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EVALUATION OF LOW COST FILTER COLUMN TO REMOVE IRON FROM DRINKING WATER

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Abstract

This study was conducted to investigate the effectiveness and performance of different low-cost filter media in the removal for iron from drinking water. Three water samples were collected from Tilagor area. The iron concentrations of the collected samples were 2.5 mg l^{-1}, 3 mg l^{-1} and 3.86 mg l^{-1} respectively. The iron concentrations of the samples exceeded the Bangladesh standard in drinking water which is 0.3-1.0 mg l^{-1}. So, the water sample was needed to be treated to lower the iron concentration to a safe level. To prepare the filter media a several numbers of low-cost materials were collected. They were Sand (0.5 to 1.0 mm) and gravel (less than 12 mm), Neem leaves ash (0.5 to 0.6 mm), Banana leaves ash (0.5 to 0.6 mm), Wood charcoal (less than 10mm) and Rice husk (0.5 to 0.6 mm). Single measurement for each of the material was obtained to measure the effectiveness of these materials for removal of iron. The efficiency of Sand and gravel, Neem leaves ash, Banana leaves ash, Wood charcoal, and Rice husk mixture were 53%, 58%, 81% and 93% respectively. A final filter column was prepared using the best combination of these media to obtain a better performance. The efficiency of recommended filter column was measured as 98% which was satisfactory indeed.

Keywords: Iron, drinking water, low-cost filter media, safe level, efficiency.

Introduction

Water is an essential element to sustain life on the earth. Now-a-days, the scarcity of safe drinking water is a major problem. According to World Health Organization, there are at least 5 million deaths per year due to the use of unsafe drinking water and at least 1.4 billion do not have access to safe drinking water supply (WHO, 2006). So the Millennium Development Goal (MDG) for water works out to delivering access to safe water supply at a rate of 100,000 people per day between the years 2000 and 2015.

Water is inevitable for human life. Drinking water should be hygienic, not only free from visible impurities, but also it should be free from all pathogens like Bacteria, Viruses so that water-borne diseases which constitute for around 50 percent of hospitalization each day (Vinay and Balappa, 2013).

Bangladesh is unique in that rural water coverage is high, yet supply is almost entirely decentralized. Rural residents collect drinking water majorly through hand pumps or tube wells. The Multiple Indicator Cluster Survey (MICS) of 2009, conducted jointly by the Bangladesh Bureau of Statistics and UNICEF, reports that individual tube wells, screened in either shallow (<150 m) or deep (> 150 m) layers, and fitted with various types of pumps, provide drinking water to 94.3% of rural households. In addition to that, roughly 1 million community tube wells installed by the Department of Public Health Engineering (DPHE), is estimated that about 10 million private tube wells are in use. In drinking water iron contamination is very common phenomena in Bangladesh which is very high in several strata of soil. In Bangladesh, 90% of drinking water (Mridha *et al.,* 1996) is supplied from groundwater sources. In rural areas, shallow tube wells are mainly used for water supply which contains relatively high iron concentration. As iron is mostly available in the upper crust of soil, so iron concentration is high in the water extract from these shallow tube wells.

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Iron is one of the major impurities that are commonly found in many sources of water. Iron deposited in the distribution system may promote the growth of microorganisms leading to high contamination in drinking water (Navratil *et al.*, 2003). Although iron is an essential mineral helping in the transportation of oxygen in the blood, its presence in groundwater above a certain level makes water unusable due to its metallic taste discoloration, odor, and turbidity and staining of laundry (Das *et al.*, 2007). Iron "overload" in drinking water may cause vomiting, bleeding and circulatory disorders (Ryoma *et al*., 2007). When the iron combines with tea, coffee and other beverages, it produces an inky, black appearance and a harsh, unacceptable taste. Vegetables cooked in water containing excessive iron turn dark and look unappealing (Illinois Department of Public Health, IDPH).

Several low cost materials can be used as filter media to reduced ironsuch as rice husk (Daifulla *et al*., 2002) ,ash produced from banana residue (Bordoloi *et al*., 2007) and neem leaves (Pandhare and Dawande, 2013). Electrocoagulation, oxidation filtration, ion exchange, lime softening, adsorption by activated carbon, BIRM media, anthracite, green sand, pebble and sand mixture, ultra-filtration etc. had been used as the methods of iron removal from drinking water (Chaturvedi and Dave, 2012).

When groundwater is contaminated it cannot restore its quality by stopping the pollutants from the source. Therefore, it is very important to design a purification system to decontaminate the supplied water. Major population in our country is living in rural areas. They cannot afford effective purification system as those systems are very costly. In this study, an attempt was made to resolve the issues of water through product design so that purity efficient and affordable purifier is developed for its best use by rural people. Hence, the study was conducted with the following aims:

- To prepare a low-cost filter column
- To analyze the filtration efficiency of different filter media in removal of iron

Materials and Methods

Filter column development

At the beginning, a 0.5 litre PET bottle was taken. Then, the base of the bottle was cut. A cloth was tied at the opening of the bottle. However, the length and internal diameter of the bottle was 15 cm and 6 cm respectively. Cotton was used to keep separate the materials. Secondly, another 0.5 litre bottle was placed at the top of a 5 litre bottle. A portion of 5 litre bottle was cut to place a beaker inside the bottle. Both sides of a 1 litre bottle were cut and places above the bottle containing filter media. After that, the sample water of known concentration was passed through the media. Lastly, filtrate water was collected at the beaker placed inside the 5 litre bottle. The final iron concentration was measured with Iron Checker (HANNA, HI3834).

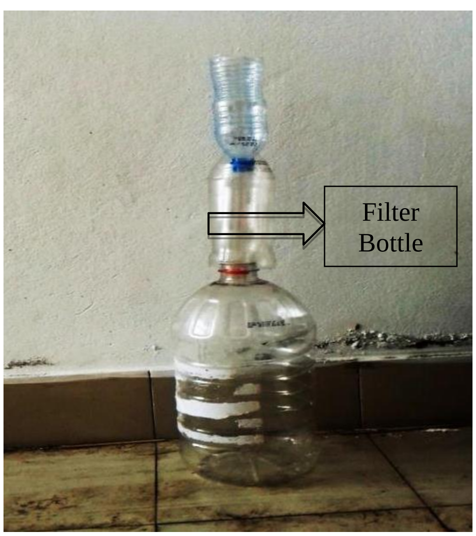

Fig. 1. Filtration model

Fig. 2. Cotton

Method used in filtration process

The method used for iron removal was adsorption. It is a very well-known and effective method of filtration. It is a process where contaminants break their bond with water molecules and chemically adhere to the filter media. It is a very easy method of filtration.In this study, different adsorption media were used for removal of iron. They were Sand,Neem leaves ash, Wood charcoal, Rice husk and different sizes of Gravel.

Experimental set-up

Experiment was set-up in two steps:

1. Iron removal capacities of different combinations of media were measured.
2. Final model prepared by using the most efficient combinations.

First step of the experiment

Plane sand and gravel**:** Three different combinations (3.5:4, 2: 2 and 3:4) of sand and gravel were used and known concentration of iron solution was passed through it. Iron removal capacity and the rate of filtration for different combinations were measured. Best combination from this set-up was used in rest of the set-up.

Neem leaves ash and sand**:** Different amounts (10 g, 8 g and 6 g) of Neem leaves ash were taken. Ideal combination of sand and gravel were used as the top and bottom layer respectively. Known concentration of iron solution was passed through this set-up. Final iron concentration and rate of filtration was calculated.

Banana leaves ash and sand**:** Different amounts of ash (15 g, 12 g and 10 g) were used with ideal combination of sand and gravel. Known concentration of iron solution was passed through these combinations and final calculation was done.

Wood charcoal and rice husk mixture: Wood charcoal and raw Rice Husk mixture (3:2 by weight) were taken with best set-up of sand and gravel. Known concentration of iron solution was passed through the mixture and final measurement was taken.

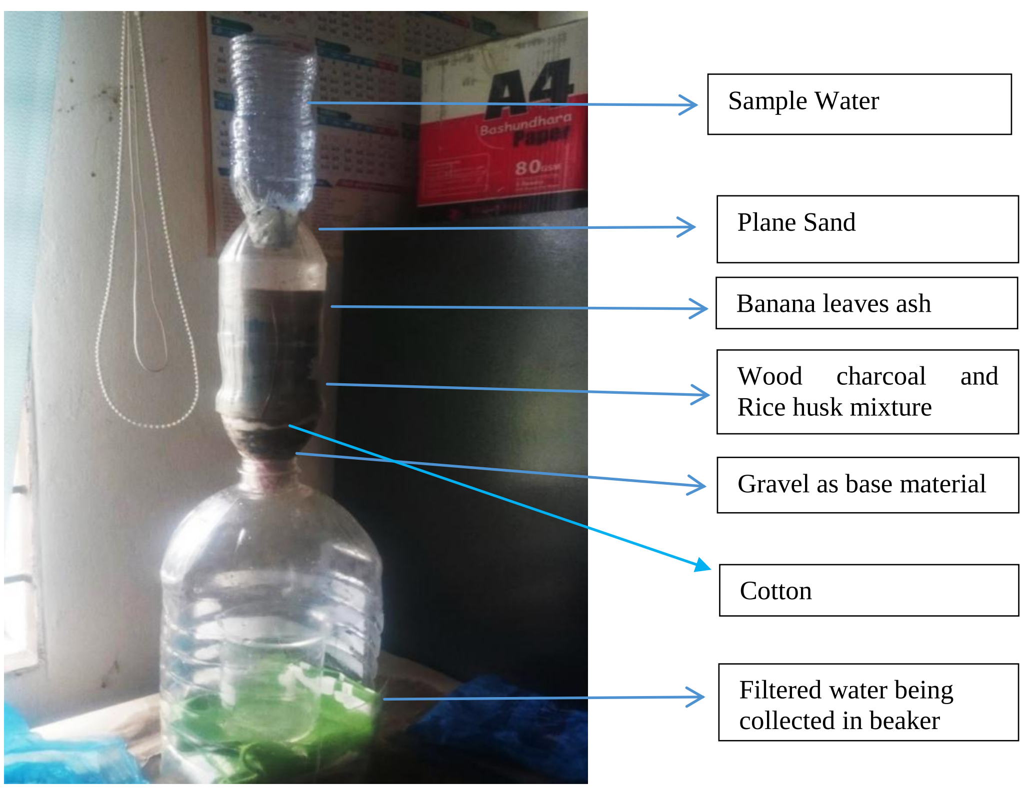

Fig. 3. Filtration in final filter media

Second step of the experiment

Final model development**:** The final filter column was prepared by using the best combinations of all them aterials. Neem leaves ash was discarded from the final filter column. As the other model, sand and gravel were used as top and bottom layer respectively. The materials were separated by using cotton layer. The known concentration of the iron solution was passed through the filter media. The filtrate was collected in a beaker. The rate of filtration was calculated and the iron concentration was measured by using Iron Checker (HANNA, HI3834). The pH and TDS were measured by digital pH meter (PH-98107) and TDS meter respectively. pH, TDS and their correlation with iron were done.

Results and Discussion

Sand and gravel

The initial iron concentration of the water sample was 3.86 ppm. The final iron concentrations for different set-up were found, 2.10 ppm, 1.96 ppm, and 1.78 ppm, respectively Fig. 4 (a and b). The best result i.e. 1.78 ppm was obtained when the thickness of sand and gravel layer was 3 cm and 4 cm, respectively. The rates of filtration for different combinations were 105 ml min^{-1}, 122 ml min^{-1} and 92 ml min^{-1}, respectively (Fig. 4 a and b).

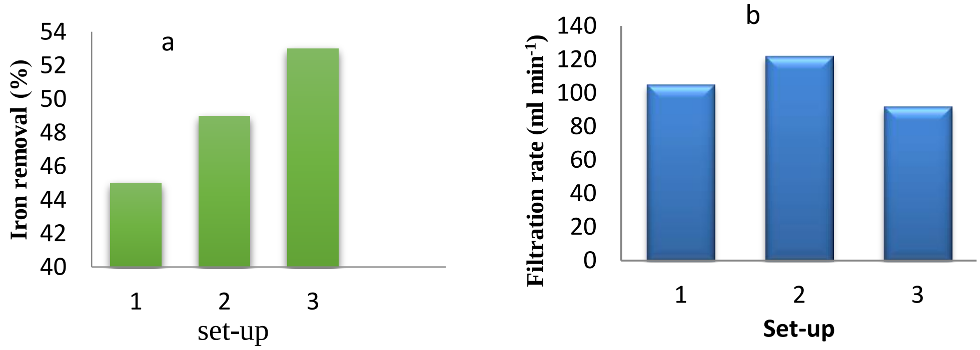

Fig. 4. Iron removal during filtration; (a) Filtration rate, (b) Sand and gravel filter

In the present study the sand used in filter column was Sylhet sand due to this the rapid sand filtration system without aeration was 53% efficient in removing iron whereas sand and gravel filter column of El-Naggar (2010) was 16 % efficient with aeration.

Neem leaves ash and sand

The results obtained by using Neem leaves ash is shown in Fig. 5 (a and b). The initial iron concentration of the water sample was 3.86 ppm. The best result i.e. 1.65 ppm was obtained when the amount of Neem leaves ash was 10 g. Iron contents for different amounts of ash were found 1.65 ppm, 1.72 ppm, and 1.80 ppm, respectively. The rates of filtration were 18 ml min^{-1}, 25 ml min^{-1} and 31 ml min^{-1}, respectively.

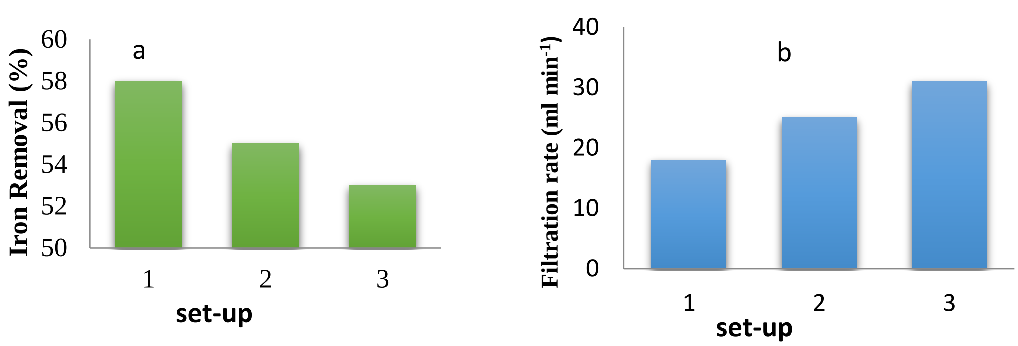

Fig. 5. Iron removal during filtration; (a) Filtration rate (b) Neem leaves ash and sand

Neem leaves ash with sand filter media was 58% effective without the use of muffle furnace in reducing iron than Kumar (2014) of 47% because of the local sand and neem ash unique combination.

Wood charcoal and rice husk mixture

The initial iron concentration of the water sample was 3.86 ppm Fig. 6 (a and b). To reduce iron content from water, three different combinations of wood charcoal and rice husk were used. When the amounts of wood charcoal were 60 g, 50 g and 30 g then the amounts of rice husk were 40 g, 37 g and 20 g, respectively. Iron concentration was reduced to 0.25 ppm when the amount of wood charcoal was 60 g and rice husk was 40g. Thus, it was selected as the best filtration option among all four filters. The rates of filtration in three setups were 7 ml min^{-1}, 15 ml min^{-1}, and 30 ml min^{-1}, respectively.

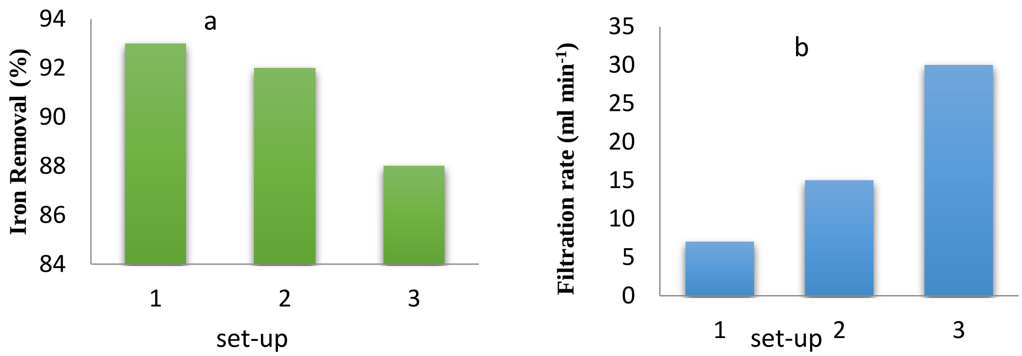

Fig. 6. Iron removal during filtration; (a) Filtration rate, (b) Wood charcoal and rice husk mixture

Hence, Kumar (2014) has found rice husk ash with sand as an effective media to remove iron up to 37% whereas the present study introduced another technique of using rice husk with wood charcoal for increasing the efficiency up to 93%.

Banana leaves ash

The initial iron concentration of the water sample was 3.86 ppm Fig.7 (a and b). Three different amounts of ash (15 g, 12 g and 10 g) were used with the best combination of sand (3 cm) and gravel (4 cm). Iron contents for the different set-up were 0.75 ppm, 0.71 ppm, and 0.81 ppm, respectively. The best result i.e. 0.71 ppm was obtained when the amount of banana leaves ash was 15 g. The rates of filtration were 37 ml min^{-1}, 25 ml min-1 and 39 ml min^{-1}, respectively. Banana leaves ash has given better results than neem leaves ash.

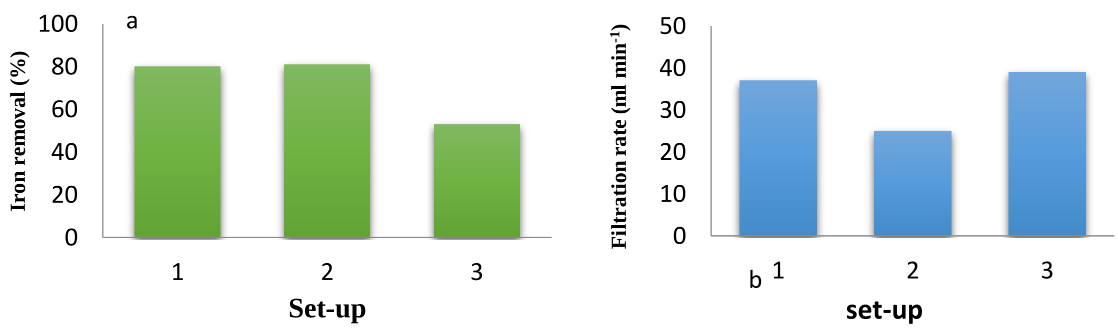

Fig. 7. Iron removal during filtration; (a) Filtration rate, (b) Banana leaves ash and sand

Banana leaves ash with sand filter was used here without bicarbonate salt to reduce the cost. This filter media was 81% efficient in removing iron which is less than Bordoloi *et al.* (2011) and Das *et al.* (2007) of 99% and 86%, respectively.

Comparison of results

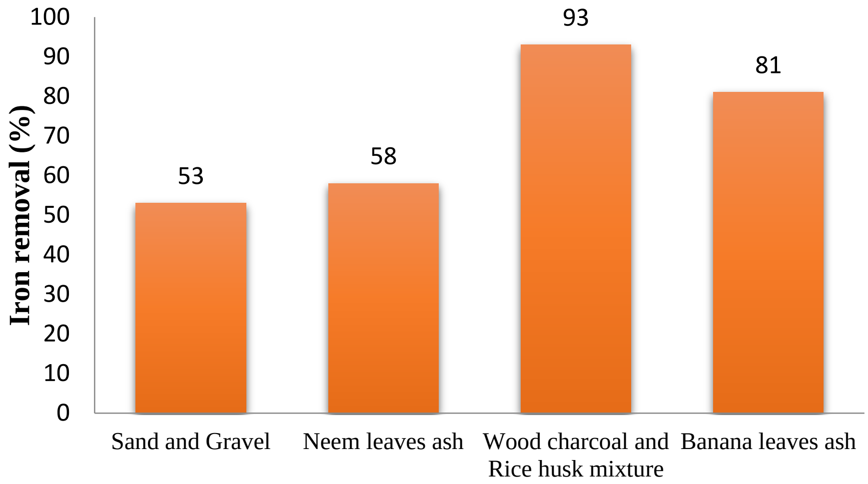

Fig. 8. Variation of percentage of iron removal with different filter media

In case of sand and gravel, the better result was obtained when the ratio was 3:4 which removed the iron concentration up to 53% (Fig. 8). In case of Neem leaves ash, the better result was obtained when 10 g ash was used which removed the iron concentration up to 58%. Wood charcoal and Rice husk mixture gave better result in 60:40 ratios which removed the iron concentration up to 93%. The better result was obtained in 12 g. Banana leaves ash setup, which removed the iron concentration up to 81%.

But the individual media of sand and neem leaves ash was not performed well in reducing iron to the permissible limit (0.3-1.0 ppm) of Bangladesh drinking water quality standard (GoB, 1997). Although, banana leaves ash and wood charcoal with rice husk filter column was effective in reducing iron to permissible limit due to their high adsorption capacity.

Results obtained from final model

A final model was developed using the best combination of all the media. The thickness of the sand layer and gravel layer was 3 cm and 4 cm, respectively. The amount banana leaves ash was 15 g. The amount of wood charcoal was 60 g and rice husk was 40 g. Due to the bitter taste of Neem, it was discarded. Initial iron concentration of the water sample was 3.86 ppm. Final iron concentration was measured after 1 hr, 2 hrs, 3 hrs, 12 hrs and 16 hrs. The best result i.e. 0.05 ppm was obtained after 16 hours. TDS and pH were also measured. Initial TDS and pH were 12.82 mg l^{-1} and 7.25, respectively. Final TDS and pH were 54.4 mg l^{-1} and 7.48, respectively.

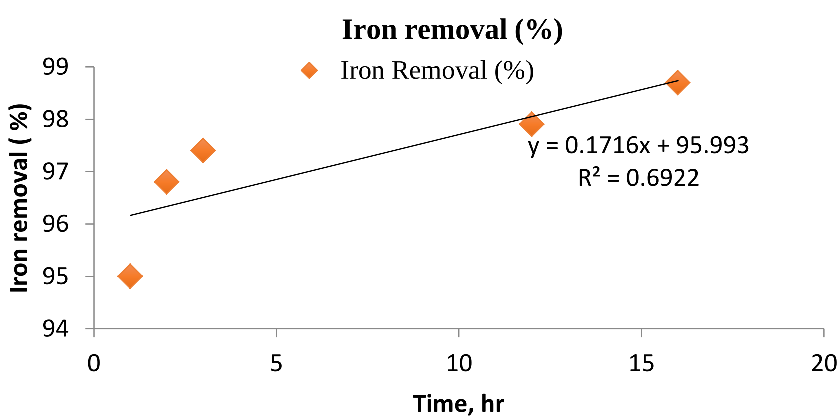

Fig. 9. Iron removal during filtration

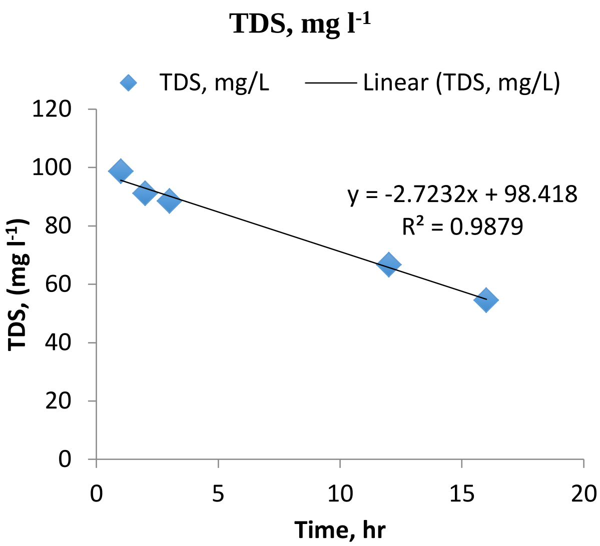

Fig. 10(a). TDS during filtration

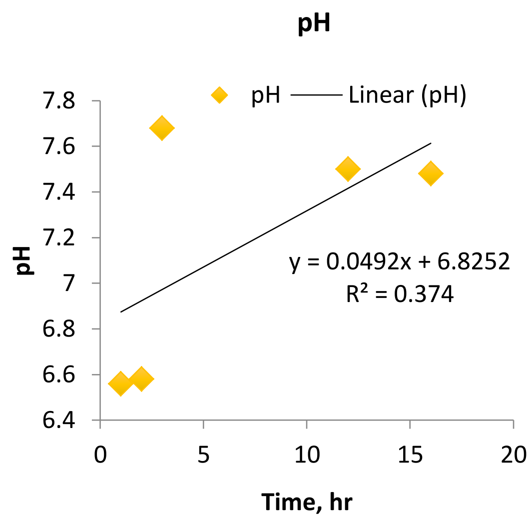

Fig. 10 (b). pH during filtration

Therefore, the final set up of sand and gravel, banana leaves ash, wood charcoal and rice husk was introduced to apply in a unique combination to reduce iron below permissible limit (GoB, 1997) up to 0.05 ppm with 98% efficiency.

Correlation studies

The relationship among Iron and TDS, Iron with pH and pH with TDS were performed to study.

Table 1. Relationship among different parameters with their value of coefficient as well as regression lines

Parameters	Relationship type	Value of r	Regression equation
Iron and TDS	Positively significant	r=0.8847	y= 311.37x+46.272
Iron and pH	Negatively significant	r=0.8709	y= -6.8087x+8.0313
pH and TDS	Negatively significant	r=0.6428	y= -21.877x+236.56

Conclusion and recommendations

The study concluded that adsorption is the simplest and cheapest technique for the removal of iron. A limited number of materials were used as adsorption media which is a drawback to the study. The study revealed that a combination of plane sand, banana leaves ash, wood charcoal and rice husk mixture and gravel was effective to remove iron most efficiently up to 98%. However, correlation analysis explores that iron and TDS are positively co-related. So, effective measures should be taken to control the TDS in water samples by proportioning the effective grain in filter column. To endure the efficiency of the filter column a backwashing technique should introduced for better results and better performance. Advantages of such filter column included simplicity, low-cost design and no need for chemical addition. Hence, periodic washing of filter media or replacement of filter media may be the only maintenance required to maintain reasonable flow rate through the system.

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