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Journal of Vibration Engineering

ISSN:1004-4523

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Field Testing of a Magnesium Oxide-Lime-Calcium Chloride-Hydrochloric Acid Based defluoridationfilter (Part2)

K. Margandan[1], R. Agrawal[2], S. Sharma[3], K Qanungo*[4]

[1]Department of Chemistry,
IFET College of Engineering,
P.O. Gangarampalayam, Dist. Villupuram,
Tamilnadu- 605108

[2]Department of Chemistry,
GGD SD College, Palwal,
Haryana-121102

[3]N-307, Gillco Heights,
Gillco Valley, Kharar,
Dist. Mohali, Punjab

[4]Department of Chemistry,
University Institute of Science,
Chandigarh University,Gharuan, Mohali, Punjab, India

margandan.123@gmail.com[1], rachnaagrawal26@gmail.com[1], sarojs_31@yahoo.co.in[3], kushalq@rediffmail.com[4]

Abstract

Field trials of a magnesium oxide-lime-calcium chloride-hydrochloric acid based fluoride filter has been carried out over a period of ten days in the house of Mr. Bhavar Singh, in a fluorosis affected village in India. The raw and filtered water was analyzed to check the working of the filter. A reduction of 65% of fluoride, 75% reduction of HCO_3^-, 72% reduction of total alkalinity, 169% increase in Cl^- and 20% increase in TDShas been observed in the filtered water as compared to the raw water.

Keywords:*water, fluoride, magnesium oxide, calcium oxide, defluoridation*

Introduction

The beneficial and harmful effects of fluoride in drinking water has been well documented[1-2].Fluoride is very important in the formation of the tooth enamel when present below 1 ppm, however when present above 1.5 ppm it severely effects bones and teeth and causesa variety of other health issues.

Accordingly, the optimum range of fluoride concentration in drinking water has been specified by the WHO to be between 0.5 to 1.00 ppm with a maximum permissible limit of 1.5ppm [3]. The BIS standardsspecifies the optimum concentration of fluoride at 1 ppm and maximum permissible limits at 1.5 ppm [4-6]. As clean sources of surface water are dwindling, people have turned to ground water as the principal source of drinking water in most parts of the world. In many places the ground water is contaminated with fluoride beyond the permissible limits. Rajasthan a desert state in the north western part of India has only one perineal river and therefore its population depends heavily on ground water for drinking and agriculture. Moreover, its ground water is at many places contaminated with fluoride and people suffer from severe fluorosis [7-9]. The government of the state of Rajasthan is putting up massive efforts for fluorosis mitigation [10].

There are several well-known methods for fluoride removal which include The Nalgonda Technique, ion exchange, bone char, clay bricks,reverse osmosis, activated alumina [2]. A new MgO based defluoridation filter that has been recently developed at IISc Bangalore in India [11-14]. Since the ground water characteristics are very different in Rajasthan than in Karnataka where the method was originally developed and many parts of Rajasthan are fluorosis affected, particularly those of the Lakshmangarh Tehsil of Sikar district of Rajasthan, the Department of Science and Technology, Govt. of India under its Water Technology Initiative had funded the adaption and testing of the filter in the region. In this particular process the flouride contaminated raw water is treated with lime, magnesium oxide and an aqueous solution of 5% calcium chloride in definite proportions, mixed well and left overnight for 16 hours. This water which is now basic, is then filtered into another vessel. To lower the pH of the water to the potable range a dilute aqueous solution of sodium bi-sulphate is added and now the water is ready for drinking.

After numerous experiments a suitable ratio of lime, magnesium oxide and the volume of 5% solution of $CaCl_2$was determined. Due to excess of SO_4^{-2} in the pH adjusted water,dilHCl was used instead of sodium bi-sulphate in laboratory trials of the filter conducted earlier. In continuation of our ongoing study[15-19]to assess the performance of the defluoridation filter in actual practice, we had conducted a series of tests of the filter in the village PilaniyonkiDhani (PKD) (a small sub-village of Shola village) in Lakshmangarh. In this paper we report the results of this particular user trial in the house of Mr. Bhanwar Singh.

Materials and Methods

The fluoride filter was fabricated using the procedure described earlier [13]**.** The filter was installed below the staircase of a house (Mr. Bhanwar Singh) in PilaniyonkiDhani (Village Shola) (figure 1). The household was provided with 5 bottles, 500 ml of 7.5% $CaCl_2$ in demineralised water, 150 ml of 0.38 N HCl in demineralised water and 5 food grade polythene packets of 40.0 gmMgO + 50.0 gmCaO mixture. The performance of the filter was monitored at his home over a period of ten days (5^{th}, 7^{th}, 9^{th}, 12^{th} and 14^{th}) in the month of April 2014. The tap water and the filter treated water was brought (on each of the days mentioned) from the village and tested in the laboratory located at MUST, Lakshmangarh.

Fluoride was measured using an Ion Selective Electrode (Orion-Thermo Scientific, USA) using Total Ionic Strength Adjustment Buffer (III) as buffer with two point calibration. The alkalinity was determined by titrating with dil. H_2SO_4. The pH, TDS were measured using hand held Hanna pH and TDS meter (USA). Calcium and magnesium hardness was determined by EDTA method. Chloride was

Figure 1.Photo of the field trials of the defluoridation filter in the house of Mr. Bhavar Singh vil. Pilaniyon Ki Dhani.

determined by titrating with $AgNO_3$ solution. The concentrations of SO_4^{2-} and NO_3^- were monitored during lab trials and since no change was observed they were not monitored for this particular user trials.

Result and Discussion

Numerous experiments were carried out in the laboratory using water brought from the village PKD before the field work commenced. The raw water and filter treated water was analyzed for various water quality parameters. The measured quality parameters in the filtered water (like the pH, TDS, Ca, Mg, hardness, CO_3^{2-}, HCO_3^-, Total alkalinity, SO_4^{2-}, Cl^-) were within the permissible limits. However, there was high concentrations of nitrate. This was understandable because in the tap water itself had high concentrations of nitrate (earlier work) [16]. The defluoridation filter was put to field testing after the filter passed the lab tests successfully.

Under actual user conditions it was found in five trials, that 150 ml of 0.38 N HCl was sufficient to bring down the pH to within potable limits (figure 2). Note that though the lowering of pH is consistent there is not much change in the pH values of the untreated and filtered water.

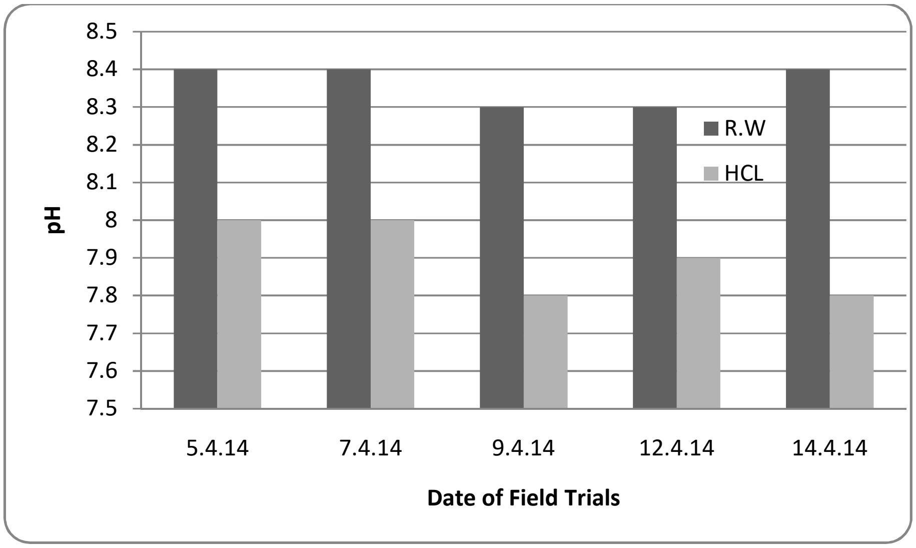

Figure 2.Comparative pH values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.)

The reduction of F^- levels occurred by an avg. 1.16 ppm (65%), (figure 3) in this actual user trials. A combination of precipitation of $Mg(OH)_{2-x}F_x$[14] and CaF_2[20] results in the lowering of fluoride removal.

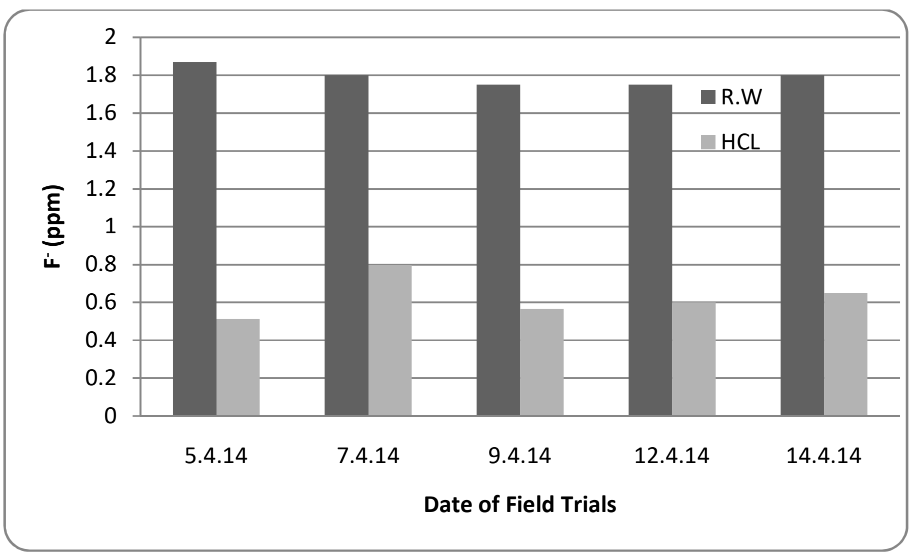

Figure3.Comparative F^- values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.)

There is considerable lowering of HCO_3^- ion levels by 1324 ppm(75%),(figure 4) in the treated water as compared to the tap water in this particular user trials. This is ascribed due to the formation of insoluble $CaCO_3$.

$$HCO_3^- + Ca^{+2} + OH^- \rightarrow CaCO_3\downarrow + H_2O \qquad \text{(eqn.1)}$$

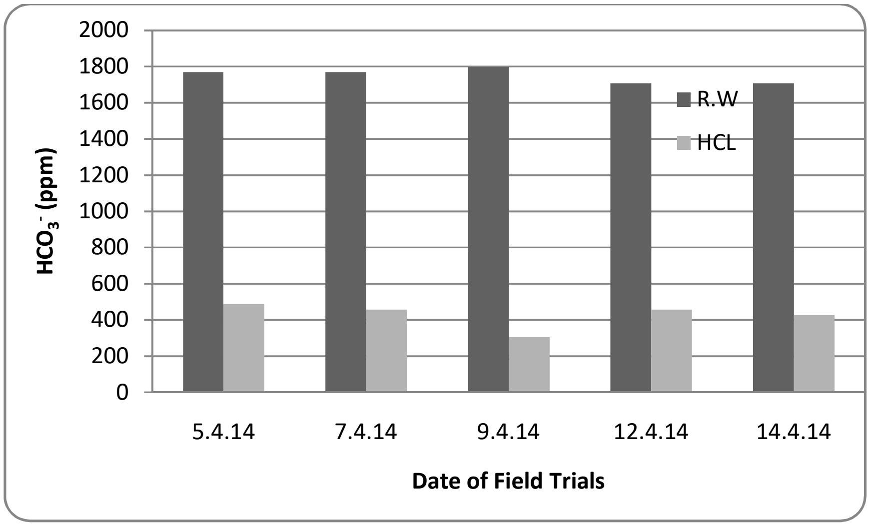

Figure 4.Comparative HCO_3^- values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.)

No clear trend has emerges in the CO_3^{2-} values in filtered and tap water (figure 5). This is because of the combined effects of the presence of $CO_3^{2-} + H^+ \leftrightarrow HCO_3^-$equilibrium in these systems and the precipitation of CO_3^{2-} as $CaCO_3$ due to the presence of adding excess calcium in form of calcium chloride and lime in water.

$$Ca^{+2} + CO_3^{-2} \rightarrow CaCO_3\downarrow \quad \text{(eqn.2)}$$

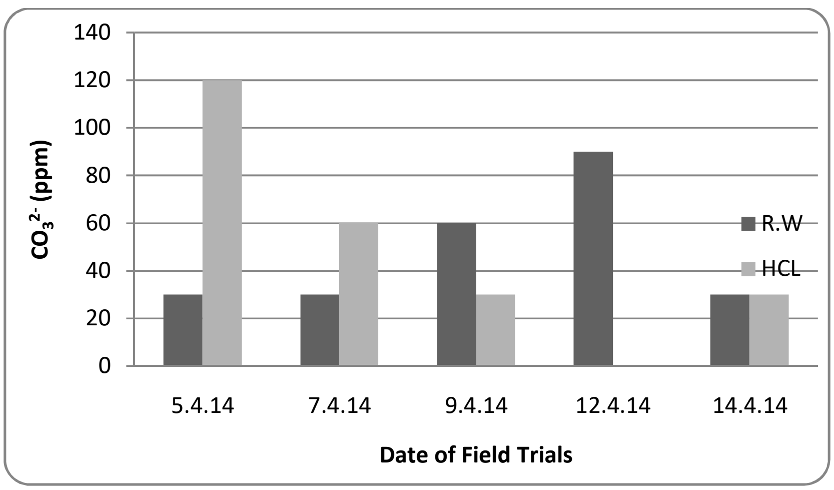

Figure 5.Comparative CO_3^{2-} values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.)

The Total Alkalinity is lowered by 1040 ppm (75%),in filtered water as compared to raw water for user trials (figure 6).

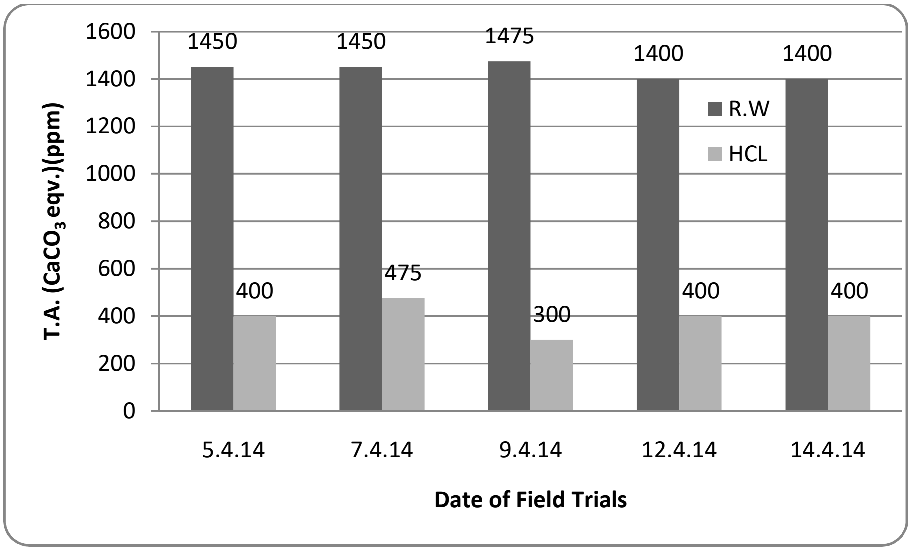

Figure 6.Comparative Total Alkalinity values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W)

The added calcium in form of calcium chloride and lime gets precipitated in the form of $CaCO_3$ (eqn. 2) therefore the Ca^{2+}levels does not increase much in treated water (figure 7).

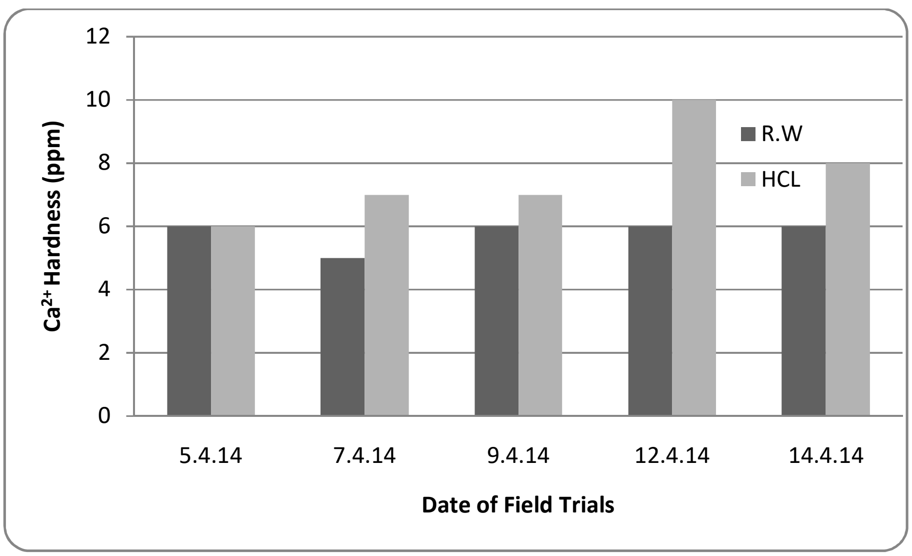

Figure 7.Comparative Ca^{2+} Hardness values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.)

Due to very little solubility of $Mg(OH)_2$ in water (K_{sp}=5.0 × 10^{-12}) [21], the Mg^{+2} levels does not differ much in the filtered water as compared with untreated water (figure 8).

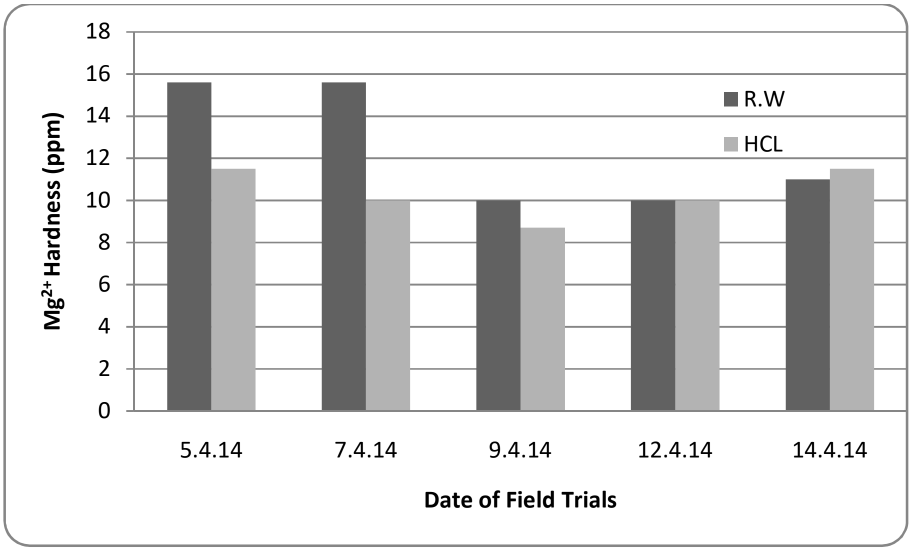

Fig. 8 Comparative Mg^{2+} Hardness values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.).

In line with above the Total Hardness of the water also does not change as compared to untreated water for field trials (figure 9).

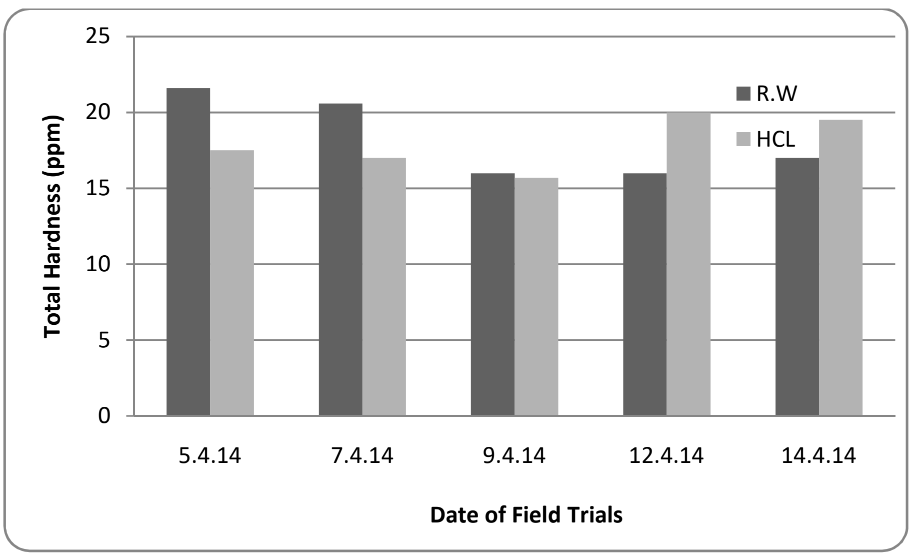

Figure 9.Comparative Total Hardness values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.).

However, the chloride concentration increases noticeably by 486 ppm (169%),in field trials (figure 10). This is due to the added Cl^{-} in form of HCl required for the lowering of pH.

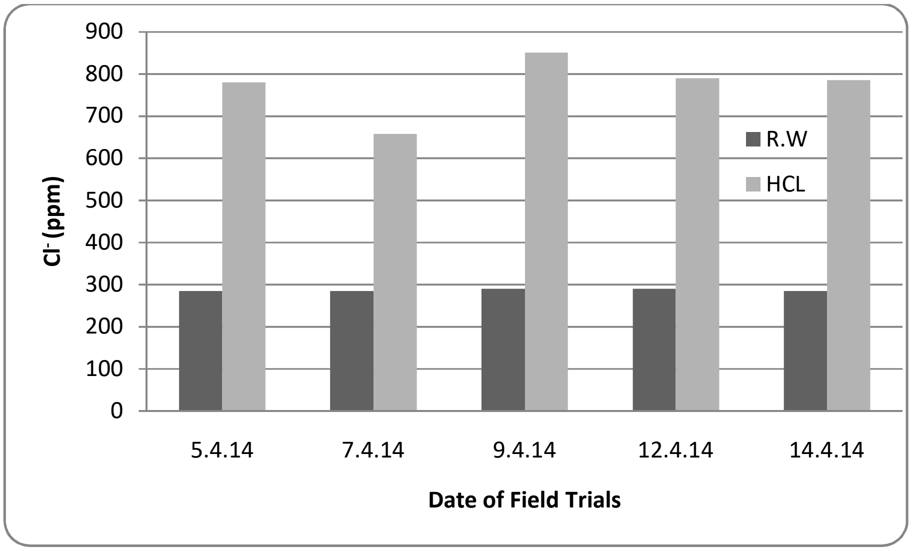

Figure 10.Comparative Cl^- values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.).

There is an average increase of 242 ppm (20%),in TDS, of the filtered water as compared to the raw water (figure 11). This is in part due to the addition of oxides of Mg and Ca together with $CaCl_2$ and finally HCl to the water.

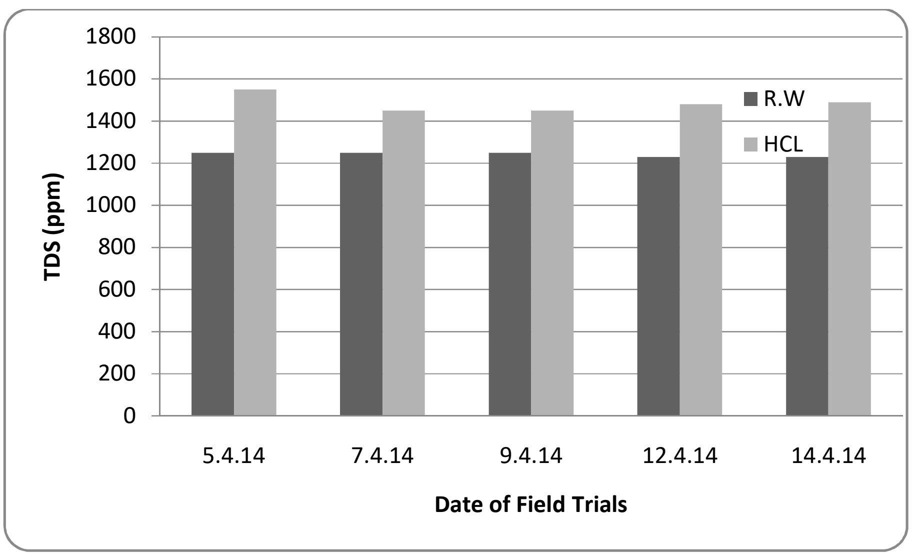

Figure 11.Comparative TDS values of raw and filtered water during field trials of the filter in the house of Mr. Bhavar Singh (vil. PKD, Manish T.W.).

The sludge generated from the user trials of the filter was transported to the laboratory at MUST, Lakshmangarh for making of compressed sludge mud blocks stabilized using cement. A very little change of taste of water from the filter as compared to tap water was observed and during field visits it was observed that the household were enthusiastic about the trials of the filter taking place in their home.

Conclusion

To conclude we have carried out the user field trials of the magnesium oxide based filter and found that HCl dosage had to readjusted in user trials. The filter operated at an efficiency of 65% with respect to lowering of fluoride levels. There was a minimal change in the taste of the filtered water as compared with tap water and the user trials of the filter was welcomed at the rural household.

Acknowledgements: Financial help from (Water Technology Initiative) DST, Govt. of India is acknowledged in form of project No. (DST/DT/WTI/2k8/95). Prof. S. SudhakarRao, IISc, Bangalore is thanked for advice. The authors thank MUST, Lakshmangarh for the necessary lab facilities, KM thanks IFET, Villupuram and RA thanks GGD SD college, Palwal and KQ thanks CU, Gharuan for support and encouragement.

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