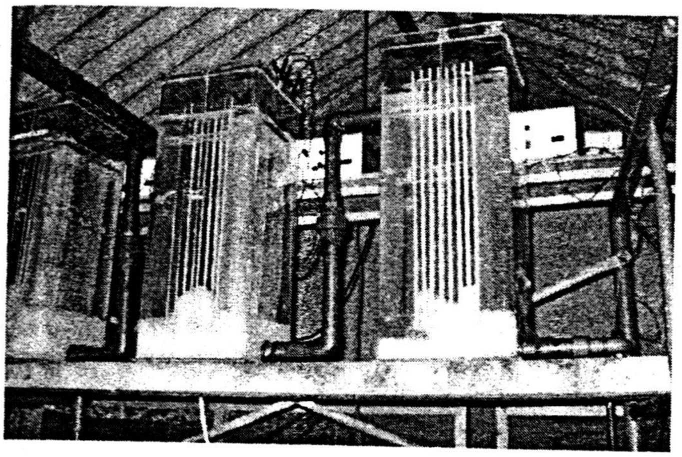

Figure 05: Tube reactors with 20L capacity

Figures 06 and 07 show the fluoride removal efficiency in the reactors and they are in the range of 80 – 90 % and that of hardness removal was in the range of 50 – 70 % for 12 months.

On the other hand, the removal of plates in the reactors was much easier than that of tube reactors for maintenance purposes. Female operators were happy to operate these plate reactors rather than tube rectors thus achieving high efficiency in village level operations.

In the Electrocoagulation technology the sludge production rate is higher compared to chemical coagulation and hence a sludge recovery tank was connected in order to reduce the loss of processed water.

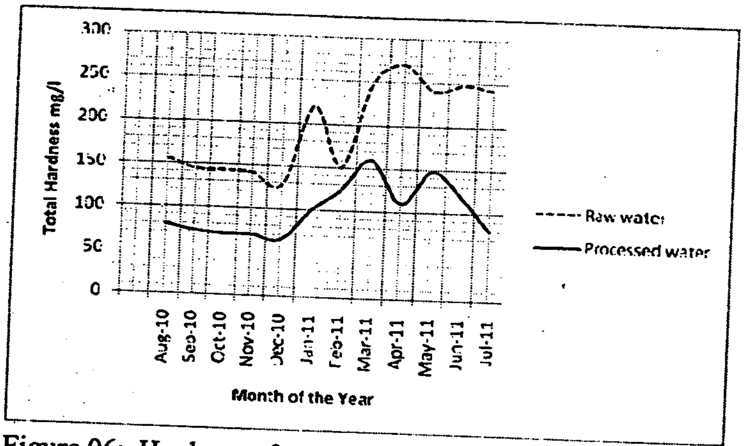

Figure 06: Hardness of water before and after processing

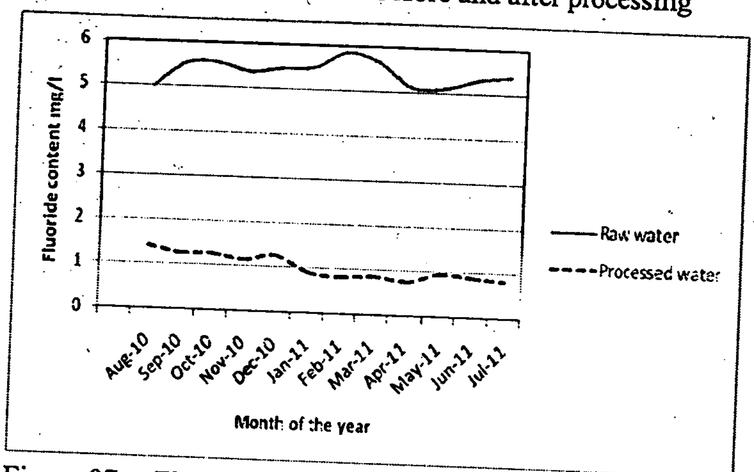

Figure 07: Fluoride content of water before and after processing

CONCLUSIONS

The Electrocoagulation water purification technology is a viable option for removal excess hardness/ fluoride in drinking water in Rural Water Supply Schemes. It shows high efficiencies in removing fluoride and total hardness in water with a considerably low cost.

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