Indigenous Household Groundwater Filter Unit of North Guwahati (Assam) for Iron and Fluoride Removals

Ankit Soni and Mohammad Jawed

Abstract The rural population of Amingaon, North Guwahati (Assam) relies heavily on groundwater for their domestic needs. But groundwater is reported to be contaminated with excessive amounts of iron and fluoride. The population uses indigenous household groundwater filter units for iron removals. These units are fabricated using reinforced cement concrete (RCC) circular pipes, tin containers, and plastic buckets with river sand, wooden charcoal (in some cases), and gravel serving as filtering media either in layered or mixed form. The present work aims to review and document the different types of indigenous household groundwater filter units being used in this area. In addition, efforts are also made to evaluate the performance of a selected filter unit for iron and fluoride removal from the groundwater. The iron concentration in groundwater of Amingaon, North Guwahati varies from 0 to 11.03 mg/L exceeding the permissible limit for drinking water (0.3 mg/L), whereas fluoride concentration varies from 0.10 to 0.68 mg/L—always meeting the permissible limit 1.5 mg/L. A selected indigenous household groundwater filter unit is monitored to assess its performance over a period of 86 days. The filter unit is found to be highly effective in iron removal of 99% or more from an initial concentration of 1.33–2.08 mg/L down to 0–0.2 mg/L meeting the limit of drinking water quality. The iron removal is mainly due to increase in DO levels which precipitates out the iron and the precipitated iron is filtered out through the filter unit. The concentration of fluoride in the groundwater is not exceeding the permissible limit of 1.5 mg/L. Fortunately, the filter unit is not reducing the fluoride concentration present in the groundwater.

Keywords Indigenous household groundwater filter unit · Drinking water · Iron · Fluoride · Groundwater · North Guwahati

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1 Introduction

Groundwater is the major source of freshwater, which contributes 29% of total available freshwater on the earth. Roughly, 2 billion people in the world are dependent on groundwater for their daily needs and irrigation purposes. Groundwater fulfills 50% of agricultural needs and 80% of total drinking and cooking water requirements in rural India [12]. But groundwater is generally contaminated with iron, fluoride, arsenic, and nitrate. Assam, a northeastern state of India is facing the problem of fluoride and iron contamination in groundwater. Karbi Anglong and Nagaon districts are severely affected by the fluorosis problem [4]. Fluoride concentration varies from 0.2 to 18.1 mg/L in groundwater of Assam [12]. In and around Guwahati city, fluoride and iron concentration in groundwater varies from 0.2 to 6.9 mg/L [5] and from 1 to 10 mg/L [1], respectively. Iron does not cause any harmful effect on human health but this is unacceptable due to its visual appearance and taste. Excessive concentration of fluoride in drinking water severely affects human health. Fluoride concentration more than 1.5 mg/L causes dental and skeletal fluorosis [17]. The prescribed limits of iron and fluoride in drinking water are 0.3 mg/L and 1.5 mg/L, respectively [9].

Many treatment techniques have been developed all over the world for iron [2, 6, 7, 13, 18]; Polasky [15] and fluoride removal [19, 8, 10, 11, 14, 16] from groundwater. But these techniques are not widely used in rural and semi-urban areas due to its high capital and operational cost, and unavailability of raw materials in rural areas. The rural population of Assam is using indigenous household groundwater filter units to remove excessive iron concentration from groundwater [1]. Fluoride remains in dissolved form in groundwater and does not give any visual appearance, in contrast to iron, thereby escaping the attention. The design and operation of indigenous household groundwater filter is based on traditional knowledge and experiences of rural people. Sand, gravel, and charcoal are generally used as a filter media as these materials are cheap and locally available to rural community.

Rural population of Amingaon—a village located in the North Guwahati area of Assam is heavily dependent on groundwater for their daily needs. However, no attempts have been made to assess iron and fluoride contaminations in groundwater of Amingaon. The people of Amingaon are using different types of indigenous household groundwater filter units to remove excessive iron contamination from groundwater. Unfortunately, the detailed scientific studies are lacking to document the fabrication and operation of different types of filter units in use, to assess the capability of the filter units for contaminant (iron and fluoride) removal. Hence, this research work is focused to understand the fabrication and operation of different types of filter units in use, to assess iron and fluoride contaminations in groundwater of Amingaon (North Guwahati) and to monitor the performance of a selected indigenous household groundwater filter unit.

2 Materials and Methods

2.1 Field Survey

In order to understand the fabrication and operation of different types of filter units in use and to assess iron and fluoride contaminations in groundwater of Amingaon (North Guwahati), a field survey was carried out during mid-June 2017–mid-July 2017 in and around rural areas located just outside the boundary of IIT Guwahati. During the course of field survey, the location of filter units was obtained by GPS. The information related to fabrication and operation of the filter units were obtained through personal interactions with the houseowner (or the landlady). Photographs were also collected for the filter units. In addition, groundwater samples were also collected to assess iron and fluoride levels in the groundwater.

2.2 Monitoring of Selected Indigenous Household Groundwater Filter Unit

The filter unit in the House-B (GPS location: 26° 11′ 01.7″ N and 91° 41′ 38.7″ E) was selected for continuous monitoring. The reasons for selecting this filter unit were: (a) the source of groundwater was located at a distance from the bank of river Brahmaputra with possibly minimum infiltration of river water and (b) filter location was close to the Environmental Engineering Laboratory of the Department of Civil Engineering, IIT Guwahati (at a distance of 400–500 m), which shall facilitate in quick transportation of the collected water samples and its analysis.

The household of the selected house collects the water from the groundwater source, stores it and then filters the stored water according to their needs. Hence, it was deemed essential to collect three samples at a time—the first sample was collected directly from the tube well (i.e., source groundwater), the second was collected from the stored water, and the third one was collected from the filtered water. The collected samples were analyzed for temperature, pH, DO, iron and fluoride—taken as important water quality parameters for monitoring of filter performance. The water samples were collected once in 3 days and analyzed since July 2017.

2.3 Methods

Temperature, pH, dissolved oxygen (DO), iron, and fluoride were selected as water quality parameters and were thus analyzed during the research work. Temperature and pH were determined by the digital pH meter (Model: LT-49, M/S Labtronics Pvt. Ltd., India). DO was determined by the Azide Modification method [3]. Iron concentration in water was analyzed by Phenanthroline method [3] using spectrophotometer (Model: Spectro V-11D, M/S MRC Ltd., UK). Residual fluoride was analyzed by SPADNS method [3] using spectrophotometer. GPS locations were obtained using a smart mobile phone (Model: P5 W, M/S Gionee, India).

3 Results and Discussion

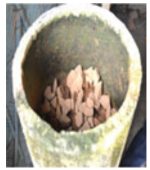
3.1 Field Survey

A field survey was carried out in Amingaon, North Guwahati area of indigenous household groundwater filter units in use in the households located outside the boundary of IIT Guwahati. During the survey, the households having groundwater filter unit in use were selected for gathering information with respect to: (i) procedure followed for fabrication of filter unit type, (ii) operation and maintenance of the filter units, and (iii) quality of groundwater with special attention on iron and fluoride concentrations. The relevant information was obtained through personal face-to-face interaction with the houseowner (or the landlady). In addition, the obtained information was further supplemented with photographic evidences collected for the filter unit in use. The groundwater samples were also collected from the surveyed household for the assessment of concentrations of iron and fluoride. A brief summary of the representative filter units in use as observed during field survey is presented in Table 1. The filter units were generally fabricated using plastic buckets, reinforced cement concrete (RCC) rings, and tin containers depending upon economic condition of respective households. Sand, gravel, and wooden charcoal (in some locations) were used as filtering media either in separate layer form or as a mixture of two or three mediums. Sand and wooden charcoal both were procured from the village market of Amingaon. Some of the filter units also used plastic net to prevent passage of sand to filtered water. The ranges of iron and fluoride concentration in the groundwater of the surveyed locations are 0–11.03 mg/L and 0.10–0.68 mg/L, respectively.

3.2 Monitoring of Selected Indigenous Household Groundwater Filter Unit

Usually, the female members of the family of the selected house (House-B) draws the groundwater from a nearby tube well, store it for a few minutes to hours, and then filter it according to their requirement of drinking and cooking water. On an average, everyday 20 L water is filtered out to meet the requirement of drinking and cooking purposes. After operation of the filter unit for a few days, black color coating is formed on the top layer of filter media (i.e., on sand particles), and

Table 1 Summary of indigenous household groundwater filter unit types in use in Amingaon, North Guwahati

Location details	Description of filter unit type in use and source groundwater quality		
House-A at Ghoramara (400 m from IIT boundary) GPS Coordinates: 26° 11′ 11.6″ N, 91° 42′ 08.2″ E	Filter unit fabricated using a plastic bucket of 29 cm internal diameter and 37 cm height. Filter media comprises of mixture of sand, gravel and a little amount of charcoal. Source groundwater contained 0.22 and 0.45 mg/L of iron and fluoride, respectively	 Front view	 Top view
House-B at Lothia Bagisa (300–400 m from IIT boundary) GPS Coordinates: 26° 11′ 01.7″ N, 91° 41′ 38.7″ E	Filter media placed in a circular plastic bucket of 38 cm internal diameter and 30 cm height in layered form of 13 cm each—sand (on top) and gravel (at bottom). Plastic net placed at the bottom of filter bed to prevent sand particles from passing to filtered water. Source groundwater contained 1.13 and 0.64 mg/L of iron and fluoride, respectively	 Front view	 Top view
House-C at Ghoramara (50 m from IIT boundary). GPS Coordinates: 26° 11′ 10.6″ N, 91° 42′ 02.4″ E	Two circular RCC pipes used for filter unit—top pipe holds filter media in layered form (14 cm sand layer above 7 cm of gravel bed) and bottom pipe stores filtered water. Plastic net placed below sand bed to prevent washing of sand to filtered water. Source groundwater contained 11.03 and 0.68 mg/L of iron and fluoride, respectively	 Front view	 Top view

(continued)

Table 1 (continued)

Location details	Description of filter unit type in use and source groundwater quality		
	Filtered water from the unit used for washing purposes. Constructed using single circular RCC pipe. Sand and gravel mixed to form filter bed of 60 cm depth. Bricks placed on top to prevent disturbing sand bed during pouring of water into the filter. Source groundwater contained 11.03 and 0.68 mg/L of iron and fluoride, respectively	 Front view	 Top view
House-B at Lothia Bagisa (300–400 m from IIT boundary) GPS Coordinates: 26° 11′ 01.7″ N, 91° 41′ 38.7″ E	Household filter unit constructed using two circular RCC pipes with internal diameter 43 cm and height 86 cm. Top RCC pipe holds filter media in layered form—on top 13–17 cm sand, in middle 10–13 cm charcoal and at bottom 10–13 cm gravel and the bottom RCC pipe stores filtered water. Source groundwater only contained 0.10 mg/L of fluoride (but no iron)	 front view	 Top view
House-C at Ghoramara (50 m from IIT boundary). GPS Coordinates: 26° 11′ 11.2″ N, 91° 42′ 02.6″ E	Tin container used to fabricate the filter unit. Filter bed of 24 cm depth prepared by mixing sand and charcoal and placed into the container. Plastic net placed at bottom of the container to prevent sand from passing to the filtered water. Source groundwater contained 3.73 and 0.63 mg/L of iron and fluoride, respectively	 Front View	 Bottom View

clogging problem appears in the filter unit. Filter unit needs dismantling and reinstallation after every 45–60 days of continuous operation to eliminate the problem of clogging and black color coating on sand particles.

As a part of continuous monitoring for assessment of the performance of filter unit operating at the House-B, it was decided to collect three samples at a time every third day—the first is collected directly from the tube well (i.e., source groundwater), the second is collected from the stored water, and the third one i collected from the filtered water. Water quality parameters, namely temperature, pH, DO, iron, and fluoride concentrations were considered relevant for performance monitoring and analyzed for the collected samples. The variations in concentrations of iron and fluoride are shown in Fig. 1, pH and temperature in Fig. 2, and DO in Fig. 3. In groundwater (source) samples, temperature varied from 25.8 to 29.9 °C, pH from 6.37 to 6.69, DO from 0 to 0.5 mg/L, iron from 1.33 to 2.08 mg/L, and fluoride from 0.56 to 0.67 mg/L. In stored groundwater sample, the range of variation in temperature, pH, DO, iron, and fluoride were 26.1–30.3 °C, 6.49–7.03, 3.6–6.6 mg/L, 0.05–1.63 mg/L, and 0.55–0.65 mg/L, respectively. It is important to note that upon storage of fresh groundwater, there was an increase in DO levels from 0 to 0.5 mg/L to 3.6 to 6.6 mg/L leading to reduction of dissolved iron concentration from 1.33 to 2.08 mg/L to 0.05 to 1.63 mg/L. However, there was no impact on fluoride concentration upon storage. The stored groundwater with reduced dissolved iron served as the input for the filter unit. Filtered water samples showed the variation in temperature from 26.6 to 30.6 °C, pH from 6.75 to 7.54, iron from 0 to 0.2 mg/L, and fluoride from 0.48 to 0.64 mg/L. DO was not estimated for filtered water samples. The filter unit consistently produced filtered water with iron concentration less than 0.3 mg/L—the regulatory limits for drinking purposes during the monitoring period. Fluoride concentration of all three samples (groundwater, stored water and filtered water) did not show any significant changes during the monitoring period. pH always remained in the following order: groundwater pH $\leq$ stored water pH $\leq$ filtered water pH. DO was measured only

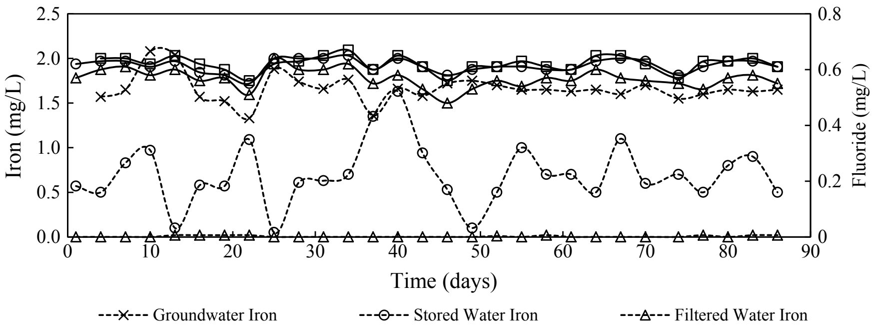


Fig. 1 Variation in iron and fluoride concentrations during the monitoring period of the filter unit

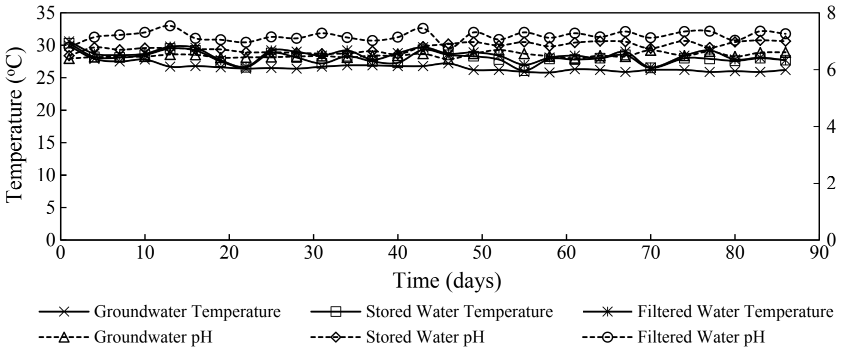


Fig. 2 Variation in temperature and pH levels during the monitoring period of the filter unit

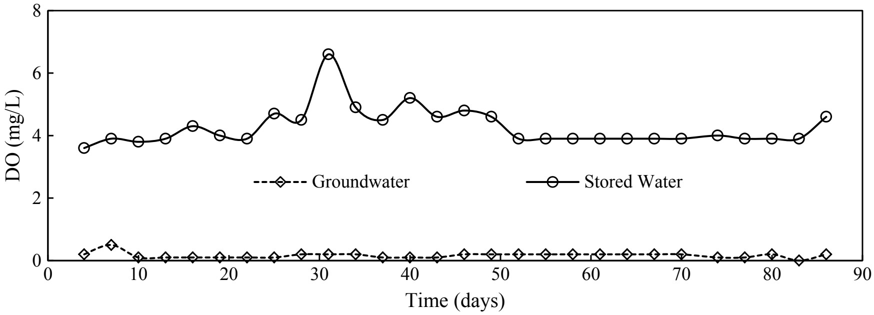


Fig. 3 Variation in DO concentrations during the monitoring period of the filter unit

for the groundwater and stored water (input). Groundwater showed very less DO level, whereas stored water showed variations in DO level; it changed according to the weather condition and storage time of water. Table 2 presents the summary of the performance parameters of filter unit during 3 months of monitoring.

The monitoring works clearly indicated that the iron concentration was the highest in the source groundwater which reduced by more than 50% upon storage for a few hours. During storage, DO levels increase led to precipitation of iron. The filter unit consistently indicated iron removal of 99% and more possibly the sand bed acted as a filter to remove the unsettled iron precipitate. The filter unit was not able to remove fluoride contamination from groundwater. The pH always remained in its permissible limit for drinking water (6.5–8.5). After operation of the filter unit for a few days, black color coating on sand particles was formed. The black coating looked bad esthetically and possibly led to clogging of the filter.

Table 2 Summary of performance parameter of the selected filter unit during 1–86 d of monitoring

Monitored water Quality parameters		Monitoring days		
		1–31	34–61	64–86
Iron (mg/L)	Ground water	1.07 ± 0.24 (10)	1.65 ± 0.48 (10)	1.63 ± 0.15 (8)
	Stored water	0.59 ± 0.32 (11)	0.82 ± 0.44 (10)	0.70 ± 0.22 (8)
	Filtered water	0.01 ± 0.01 (11)	0.00 ± 0.01 (10)	0.01 ± 0.01 (8)
Fluoride (mg/L)	Ground water	0.62 ± 0.03 (10)	0.61 ± 0.03 (11)	0.62 ± 0.03 (8)
	Stored water	0.61 ± 0.03 (11)	0.61 ± 0.02 (10)	0.62 ± 0.02 (8)
	Filtered water	0.59 ± 0.03 (11)	0.55 ± 0.04 (10)	0.56 ± 0.02 (8)
Temperature (°C)	Ground water	27.2 ± 1.04 (11)	26.5 ± 0.48 (10)	26.6 ± 0.15 (8)
	Stored water	28.3 ± 1.06 (11)	27.8 ± 0.84 (10)	27.8 ± 0.58 (8)
	Filtered water	28.8 ± 1.05 (11)	28.1 ± 0.76 (10)	28.1 ± 0.81 (8)
pH	Ground water	6.46 ± 0.04 (11)	6.50 ± 0.09 (10)	6.55 ± 0.09 (8)
	Stored water	6.66 ± 0.10 (11)	6.80 ± 0.16 (10)	6.94 ± 0.11 (8)
	Filtered water	7.14 ± 0.20 (11)	7.16 ± 0.20 (10)	7.24 ± 0.13 (8)
DO (mg/L)	Ground water	0.17 ± 0.13 (10)	0.17 ± 0.05 (10)	0.15 ± 0.08 (8)
	Stored water	4.32 ± 0.87 (10)	4.42 ± 0.49 (10)	4 ± 0.24 (8)

[The data is presented in aa ± bb (cc) format where aa is the average value, bb is the standard deviation, and cc is the number of data points considered for obtaining average and standard deviation]

4 Conclusion

The iron concentration in groundwater of Amingaon, North Guwahati varies from 0 to 11.03 mg/L exceeding the permissible limit for drinking water (0.3 mg/L), whereas fluoride concentration varies from 0.10 to 0.68 mg/L—always meeting the permissible limit 1.5 mg/L. The population is using different types of indigenous household groundwater filter units to remove excessive iron concentration from groundwater to make it suitable for potable purposes. The filter units are fabricated using locally available materials such as plastic bucket, tin container, or circular reinforced cement concrete pipes for filter body. The sand, gravel, and charcoal (in some cases) either in layered form or a mixture of two and three media is used filter media. A selected indigenous household groundwater filter unit is monitored to assess its performance over a period of 86 days. The filter unit is found to be highly effective in iron removal of 99% or more from an initial concentration of 1.33–2.08 mg/L down to 0–0.2 mg/L meeting the limit of drinking water quality. The iron removal is mainly due to increase in DO levels, which precipitates out the iron and the precipitated iron is filtered out through the filter unit. The concentration of fluoride in the groundwater is not exceeding the permissible limit of 1.5 mg/L. Fortunately, the filter unit is not reducing the fluoride concentration present in the groundwater.

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