Natural filtration unit for removal of heavy metals from water

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Abstract. Occurrence of iron in the potable water is responsible for several issues related to environmental, economic, and public health. Water remediation from iron is very vital step for ensuring the safety of potable water. Hence, many treatment techniques, such as chemical precipitation and reverse osmosis, have been proposed in recent literature. However, these methods are either expensive or possess some negative environmental impacts. This paper therefore studies the possibility of utilizing farms’ wastes (straw and reed) to produce a filtration system for remediating water from iron ions. This natural filtration cell (NFC) was manufactured by mixing equal weights of straw and reed (1:1 ratio), while the artificial iron solution (10.0 mg.L\textsuperscript{-1}) was synthesized by dissolving suitable amount of iron sulfates in deionized water. This artificial solution was treated in the NFC at different retention times (RTS) (ranging from 10 to 90 minutes) and initial pH of solution (IPS) (ranging from 4 to 9). The remaining iron in the solution, during the course of filtration process, was calculated utilizing a spectrophotometer and a standard iron cuvette test. The outcomes of this study revealed that 33.1\% of iron was absorbed at RTS and IPS of 80 minutes and 7.0, respectively. Even though the research’s outcomes proved that the NFC possesses an acceptable capacity for iron removal from water, light brownish color was formed in the produced water, so another suitable treatment technique is needed to decolorize the produced.

1. Introduction
Potable water quality is not only essential for human health, but also it is one of the basic human rights that must be met by applying suitable water treatment techniques, management and monitor/control the wastewater [1-5]. The pollution by heavy metal has become a common environmental issue in the last few years, particularly for sources of freshwaters, due to natural and anthropogenic activities [6-9]. For example, in many parts of the world, especially in the third world countries, water contamination with heavy metals is becoming a critical environmental issue owing to the continuous discharging of improperly treated wastewaters that produced from anthropogenic activities (mainly agricultural and industrial activities) into surface water bodies [7, 10-13]. There are several studies, in the literature, dealt with the applications of high-efficiency methods and technologies for heavy metal separation from waters or anthropogenic effluents, such as electrochemical and membranes filtration [2, 14]. Nevertheless, some studies highlighted that several of applied methods of treatment in the third world countries are not cost-effective or unsustainable [15]. Though this water contains a significant amount of heavy metals, iron is among the most prevalent heavy metals that presence in freshwaters (surface and ground water) because of its high concentration in the
lithosphere and in the effluents of industries, like a liquid waste that produced from iron and mining industries [6]. Generally, iron pollution in freshwaters results mainly from two sources; natural and anthropogenic sources. The first one (natural sources) is the represented by the amount of iron that washed out from the surrounding rich-iron soils and rocks due to the runoffs [6]. The second source (anthropogenic one) is resulted from human-related activities, such as medical, agricultural and mining industries [6, 16]. Another important fact must be highlighted about drinking water contamination with iron; it was found that treated drinking water could be polluted during the distribution process due to oxidation of underground iron pipes that used for distribution water, is considered as the second and most significant source of iron in drinking water [6]. Though iron is categorised as an essential nutrient in living cells [16], the presence of iron in high concentrations in water could indeed cause severe health impacts, like skin cells damage and hemochromatosis [6, 16]. Furthermore, the high iron concentration changes the physical water characteristics, like the colour, and fasts the growth of some kinds of bacteria, which in turn leads to other issues like clogging of pipes that are required expensive repairing [6, 16]. For the potable water, the Environmental Protection Agency (EPA) has made many regulations ensure the quality and safety of water; iron is limited to 0.3 mg/L in drinking water [17]. There are many techniques for removing iron from water, like chemical precipitations, oxidation and ion exchangers [8, 17]. According to the literature, the third world countries have limited access to the advanced (usually expensive) techniques that necessary for iron removal [18]. Nevertheless, these poor countries have natural resources, which could be utilised as adsorption mediums for iron removal from water, like cotton, coconut, charcoal and sand [7, 11]. In the recent few years, many natural materials have been investigated to develop low-cost and more effective filtration mediums for water remediation [15]. Using natural waste like agricultural wastes, that could be used to treat water in countries that have limited access to advanced treatment techniques, has been substantially expanded. For instance, sugarcane bagasse and activated carbon from coconut coir was applied as natural filters to remediate water from heavy metal contamination [19]. Using natural low-cost adsorbents, like coconut husk, neem leaves and mango peels, to remove heavy metal contamination from water was also investigated in a previous study, which revealed that optimum heavy metals removal was achieved by coconut husk [20]. Similarly, in this investigation, filter produced of natural materials was utilised to clean water up of iron. The goal of the current study is to study the possibility of utilising agricultural wastes, reed and straws, as a low-cost and eco-filter filtration medium to remove iron from the water.

2. Methodology

2.1. Setup of the Experiment

A new filtration system has been setting up utilizing a unit with a cylindrical shape of 20 cm in height and 10.16 cm in diameter, filled with 0.250 kg of straw and reed, as seen in Figure 1. Equal weights of straw and reed (1:1 ratio) were mixed to produce this new natural filter. A sponge piece was put on both bottom and top of the straw-reed layer, the piece of sponge that placed on top was worked as barriers for preventing the straw-reed materials from floating since those two materials lighter than water. The sponge in the bottom of the filter was utilized to avoid the scape of fine segments of the straw and reed from the filter.
2.2. Chemicals and Reagents
Fresh water samples, having 10 mg of iron per litre of water, were produced using suitable amount of iron sulfates. The later was dissolved in deionised water and stirred for a proper period to completely dissolve it in solution. The ISP value of the produced solutions was fixed to the necessary level utilising solutions of 1 M NaOH or 1 M HCl [19]. To adjust the water conductivity to 0.32 mS/cm, suitable amounts of NaCl salt were used [6].

2.3. Experimental Part
In each single experiment, the new filtration medium was applied to filtered 1000 mL of freshly prepared iron solutions. In this research study, the relationship between the IPS and iron adsorption on the straw-reed medium was investigated at six values of IPS (from 4 to 9) (moderate basic, slight basic, neutral, slight acidic and moderate acidic levels) for 30 minutes, to determine the optimum pH value for removing iron. While the relationship between the RTS and iron adsorption on the straw-reed medium was investigated at nine periods (from 10.0 to 90.0 minutes). The optimal RTS is determined according to the obtained removals of iron.

During the course of each single experiment, iron removal development has been tracked by taking few millilitres of solution from the filtration system at intervals of 10 minutes, then filtered on Whatman filter paper to remove undesirable solids [6], after that the remain concentration of iron in the filtrate has been measured utilising Hach-Lange spectrophotometer and Hach-Lange iron cuvettes test. Both tests were carried out at normal laboratory temperature (about 20°C).

3. Results of Experimental work and discussion
3.1. The initial pH Impact
One of the essential factors in absorption technique is the IPS, since the latter impacts the metal ions solubility that greatly influences the process of adsorption [19]. In the current investigation, the impacts of the IPS on adsorption of iron in straw-reed filter was investigated for six levels of IPS (from 4 to 9), whereas the RTS and concentration of iron were kept fixed at 30 minutes and 10 mg/L, respectively. Very low IPS (<4) were not considered here as many researches showed that at such levels; H⁺ ions become abundantly presence in water that could prevents or substantially minimizes the adsorption of metal ions [21].

Figure 2 illustrates that the increasing the IPS from 4 to 7 (from acidic to neutral) leads to an increase in the iron removal. For instance, the increasing the IPS from 4 to 5, 6 and 7 led to increase iron removal percentages from 20.1% to 20.5%, 21.4% and 22.8%, respectively. The optimum removal of iron was

![Figure 1: Reed-straw filtration.](image-url)
achieved at IPS of 7.0. The results gained in this investigation were compatible with the literature that showed that the optimum removal of iron was gained at IPS range of 5-7 [21]. Figure 2 also indicates that the percentage of adsorbed iron decreased from 22.1% when IPS was 8 to 21.7% at IPS of 9.0. The variation in the impacts of IPS on the capacity of the new filter for adsorption of iron could be returned to the competition between the H+ (at low IPS) and hydroxides (at high IPS) and ions of iron in the binding sites [22]. Consequently, IPS of 7 might be the optimum value in the present research to conduct the experiments of RTS.

![Figure 2](image)

**Figure 2**: Impact of initial pH on removing of iron.

3.2. Influence of contact time

RTS has a significant role in iron removal by adsorption techniques as it governs the chance of binding the pollutants (ions) to the available active sites on the filtration medium. In the current investigation, the impacts of the RTS on adsorption of iron in straw-reed filter was investigated for nine levels of RTS (from 10 to 90 minutes), whereas the IPS and concentration of iron were kept fixed at 7 and 10 mg/L, respectively. Figure 3 shows a positive relationship between the RTS and iron adsorption in straw-reed medium. Increasing the RTS enhanced the removed percentage of iron, where the later increased from 8.8 percent at RTS of 10 minutes to reach its maximum level (33.1% percent) at RTS of 80 minutes and kept the same level during the last 10 minutes.

![Figure 3](image)

**Figure 3**: Impact of RTS on iron adsorption by the straw-reed filter.
At the end of treatment using the natural straw-reed filter, light brownish color was formed in the produced water. Therefore this color must be removed using a proper treatment method. Here, the authors recommend using the electrocoagulation method to remove the color as it is very efficient in the removal of colors [23-25], cost-effective [1, 8, 14], easy to be performed [26, 27] and it has the ability to remove several pollutants, such as iron [6], fluoride [28], nitrate [29], phosphate [30] and bacteria [31]. Additionally, In comparison with traditional, such as the biological methods [32, 33], the electrocoagulation method generates smaller volumes of sludge that is positively reflected on the operating cost of the electrocoagulation technique because it decreases the cost of management of sludge (as solid wastes) and landfills, the latter is usually very expensive [34-36]. Furthermore, the produced sludge from the electrocoagulation could be recycled in building blocks and construction industry [37-43].

Finally, as it has been mentioned in this paper that iron contamination could occur during distribution of treated water to the consumers due to the oxidation iron pipes. Therefore, the authors recommend to use some sensors (at homes) to monitor iron concentration, because the sensor technology witnessed dramatic advances [44-48], which makes it suitable for such purposes.

4. Conclusions
In conclusion, results from this study showed that the agricultural wastes (reed and straw) could be used to manufacture low-cost and eco-friendly adsorbents for removal of heavy metals (iron as a case study) from water. Additionally, the outcomes from this research showed that the percentage of iron adsorption is greatly depending on the RTS and the IPS. Generally, the alkaline medium and long contact time are preferable for removing iron by the new straw-reed filter, where the highest iron removal has been observed at IPS of 7 and RTS of 80 minutes.

Although this investigation has proved that the straw-reed filter as a potential low-cost and eco-friendly treatment method, light brownish color was formed in the produced water. Therefore, another suitable treatment should be used to remove the color.

For future work, the ability of reed-straw filtration for the removal of other pollutants, such as dyes and organic matter, could be investigated.

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