SSRG International Journal of Civil Engineering
ISSN: 2348-8352/ https://doi.org/10.14445/23488352/IJCE-V11I5P108

Volume 11 Issue 5, 72-76, May 2024

Original Article

Screening of Sustainable Biochar Adsorbent for Iron Removal from Water

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Received: 07 March 2024 Revised: 09 April 2024 Accepted: 08 May 2024 Published: 31 May 2024

Abstract - *Biochar is regarded as a green material. It can also be used as an efficient adsorbent for the removal of multiple types of water contaminants, including heavy metals including iron. Iron is found in water, and it may create some operational challenges in the water supply system along with some gastrointestinal health disorders in human beings. Therefore, WHO and BIS have prescribed the limit for iron in drinking water, i.e. 0.3 mg/L (maximum). Further, in this study, locally available biomasses (rice husk, wheat straw, pea nutshell and Kalibasuti) were used to derive biochar adsorbents for the removal of iron from water samples. Out of these four biochar adsorbents, rice husk biochar adsorbent was found to be most effective (i.e. 79% removal) in the removal of iron from water as compared to other biochar adsorbents. Moreover, it is cheap (or freely available) natural agro-waste material that can be converted as a value-added product (i.e. biochar) for iron removal from water. Scanning Electron Microscopic image of the Rice husk biochar has shown the rough surface of the adsorbent that is considered as beneficial character for the adsorption process. Therefore, the present study can be the basis for designing extensive research on iron removal using sustainable adsorbents like Rice husk biochar.*

Keywords - *Rice husk biochar, Iron removal, Adsorption, Agro-waste management, Adsorption optimization.*

1. Introduction

Water contamination has become one of the great challenges of the 21st century because of diverse types of human-induced chemicals. In developing countries, the scenario is really alarming because of industrial wastewater generation and the lack of insufficient treatment processes (Schwarzenbach et al., 2010). For instance, millions of Indian citizens are not having safe drinking water due to mismanaged water resources. fluoride and nitrate), Heavy metals are among the major problems for water treatment as these are particularly coming from industries (Beesley and Marmiroli, 2011; Gwenzi et al., 2017).

Iron is present in industrial wastewater, and it has become a big challenge to reduce its level in the agreement of WHO and BIS standards. The bad health of iron is not reported well; however, imparting a bad taste in water, acting as a discolouring agent, loss of the water supply pipes, along high turbidity values in the water are some challenges caused by high levels of iron (Sharma, 2001). As per the studies, WHO adsorption is found among one of the best techniques for water treatment. Biochar is a low-cost, sustainable, renewable adsorptive material produced from agricultural residues, forest residues, etc. Biochar is reported as a renewable, sustainable, recyclable, cost-effective and potent adsorbent to remove various types of contaminants, including dyes, inorganic contaminants (e.g. Heavy metals, Nitrate, Phosphate, Silver etc from aqueous solutions (Peiris et al., 2017; Vikrant et al., 2017) which also regarded as "Green Carbon" as it is produced by thermal treatment of naturally available ample biomass such as wood, plant residues etc. (Ghaffar et al., 2017). Biochar has been given preference in environment-clean applications due to its significant physicochemical characteristics, such as high adsorption capacity, high surface area, and microporosity (Oliveira et al., 2017**).**

In Baddi-Barotiwala-Nalagarh (BBN) industrial areas of the state Himachal Pradesh, India, the level of iron was observed to be very high in wastewater and groundwater, too, as compared to the prescribed standards. The removal of iron is not well explored in using local biomass base cost-effective bioadsorbent. Therefore, this study was focused on the removal of iron using rice husk-based adsorbents. Moreover, rice husk bio adsorbent was relatively found to be better as compared to the other three bio adsorbents and it is abundantly available in the local area. Therefore, the present study was focused on the removal of iron from water using biochar adsorbents. For this purpose, locally available agro-wastes were collected and converted into biochar adsorbents for iron removal from industrial water.

2. Materials and Methods

A Muffle furnace was used to produce biochar adsorbents using different types of biomasses such as rice husk, wheat straw and peanut shells and used in the adsorption experiments to remove iron from water. These raw materials have been used because of their abundant availability in the local region. Moreover, it can be helpful in the development of low-cost biochar adsorbents for water treatment.

Many researchers reported the use of the adsorbents derived from these raw materials in water treatment, such as in the removal of colour and heavy metals using peanut shells (Wu et al., 2019; Gautam et al., 2020); rice husk (Chandrasekhar and Pramada, 2006) and also wheat straw (Chakraborty et al., 2022). Therefore, on the basis of literature and abundance, these raw materials were selected for the production of biochar for water treatment.

Further, the wood of the kali basuti plant (commonly found in Haryana and Himachal Pradesh) was also used to prepare the biochar adsorbent for water treatment. Iron was determined in water samples using Atomic Absorption Spectroscopy. Batch experiments were conducted to remove iron from water. The experiments were conducted for the screening of the adsorbents, optimization of contact time, adsorbent dosages and pH ranges. All the experiments were carried out in triplicate and the average values are reported.

3. Results and Discussion

In the present study, the raw materials were kept at 350°C temperature for 6 hours to produce biochar for further experimentation. In many studies, activated rice husk was used to treat different types of pollutants from water. In the present study, the removal of iron was observed using simple methods, like temperature was kept at 350° C, which saved energy as many of the bioadsorbents were prepared > 600 ° C (Sharma, 2001). Before pyrolysis, the raw materials were washed with distilled water to remove all the dust and other impurities. Thereafter, these materials were air-dried, followed by a pyrolysis process. Figures 1 to 4 are the representation of the biochar adsorbents prepared in the lab for water treatment purpose.

Fig. 1 Biochar adsorbents produced from wheat straw

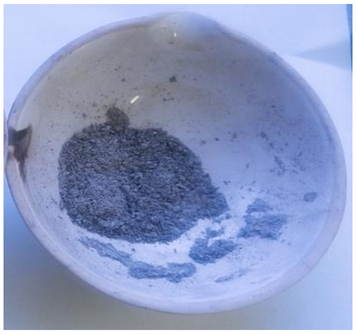

Fig. 2 Biochar adsorbents produced from rice husk

Fig. 3 Biochar adsorbents produced from peanut shell

Fig. 4 Biochar adsorbents produced from Kali Basuti Wood

3.1. Results of Initial Biochar Experiments

Based on the industrial water testing results, Biological Oxygen Demand (BOD), iron and colour were found to be high (above standard) in the water sample. The BOD was 9.3 mg/L, iron was 0.96 mg/L, and colour was 320 Hazen units. These parameters were found to be above the standard prescribed for drinking water except BOD (BIS, 2012; WHO, 2003). The standard values for BOD, iron and colour in water are <2 mg/L, 0.3 mg/L and 5-15 Hazen units, respectively. Therefore, in the present study, iron removal from the water samples was performed through adsorption experiments using biochar adsorbents. All the experiments were performed at room temperature and the distilled water was used to wash the impurities and experimental activities to maintain the quality.

Four biochar adsorbents used in adsorption experiments are wheat straw, rice husk, pea nutshell and kali basuti stem. The results of adsorption experiments are shown in Figure 5.

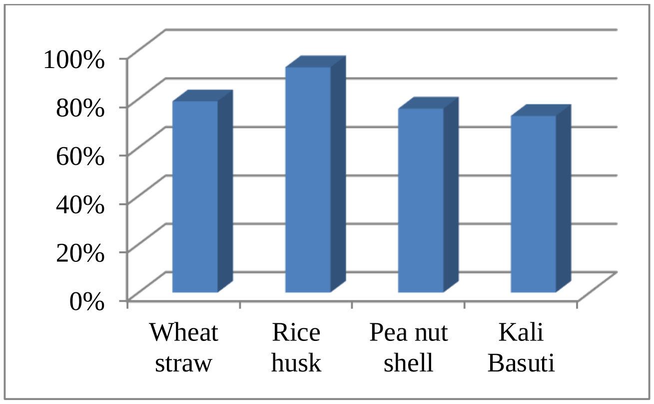

Fig. 5 Percent removal of iron using biochar adsorbents

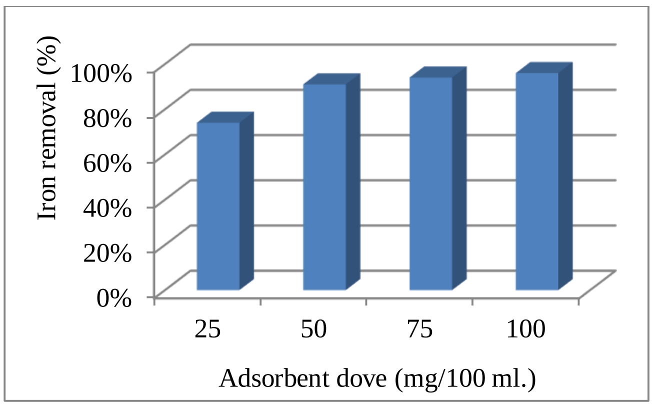

Fig. 6 Effect of adsorbent dosages on iron removal using rice husk biochar adsorbent

From the above figure, it can be seen that iron removal from the water was found as 79%, 93%, 76% and 73%, respectively, for wheat straw bio adsorbent, rice husk bio adsorbent, peanut shell bio adsorbent, and kali basuti adsorbent. However, rice husk could remove around 93% iron from water samples. The adsorbent dosage contact time of the adsorption experiments for iron removal was 50 mg/100 mL and 2 hours, respectively. However, the initial pH was 8.7 before adsorption and 9.0 after adsorption.

3.2. Screening of Biochar Adsorbents

Based on the above diagram (Figure 5), rice husk was selected for the optimization adsorption phenomenon for the removal of iron from water samples as it is a local resource and abundantly available in the local areas. Therefore, rice husk could be an ideal agent (raw material) for biochar production to remove iron from water. Moreover, it is available free of cost or at minimal cost along with fulfilling the aim of agro-waste management.

3.3. Experimental Results for Iron Removal Using Rice Husk Biochar Adsorbent

3.3.1. Effects of Adsorbent Dosages on Iron Removal

During the screening of adsorbents, rice husk-based biochar adsorbents were found to be better for iron removal from water samples (93% removal efficiency). Further, in order to determine the optimum dosage of the biochar adsorbent, the dosage effect was investigated, as shown in Figure 6.

From Figure 6, it can be seen that the adsorbent dosage of rice husk was varied from 25 mg, 50 mg, 75 mg and 100 mg for 100 ml of water sample. The removal of iron was achieved at 74%, 91%, 94% and 96%, respectively, at the above adsorbent dosages. It is clearly visible that 74% removal of iron was achieved using 25 mg of adsorbent dosage. However, after 50 mg adsorbent dosage, an insignificant increase (i.e. from 94-96%) was observed. An insignificant increase in the removal of iron may be due to the overlapping of active sites on the adsorbent surface. However, rapid adsorption of iron took place because of the availability of relatively higher numbers of active sites for the adsorption (Swain et al., 2011). Therefore, 50 mg/100 ml adsorbent dosage has been found as the optimum rice husk-based biochar dosage for the removal of iron from water.

3.3.2. Effects of Solution pH on Iron Removal

pH is a very important factor during the adsorption experiments as it has significant effects on the removal efficiencies of the adsorbents (Raichur and Basu, 2001). Similarly, the experiment was conducted to record the optimum pH for iron removal from water using rice husk biochar adsorbent, as presented in Figure 7.

From Figure 7, it can be seen that the pH of the solution was kept at 2, 4, 6, 8 and 10 during the adsorption experiments. The removal of iron was achieved at 72%, 74%, 89%, 90% and 91%, respectively, at the above solution pH ranges. It is clearly visible that between pH 6-8, 89-90% iron removal was recorded using rice husk biochar adsorbents. However, at a very deep acidic range (pH = 2), 72% and also at a high alkaline level (pH = 10), the removals of iron were comparable. However, it may raise the cost of treatment as it will again require post-treatment of treated water because of the low or high pH of treated water (Bhatnagar and Sillanpaa, 2011). Therefore, it was inferred that a range of 6-8 pH could be considered as the optimum pH for the removal of iron from water samples using rice husk-based biochar adsorbent.

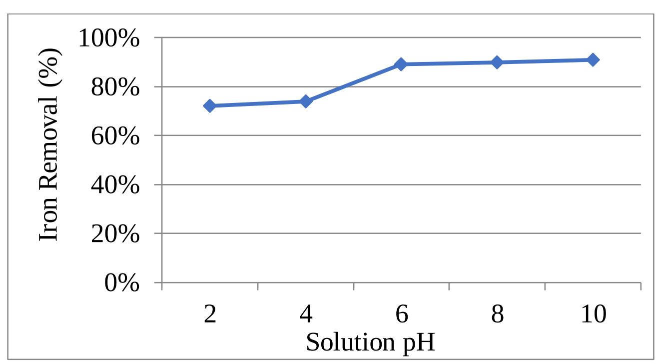

Fig. 7 Effect of solution pH on iron removal using rice husk biochar adsorbent

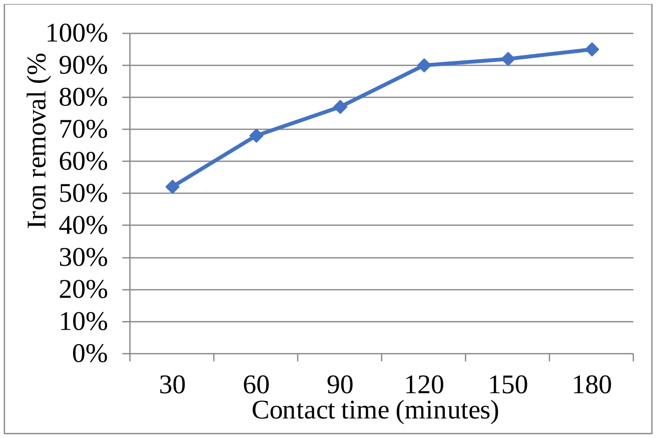

Fig. 8 Effect of contact time on iron removal using rice husk biochar adsorbent

3.3.3. Effects of Contact Time on Iron Removal

Along with pH, contact time is also a crucial and governing factor during the adsorption experiments as it has significant effects on the removal efficiencies of the adsorbents (Khan et al. 2009). Hence, the experiment was conducted to inves8tigate the optimum contact time for iron removal from a water sample using rice husk biochar adsorbent, as presented in Figure 8.

In order to know the optimum contact time for iron removal, the contact time was varied from 30 minutes, 60 minutes, 90 minutes, 120 minutes, 150 minutes, and 180 minutes during the adsorption experiments. The removal of iron was achieved 52%, 68%, 77%, 90%, 92% and 95%, respectively at the above selected time intervals. It is clearly visible that 90% iron removal was achieved within 2 hours (120 minutes) of contact time.

However, after 2 hours of the contact time period, an insignificant increase (i.e. from 92-95%) was recorded in comparison to early hours. A significant increase in the removal of iron with an increase in an early stage of contact time intervals may be due to the availability of plenty of active sites on the surface of the adsorbent (Khan et al., 2009; Sharma et al., 2009). Therefore, 120 minutes (2 hours) of contact time can be noted as the optimum contact time for the removal of iron from water using rice husk-based biochar.

4. Scanning Electron Microscopic (SEM) Image

SEM images of rice husk adsorbent have been carried out at the Indian Institute of Technology, Mandi (Himachal Pradesh), to diagnose the surface morphology/properties of the adsorbent for beneficial adsorption purposes. Figure 9 shows the SEM image of the rice husk adsorbent.

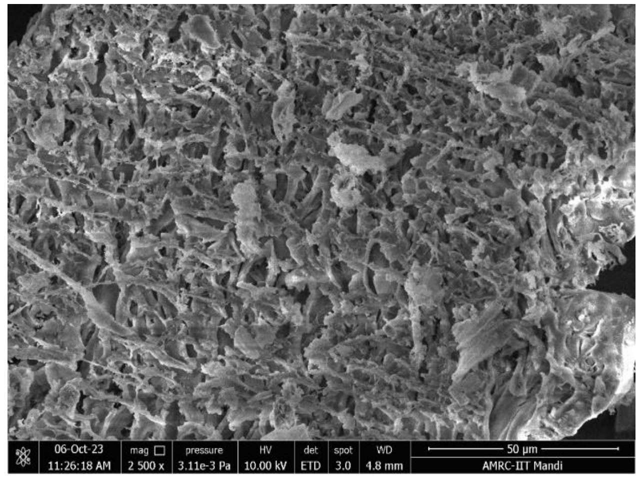

Fig. 9 Effect of contact time on iron removal using rice husk biochar adsorbent

From the above SEM image, a rough surface of the rice husk adsorbent has been observed. It could be one of the beneficial characteristics for the elevated level of iron adsorption using rice husk adsorbent, as the rough surface may have a better capacity to adhere to the adsorbate ions on its surface.

5. Conclusion

Iron contamination in water is a big challenge for water distribution systems, and it may also have some mild health impacts on human beings. Rice husk was used to develop biochar adsorbents for the removal of iron from water because it is locally available biomass and also a low-cost agro-waste material. Rice husk biochar was comparatively better for iron removal than wheat straw, pea nutshell and kali basuti (a wild plant sp.) based biochar adsorbents. The optimization of adsorption parameter experiments showed that the 6-8 pH range, 50 mg/100 mL adsorbent dosage and 120 minutes contact time were found to be very well for the removal of iron from water using rice husk-based biochar dosage. The SEM image of the adsorbent was rough, which seems good for the adsorption of iron from water. Most importantly, the raw material (i.e. rice husk) is a low-cost (or freely available) agro-waste material that can be used for developing adsorbents for the removal of water contaminants. The conclusion section should clearly explain the main findings and implications of the work, highlighting its importance and relevance.

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