J. Appl. Sci. Innov. Technol. 1 (2), 52-55 (2022) ISSN (online): 2583-505X

Journal of Applied Science, Innovation & Technology (JASIT)

https://prakritimitrango.com

Research Article

Adsorptive removal of Arsenic (III) from magnetic biochar fabricated from agricultural waste biomass

Naincy Sahu* and Siddharth Shukla

Department of Environmental Science, Dr. Rammanohar Lohia Avadh University, Ayodhya-224001, Uttar Pradesh, India

ARTICLE INFOR: *Received: 17 November 2022; Revised: 02 December 2022; Accepted: 03 December 2022*

CORRESPONDING AUTHOR: E-mail: naincysahu.29@gmail.com (N. Sahu), Tel: +91-7786922530

Abstract

Large number of agricultural wastes like vegetable peel, saw dust, bagasse, rise husk, shells, rotten and scraped portions of food is generated from the agriculture fields, vegetable markets, households and its management are very essential to avoid its open dumping. Adsorbent preparation can be a new way to utilize agricultural waste. Hence in the present study, agricultural waste was used for the preparation of magnetic biochar at 400˚C temperature. The synthesized biosorbent is denoted as mBC-400 and its utilization for the biosorption of As(III). Characterized the prepared biosorbent by using scanning electron microscopy (SEM-EDX) and point zero charge (pH_{zpc}). SEM of mBC-400 revealed that shapes of particles were irregular and shows huge number of pores on the adsorbent surface. EDX analysis indicates the higher carbon content in mBC-400. The pH_{ZPC} of the mBC-400 was found to be 3.04. The batch study was conducted with various initial concentrations, adsorbent dosages and pH values. Adsorbent mBC-400 was efficient for the biosorption of As(III). The maximal percentage removal of As(III) was found to be ~74% at 0.5 mg/L initial concentration. This study is focused on utilization of agricultural waste for purification of drinking water, wherever by using this solid waste feedstock for preparing the biosorbent it will reduce the agricultural waste problem and protect our environment. The prepared biosorbents were applied successfully to remediate the pollution problem.

Keywords: Agricultural waste; magnetic biochar; As(III); biosorption

1. Introduction

Agricultural development in agrarian countries has also increased the agricultural waste production. Today; this agricultural waste has become a significant source of pollution. A variety of issues have been happened through spontaneously burning of straw and livestock excrement in the agrarian countries. Even more worrying is the rise of practises like direct combustion and uncontrolled waste disposal, which pose a significant threat to rural ecosystems and the quality of life of farmers. Disposing of agricultural waste in unconventional ways results in environmental damage and the loss of numerous bioenergy resources. It is well acknowledged that conserving the environment, the energy infrastructure, and agricultural advancement may all benefit from the recycling and reuse of agricultural waste. Waste management difficulties have been mitigated, and recycling used materials has not created any new issues (Thines et al., 2017).

Arsenic species is considered most toxic element in environment. The permissible limit of arsenic in ground water is 10 µg/L (Sahu et al., 2022). Arsenic may introduce into environmental bodies from earth crust dissociation of minerals with water, industrial effluents and burning of fossil fuels. Trivalent arsenic is 60% more toxic than pentavalent arsenic state due to its highly reactivity with phosphate group during ATP formation, having similar structure as phosphate group (Basu et al., 2014).

Arsenic pollution reported worldwide problem including South east countries like India and Bangladesh. In India, arsenic is reported in groundwater of areas of West Bengal, Jharkhand, Bihar and Uttar Pradesh (Bindal and Singh, 2019). In order to reduce the level of arsenic ions in water and wastewater, processes such as ion exchange, osmosis, membrane filtration, and adsorption may be utilised. Among all, adsorption is mainly used because of its features like, low cost in nature, simple in operation, minimum use of chemicals, fast process (Malik et al., 2017).

2. Materials and chemical

The waste agricultural residue (pea plant waste) was collected from a vegetable farm nearby Dr. Rammanohar Lohia Avadh University, Ayodhya, U.P, India. Sodium arsenate, hydrochloric acid and sodium hydroxide, potassium iodate, antimony potassium titrate, ammonium molybdate, sulphuric acid, L-Ascorbic acid, ferric chloride anhydrous was brought from Thermo Scientific, India. In present study analytical grade chemicals and reagent was used.

2.1. Synthesis of biosorbent

In this study, waste agriculture residue (pea plant waste) cleaned and rinsed with double distilled water 3 to 4 times, the pea plant waste was dried at oven and that dried pea plant waste was ground and sieved. About 7.5 gram Iron chloride hexahydrate ($FeCl_3.6H_2O$) was dissolved in 75 mL digital water and then add 15gram powder sample and mixed sample was oven dried for 2 hrs at 100°C. After that mixed sample were treated in muffle furnace at 400°C for 2 hours (Fig. 1). After heat treatment sample was cooled at room temperature. Then the synthesized sample was washed 4 to 5 times and dried sample was kept on air tight box for future use.

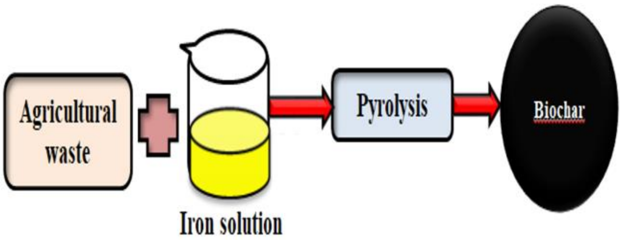

Fig. 1 Pictorial representation of mBC-400 synthesis.

2.2. Characterization of mBC-400

Using scanning electron microscopy (SEM) accompanied with energy dispersive X-ray spectroscopy (EDX) (Model no. JEOL-6490 LV, Japan), the surface morphological structure and elemental composition analysis of biosorbent were studied. After adding 0.2 gram of biosorbent to 20 millilitres of 0.01M NaCl solution, the mBC-400's pHzpc was measured, and the pH was successfully adjusted from 2 to 10 with 0.1M solutions of NaCl and hydrochloric acid (HCl). After 48 hours, the final pH level was measured (Mishra et al., 2019).

2.3. Batch Study

Batch biosorption experiment was run for As (III) elimination by using conical flask (250 mL). Conical flask contains 50 mL of As (III) solutions with various mBC-400 dosage, initial concentration, pH, temperature were kept in orbital shaker at 100 RPM speed and at 25ºC temperature (Fig. 2). After saturation time samples were filtrated and the remaining concentration of As(III) was detected through UV-Visible Spectrophotometer (Model no. 2703, Systronics, india) at 880 nm absorbance wave length. The removal efficacy of As(III) was calculated by given equation (Sahu et al., 2019; Bhan and Singh, 2022)

$$Removal\ \% = \frac{C_o - C_t}{C_o} \times 100 \qquad (1)$$

$$Adsorption\ capacity\ (q_e) = \frac{C_o - C_t}{m} \times V \qquad (2)$$

Here, C_o= initial As (III) concentration, C_t= remaining As (III) concentration, q_e= concentration at equilibrium, m= adsorbent mass in gram, V= liquid phase volume (L).

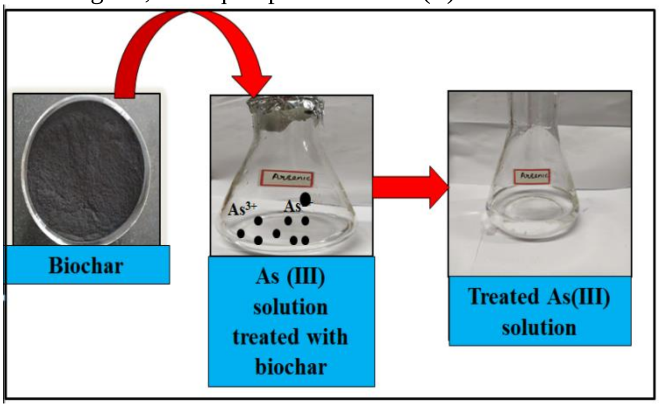

Fig. 2. Pictorial representation of treatment of As(III) solution with biochar (mBC-400)

3. Results and discussion

3.1. Characterization of mBC-400

The study of surface morphological structure and elemental analysis mBC-400 was accomplished by using SEM that was equipped with EDX. Fig.3.a. revealed that the shape of mBC-400 was irregular with rough surface. Elemental composition of mBC-400, which has carbon, iron and oxygen content, was present (Fig.3.b). The pH_{ZPC} value of biosorbent is most essential factor that describes the net surface charge of biosorbent. The pH_{ZPC} of synthesized mBC-400 was found 3.04 (Fig.3.c). Adsorbent surface was shown to be negatively charged in the experiment.

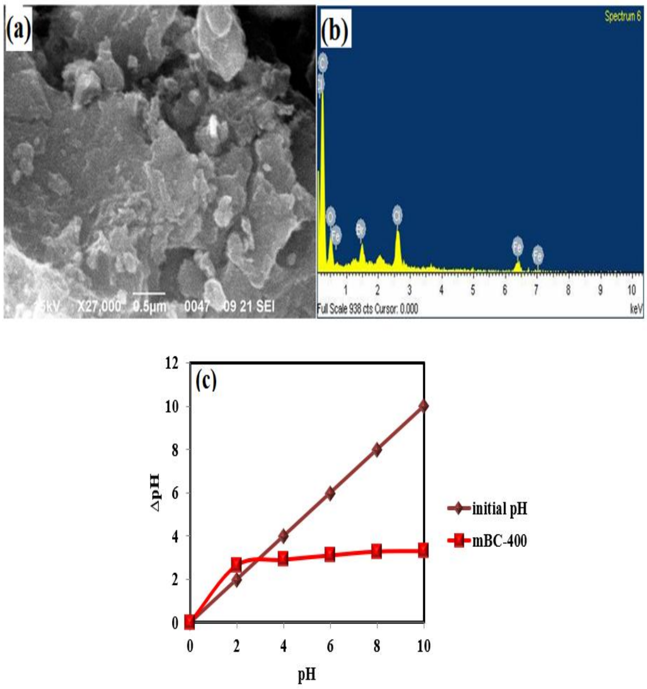

Fig. 3 (a) and (b) SEM and EDS analysis of mBC-400 and (c) point zero charge

3.2. Biosorption experiments

3.2.1. Effects of mBC-400 amount

As represented in Fig.4a, various dosages from 1 to 4 g/L of mBC-400 were performed for the amount study at fixed As (III) concentration-1mg/L, pH-7 and 25ºC. The dose study results demonstrated that removal efficiency of As (III) was increased with enhancement in adsorbent doses. This type of trend is mostly ascribed to an enhanced in the active site (Verma and Singh, 2022; Adetokun et al., 2019). As per results, maximum biosorption of As(III) was found to be 72% with 3g/L dose. However, Maximum biosorption of As (III) was achieved with 3g/L dose, so that it was selected for further study.

3.2.2. Effect of pH

The pH effect is most significant part in biosorption of As(III). The impact of pH on As (III) biosorption was studied in several pH range from 2 to 10. From the Fig.4b, it was found that removal efficiency of As(III) was increased slightly, when the pH was enhanced from 2 to 7 after this pH removal was constant. The maximal bisorption of As (III) was ascertained 72% at pH 6 with an optimum concentration (1 mg/L) and 3 g/L dose, at 25ºC temperature. The lowest biosorption was found for As (III) was achieved about 47% at pH 2 because of electrostatic repulsion (Niazi et al., 2018).

3.2.3. Influence of As (III) concentration

The impact of different initial concentration of mBC-400 (0.5 mg/L, 1 mg/L, 1.5 mg/L, 2 mg/L, 2.5 mg/L) on As(III) biosorption as represented in Fig. 5a. The highest biosorption of As (III) was found to be 74% at lowest concentration of mBC-400 (0.5 mg/L). The result revealed that removal efficacy in percentage was decreased with an enhancing the As(III) concentration. This is due to the face of essential driving force overcome the solid phase and liquid phase is provided by initial

As(III) concentration (Li et al., 2015). To study the influence of contact time on As(III) biosorption on the mBC-400 surface, batch study was done at several time intervals and total time of biosorption was kept 420 min. Fig. 5b demonstrates that biosorption of As(III) was increased with an enhancing contact time; however, after 300 min there is no further increment in As(III) biosorption, so biosorption equilibrium was obtained at 300 min at this point removal rate of As(III) was constant because removal of As (III) on the mBC-400 surface is equivalent to the desorption rate (Sahu et al., 2022).

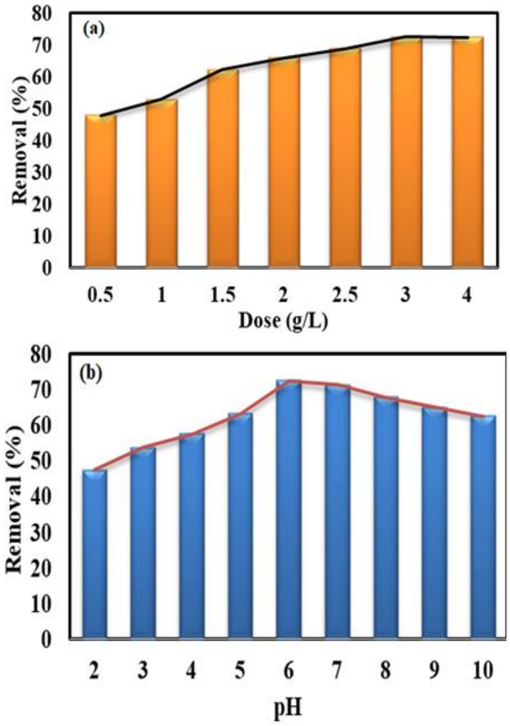

Fig. 4. Effect of mBC-400 dose (a) and pH (b) on removal of As (III)

3.2.4. Effect of temperature

Temperature study plays an important role in biosorption process. Temperature study was examined at different temperature (25ºC, 35ºC, 45ºC and 55ºC) and other parameters were kept constant. Impact of temperature is an essential factor for biosorption mechanism. As(III) removal efficiency was increased with an enhancing the temperature (Fig.5c). The results indicate that nature of biosorption process is endothermic. Maximum biosorption of As (III) was found 80% at highest temperature 55ºC.

3.3. Mechanism of As(III) biosorption

The possible mechanism process such as electrostatic attraction and surface complexion involved in As(III) elimination from aqueous solution uses iron modified biochar (mBC-400) (Fig. 6). Electrostatic attraction and surface complexion may occur through different functional group like –OH, $–CH_3$, $–CH_2$, NH_2, COO^- (Sahu et al., 2021). The mechanism depends on pH factor. The pH_{ZPC} of mBC-400 is observed to be 3.04. In the process of As (III) biosorption, the most favourable pH range was found to be 2 to 6due to the presence of negative ions species such as $H_2AsO_3^{-1}$ and $HAsO_3^{2-}$ (Dhoble et al., 2018).

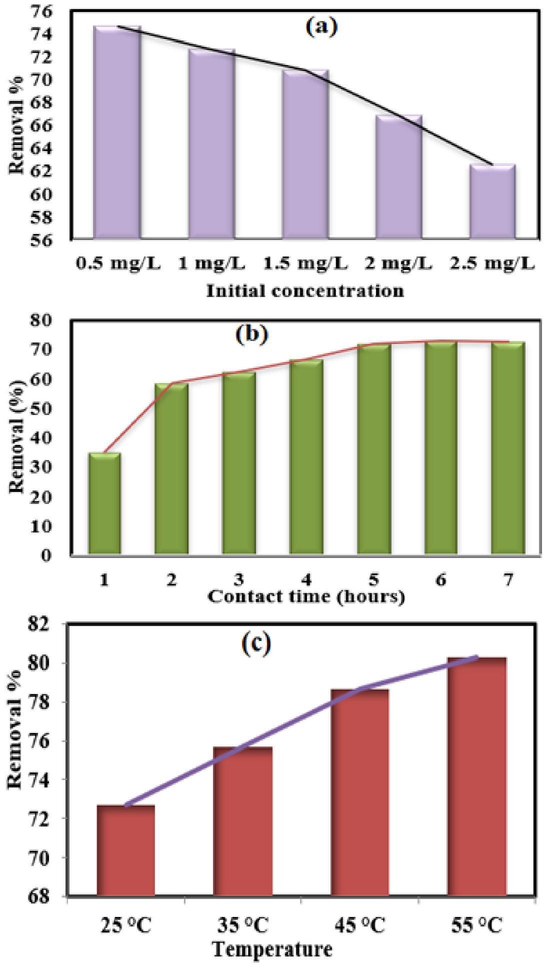

Fig. 5. Effect of concentration (a), Effect of contact time (b) and Effect of temperature (c).

4. Conclusion

In this research, magnetic biochar was prepared from pea plant waste with iron impregnation at 400ºC temperature and it was applied for As(III) biosorption from an aqueous solution. SEM results clearly shows the rough surface of biosorbent are irregular in shape EDX analysis illustrated that the presence of iron, carbon and oxygen on surface of mBC-400, which revealed that surface of mBC-400 are rich in carbon. In the batch study, maximum biosorption was found to be 74%, attained with an initial concentration i.e., 0.5 mg/L. The higher temperature was favourable for the As(III) removal, maximum As(III) biosorption was found at 55ºC temperature. So that, the nature of biosorption process is endothermic. It is also presented that at the pH level of 6, As (III) is removed most effectively. It is determined by analyzing pHzpc that the biosorbent is negatively charged. It is concluded that pH 6 is favourable for the biosorption of As(III) by using mBC-400. The results concluded that the synthesized biosorbent (mBC-400) is economic and environmentally friendly for the removing of As (III) from the contaminated water.

Acknowledgment

Author is grateful to the University Sophisticated Instrumentation Centre (USIC), Babasaheb Bhimrao Ambedkar University, Lucknow, for characterization of SEM & EDX.

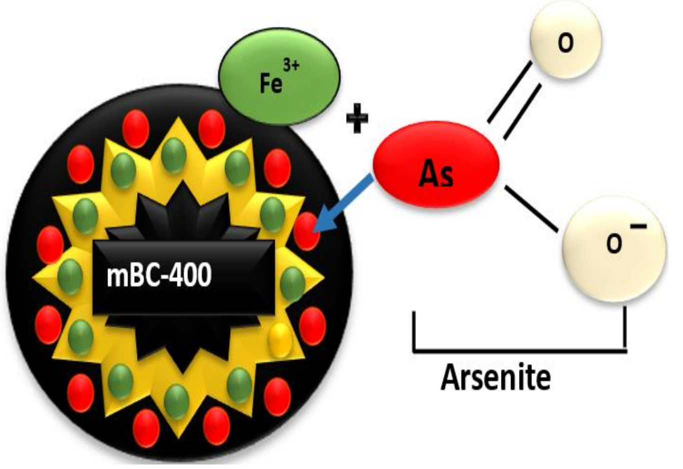

Fig. 6 Possible mechanism process for As(III) removal on to mBC-400.

Author contributions

Naincy Sahu: Methodology, Investigation, Writing - original draft. Siddharth Shukla: Supervision review & editing.

Conflicts of interest

The authors declare that they have no known conflict of interest.

Reference

Adetokun, A.A., Uba, S., & Garba, Z.N., 2019. Optimization of adsorption of metal ions from a ternary aqueous solution with activated carbon from Acacia senegal (L.) Willd pods using Central Composite Design. J. King Saud Univ. Sci. 31(4), 1452-1462.

Basu, A., Saha, D., Saha, R., Ghosh, T., & Saha, B., 2014. A review on sources, toxicity and remediation technologies for removing arsenic from drinking water. Res. Chem. Intermed. 40 (2), 447-485.

Bhan, C., Singh, J., 2022. Fabrication of an adsorbent from *Ficus racemosa* leaf biomass for fluoride removal and its preparation cost analysis. J.Appl. Sci. Innov. Technol. 1 (1), 1-5.

Bindal, S., & Singh, C. K., 2019. Predicting groundwater arsenic contamination: Regions at risk in highest populated state of India. Water Res. 159, 65-76.

Dhoble, R.M., Maddigapu, P. R., Bhole, A.G., Rayalu, S., 2018. Development of bark-based magnetic iron oxide particle (BMIOP), a bio-adsorbent for removal of arsenic (III) from water. J. Environ. Sci. Pollut. Res. 25(20), 19657-19674.

Li, C., Zhong, H., Wang, S., Xue, J., Zhang, Z. 2015. Removal of basic dye (methylene blue) from aqueous solution using zeolite synthesized from electrolytic manganese residue. J. Ind. Eng. Chem. 23, 344-352.

Malik, D.S., Jain, C.K., Yadav, A.K., 2017. Removal of heavy metals from emerging cellulosic low-cost adsorbents: a review. Appl. Water Sci. **7**, 2113–2136. http://dx.doi.org/ 10.1007/s13201-016-0401-8

Mishra, S., Yadav, S.S., Rawat, S., Singh, J., Koduru, J.R., 2019. Corn husk derived magnetized activated carbon for the removal of phenol and para-nitrophenol from aqueous solution: Interaction mechanism, insights on adsorbent characteristics, and isothermal, kinetic and thermodynamic properties. J. Environ. Manage. 246, 362-373.

Niazi, N.K., Bibi, I., Shahid, M., Ok, Y. S., Burton, E. D., Wang, H., Lüttge, A., 2018. Arsenic removal by perilla leaf biochar in aqueous solutions and groundwater: an integrated spectroscopic and microscopic examination. Environ. Pollut. 232, 31-41.

Sahu, N., Nayak, A.K., Verma, L., Bhan, C., Singh, J., Chaudhary, P., Yadav, B.C., 2022. Adsorption of As (III) and As (V) from aqueous solution by magnetic biosorbents derived from chemical carbonization of pea peel waste biomass: isotherm, kinetic, thermodynamic and breakthrough curve modeling studies. J. Environ Manage. 312, 114948..

Sahu, N., Rawat, S., Singh, J., Karri, R.R., Lee, S., Choi, J.S., & Koduru, J.R., 2019. Process Optimization and Modeling of Methylene Blue Adsorption Using Zero-Valent Iron Nanoparticles Synthesized from Sweet Lime Pulp. Appl. Sci. 9(23), 5112.

Sahu, N., Singh, J., & Koduru, J. R. 2021. Removal of arsenic from aqueous solution by novel iron and iron–zirconium modified activated carbon derived from chemical carbonization of Tectona grandis sawdust: Isotherm, kinetic, thermodynamic and breakthrough curve modelling. J. Environ. Res. 200, 111431.

Thines, K. R., Abdullah, E. C., Mubarak, N. M., & Ruthiraan, M., 2017. Synthes is of magnetic biochar from agricultural waste biomass to enhancing route for waste water and polymer application: a review. Renew. Sustain. Energy. Rev. 67, 257-276.

Verma, L., Singh, J., 2022. As(III) removal using engineered biochar synthesized from waste biomass of a Timber plant refuse. J. Appl. Sci. Innov. Technol. 1 (1), 6-9.

Cite this article:

Sahu, N., Shukla, S., 2022. Adsorptive removal of Arsenic (III) from magnetic biochar fabricated from agricultural waste biomass. J. Appl. Sci. Innov. Technol. 1 (2), 52-55.

.