Poll Res. 42 (2) : 307-310 (2023)

ISSN 0257–8050

DOI No.: http://doi.org/10.53550/PR.2023.v42i02.020

THE EFFECTIVENESS OF IRON MODIFIED BIOCHAR AS AN ADSORBENT FOR ARSENIC IN AQUEOUS SOLUTIONS

ASTHA PANDEY[A,B], SATISH KUMAR SINGH[A*], SHEETAL SHARMA[B], AJAY KUMAR MISHRA[B], AYUSH BAHUGUNA[C], PREM KUMAR BHARTEEY[C], SAYON MUKHARJEE[A], BHARTI YADAV[A] AND BHANUPRIYA PANKAJ[A]

[a]*Department of Soil Science & Agricultural Chemistry, IAS, BHU, Varanasi 221 005 (Uttar Pradesh), India*
[b]*International Rice Research Institute South Asia Regional Centre, Varanasi 221 106, Uttar Pradesh, India*
[c]*Department of Agricultural Chemistry and Soil Science, C.C.R. (P.G.) College, Muzaffarnagar 251 001, Uttar Pradesh, India*

(Received 12 March, 2023 accepted 29 April, 2023)

ABSTRACT

Arsenic contamination in aqueous environments poses a significant threat to human health and the environment. Various adsorbents have been explored to mitigate this issue, with biochar emerging as a promising candidate due to its high adsorption capacity and environmental sustainability. In this study, we investigated the effectiveness of iron-modified biochar as an adsorbent for arsenic removal from aqueous solutions. The results demonstrated that the iron-modified biochar exhibited superior arsenic adsorption performance compared to unmodified biochar. The maximum reduction was found to be 71%, indicating a significant improvement over conventional biochar.

KEY WORDS: Arsenic, Aqueous solution, Biochar, Fe modified biochar

INTRODUCTION

Arsenic is widely distributed throughout the global environment, leading to significant pollution issues, particularly affecting the United States, China, Pakistan (Jia *et al*., 2014), and Bangladesh (Manning *et al*., 2002). The excessive release of arsenic into the soil, resulting from both natural geological processes and human activities, contributes to its absorption by the food chain, posing a risk to human health. Once introduced into the soil, various reactions occur to the arsenic species, including adsorption/desorption, oxidation/reduction, dissolution/precipitation and the formation of soil colloids complex. The equilibrium established by these reactions determines the extractability, bioavailability, and toxicity of these arsenic species (Srivastava *et al*., 2011). Because of its significant toxicity and ability to cause cancer, arsenic has been classified as a group 1 carcinogen by the International Agency for Research on Cancer (IARC) in 2004. Previous research has suggested that long-term exposure to arsenic can impact various organs and systems within the human body (Kabir and Chowdhury, 2017). Arsenic primarily enters the environment through human activities such as mining, burning fossil fuels, and the use of pesticides (Gao *et al*., 2020). Due to its significant toxicity and potential to cause cancer, the contamination of groundwater with arsenic is a major global concern. In response to this issue, the World Health Organization (WHO) has established a parametric standard for drinking water, setting the maximum allowable concentration of arsenic at 10 $\mu g\ L^{-1}$ (micrograms per liter) (Holm, 2002). This standard serves as a guideline to ensure the safety of drinking water and protect human health.

Biochar, also referred to as “black gold,” is produced through a process of high temperature and anoxic conditions, involving the conversion of organic wastes like crop straw, poultry manure, and municipal sludge. This process not only reduces pollution but also maximizes resource utilization (Marris, 2006; Nguyen *et al.*, 2019; Parmar *et al.*, 2014). Numerous research studies have highlighted the beneficial characteristics of biochar, such as its extensive surface area (Ahmad *et al.*, 2014), high charge densities (Rajapaksha *et al.*, 2016), low bulk densities (Jain *et al.*, 2017; Liu *et al.*, 2018), stable porous structures, and significant organic carbon content (Herath *et al.*, 2013; Singh *et al.*, 2010). These attributes contribute to the reduction of soil bulk density and the enhancement of water holding capacity in coarse-textured soil due to the large surface area of biochar (Villagra-Mendoza and Horn, 2018). In recent years, there has been a growing interest in exploring alternative methods to mitigate the contamination of arsenic in aqueous solutions. One promising approach is the utilization of biochar, a carbonaceous material derived from biomass, as an adsorbent. Biochar has shown considerable potential in removing various pollutants from water due to its porous structure and high surface area. To further enhance its adsorption capabilities, researchers have focused on modifying biochar with iron (Fe). This modification aims to improve the efficiency of biochar as an adsorbent for arsenic, a highly toxic and prevalent contaminant in water sources. This study aims to investigate the effectiveness of Fe-modified biochar as an adsorbent for arsenic in aqueous solutions, exploring its potential application in water treatment and environmental remediation.

MATERIALS AND METHODS

In this study wheat straw biomass was collected from Agriculture Research Farm of Banaras Hindu University Varanasi U.P. India. It was pyrolyzed at a temperature of 400°C using drum method. The biochar was collected from drum after being cooled till a room temperature. The Iron modified biochar was synthesized by taking 10 g biochar and mixed with 7.23g of $FeCl_3.6\,H_2O$ in glass tube. The mixture is heated at 50°C to form a stable suspension. The Fine powdered modified biochar is filtered and dried overnight and then kept for oven dry.

Biochar and Iron modified biochar was applied at 2%,4% and 8% rate at each sample of 100mL of a 5 mg L^{-1} As (III) solution stirred at 2000 rpm and kept for one week. The Experiment was performed in triplicate. The analysis of variance (ANOVA) technique was used to find out the impact of each treatment on Arsenic in aqueous solution, pH and Electrical conductivity. All the data were subjected to statistical analysis using completely randomized design.

RESULTS AND DISCUSSIONS

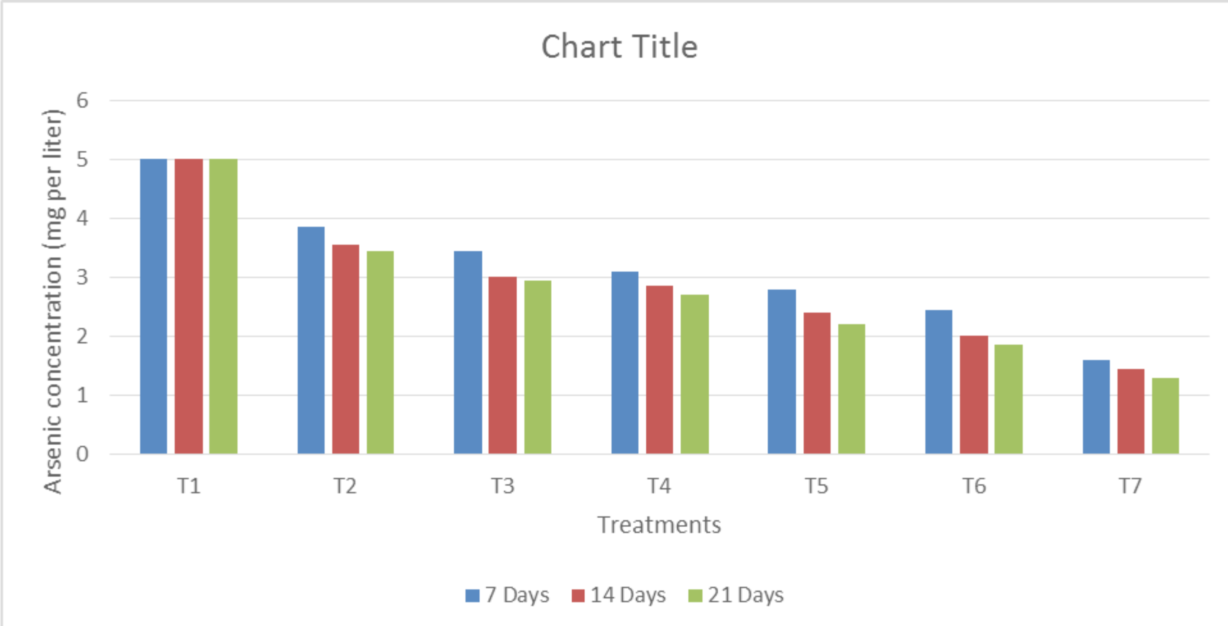
The three different rates of simple biochar and Iron modified biochar had significant effect on effect on the aqueous pH (Table 1). With application of two different biochar the pH units has changed from 0.19 to 1.08 at seven days after incubation while after 14 the change in pH unit ranged from 0.22-1.03 and after 21 days after incubation it has ranged from 0.35-1.01. While the EC has changed from 0.01 to 0.07 units at 7 days after incubation. While after 14 days. With the application of simple biochar an increase in pH is observed while with application of Fe- modified biochar a decrease in pH was observed. While in EC the increase in EC is observed in both case (Table 2) but higher EC was observed with increase dose of Iron Modified biochar.

Table 1. The impact of various types of biochar on the pH of an aqueous solution

Treatment	7 Days	14 days	21 days
T_1	7.0	6.98	7.09
T_2	7.43	7.48	7.51
T_3	6.81	6.77	6.74
T_4	7.87	7.73	7.7
T_5	6.52	6.46	6.4
T_6	8.08	8.01	8.1
T_7	6.4	6.38	6.35
SEm(±)	0.088	0.120	0.094
CD at 5%	0.272	0.371	0.288

A*=Aqueous solution with 5 ppm Arsenic
Treatment details: T_1 = A, T_2 = A + 2% simple biochar, T_3 = A + 2% Iron modified biochar, T_4= 4% simple biochar, T_5 = A + 4% Iron modified biochar, T_6 = A + 8% simple biochar, T_7= A + 8% Iron modified biochar

While in case of Arsenic a reduction is observed with application of biochar (Fig. 1) the performance of Iron modified biochar was better compare to simple biochar. The increase dose of biochar has significant reduction in arsenic content in aqueous solution. The highest dose of simple biochar has reduced the Arsenic content by 51% while the highest dose of Fe-modified biochar has reduced the Arsenic content by 68% seven days after incubation while after 14 days after reduction in simple biochar is by 60% (simple biochar) and 71% in Fe modified biochar and 21 days after incubation the reduction



A*=Aqueous solution with 5ppm Arsenic
Treatment details: T_1 = A, T_2 = A + 2% simple biochar, T_3 = A + 2% Iron modified biochar, T_4= 4% simple biochar, T_5= A + 4% Iron modified biochar, T_6 = A + 8% simple biochar, T_7= A + 8% Iron modified biochar

Fig. 1. Graphical presentation of Arsenic removal at 7 days, 14 days and 21 days after incubation

Table 2. The impact of various types of biochar on the Electrical Conductivity (dS m^{-1}) of an aqueous solution

Treatment	7 Days	14 Days	21 Days
T_1	0.023	0.029	0.41
T_2	0.099	0.108	0.125
T_3	0.12	0.162	0.179
T_4	0.134	0.143	0.158
T_5	0.165	0.174	0.187
T_6	0.187	0.193	0.200
T_7	0.197	0.204	0.208
SEm(±)	0.001	0.002	0.003
CD at 5%	0.005	0.007	0.010

A*=Aqueous solution with 5ppm Arsenic
Treatment details: T_1 = A, T_2 = A + 2% simple biochar, T_3 = A + 2% Iron modified biochar, T_4= 4% simple biochar, T_5= A + 4% Iron modified biochar, T_6 = A + 8% simple biochar, T_7= A + 8% Iron modified biochar

in highest dose of biochar observed is 63% and 74%. Initially, a significant reduction in arsenic levels was observed within days, with the highest reduction occurring at 7 and 14 days after incubation. However, there was not a significant decrease in arsenic levels observed after 21 days of incubation. The iron present in the modified biochar acts as a sorbent, meaning it attracts and binds to arsenic ions. This process is known as adsorption. When contaminated water comes into contact with iron-modified biochar, the arsenic ions are attracted to the surface of the biochar due to electrostatic forces. The iron compounds on the biochar surface form strong chemical bonds with the arsenic ions, effectively immobilizing them. Surface-modified biochar has been shown to have an excellent capacity for removing As from water and has received widespread research attention (Shaheen *et al*. 2022; Tan *et al*. 2016).

CONCLUSION

The research focused on examining how Fe-modified biochar, derived from the slow pyrolysis of wheat straw biochar, can effectively eliminate Arsenic from water solutions. The use of wheat straw as a cost-effective source for producing iron-modified biochar enables the application of this straightforward activation method to other thermally produced biochar as well. This approach offers a viable and valuable sorbent option for removing arsenic from groundwater.

ACKNOWLEDGEMENT

We would like to express our heartfelt and deep gratitude to the Department of Soil Science and Agricultural Chemistry, IAS, BHU, Varanasi (Uttar Pradesh), India, particularly for providing the necessary facilities, support, and cooperation to conduct the present investigation.

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