VOLUME 01 ISSUE 01 (2026)

Journal of Waste to Value System

Comparative Analysis of Biochar produced from *Eichhornia crassipes* and Rice Husk in Removing Contaminants from Waste Water

Ankita Thakur*

**PhD scholar, thakurankkita93@gmail.com*

***Corresponding author:** Ankita Thakur, thakurankkita93@gmail.com

https://doi.org/

Abstract

Heavy metal contamination, particularly chromium Cr (VI)), presents significant threats to the environment and human health because of its toxicity and persistence in aquatic systems. The development of low-cost and sustainable adsorbents is essential for effective wastewater treatment. In this study, biochar was prepared from rice husk and water hyacinth (*Eichhornia crassipes*) through pyrolysis at 600°C. The prepared biochars were characterized using physicochemical parameters, SEM, XRD, and FTIR analyses. Batch adsorption experiments were directed to assess Cr (VI) removal under controlled conditions of pH 3, 30°C, and varying adsorbent dosages and contact times. The results showed that both biochars exhibited adsorption potential for Cr (VI), with removal efficiency increasing with adsorbent dosage and contact time. Rice husk biochar demonstrated higher adsorption efficiency compared to water hyacinth biochar, achieving maximum removal at lower dosage. SEM analysis revealed a more porous and fibrous structure in rice husk biochar, while XRD and FTIR confirmed the presence of functional groups and structural properties favorable for adsorption. Water hyacinth biochar showed comparatively lower performance due to its structural characteristics. The study concludes that rice husk biochar is a more effective adsorbent for Cr (VI) removal, while water hyacinth biochar shows potential with further modification. The use of such waste-derived biochars offers an economical and environmentally friendly method of treating wastewater.

Keywords: Cr (VI) removal; rice husk biochar; water hyacinth biochar; adsorption; wastewater treatment

1. Introduction

One extremely important natural resource is water that is demanded by the survival of living organisms, ecological balance, agriculture and industrial uses. Though it occupies a big portion of the surface of the earth, a small percentage of it is freshwater, which can be used by human beings. Overpopulation, industrialisation, and farming activities have led to a huge demand of clean water and on the other hand, water pollution. Discharge of industrial effluent, agricultural runoff, and domestic wastewater into the natural water bodies impairs the quality of water and render it inappropriate to use. Thus, the problem of wastewater treatment has become a significant environmental issue, and the environmentally friendly solutions stress the utilization of low-cost and environmentally friendly materials based on waste biomass (Emenike et al., 2025).

The reason why heavy metals are considered some of the most dangerous water pollutants is that they are toxic, persist, and are not biodegradable. They are not easily degraded as opposed to organic pollutants and they are likely to be accumulated in aquatic systems and organisms. These metals find their way into the food chain through bioaccumulation and trophic magnification and are extremely hazardous to human health even in low levels. Heavy metal contamination is mainly caused by mining, electroplating, textile industries, and chemical manufacturing. Traditional methods of treatment are usually both expensive and inefficient to eliminate all of them, and this has created an interest in biomass-based adsorbents to treat wastewater (Okaya et al., 2020). Moreover, biomass of plants is now under investigation as an environmentally friendly resource to create adsorbents to clean the environment (Kumari et al., 2021).

One of the most predominant heavy metal contaminants in industrial wastewater is chromium, especially electroplating, leather tanning, dye manufacturing and metal finishing industries. It occurs mostly in two states namely hexavalent chromium Cr (VI) and trivalent chromium Cr (III). Of these, Cr (VI) is the most toxic, is highly soluble and mobile and thus poses a serious environmental problem. Contact with chromium may lead to lung, liver, kidney, nervous system damage as well as respiratory diseases and cancer. As such, effective extraction of chromium in the wastewater is critical. In recent works, the power of water hyacinth and its biochar as cheap adsorbents to remove heavy metals has been emphasized (Ullah and Rahman, 2024).

Wastewater treatment may be done with different physical, chemical and biological treatment processes; these include coagulation-flocculation, chemical precipitation, electrochemical treatment, ion exchange and membrane filtration. These methods are effective but they have a high cost of operation, are cumbersome, and produce secondary waste. Adsorption has also been found to be a simple and cost-effective method of pollutant removal. Biochar-based materials, especially with modification, have demonstrated better usage in contaminants removal (Flafel et al., 2024). In the same manner, waste biomass like water hyacinth has been reported to yield promising biochar and nanobiochar to eliminate metal ions in aqueous solutions (Elbehiry et al., 2022).

Biochar is a high-carbon substance that is produced when biomass is thermally broken down with little oxygen. It has porous structure, high surface area and functional groups that increase the adsorption capacity. Agricultural and aquatic wastes are the most commonly used feedstock as they are cheap and readily available. Rice husk is a rich farming waste which includes components of carbon and silica that aid in effective adsorption. Husk of rice biochar has been extensively researched to be used in the removal of pollutants because of its adsorption capacity (Emenike et al., 2025).

Eichhornia crassipes is a water hyacinth that has the potential of uptaking pollutants. In spite of its invasive nature, it can be turned into biochar that is useful. Research has indicated that water hyacinth biochar has characteristics that can be used in environmental application (Najmudeen et al., 2019) and eliminate organic and inorganic pollutants (Mishra and Maiti, 2017).

The current research assesses the possibilities of rice husk and water hyacinth biochar to remove chromium in aqueous solution. Waste biochar is a cost-friendly and green alternative to traditional approaches to biochar. The use of processed water hyacinth as efficient pollutant removal material has been reported (Abd Aziz et al., 2025), along with biochar made out of *Eichhornia crassipes* as potentially useful in adsorbing dyes present in aqueous media (Farzana et al., 2026). Nanomagetite-supported biochar. modified biochar systems have also been reported to show better adsorption performance (Doan et al., 2021). Comparative research suggests that the efficiency of adsorption is determined by the type of biomass and the conditions of its preparation (Negi et al., 2025). As such, this research is aimed at preparing, characterizing and assessing biochar in rice husk and water hyacinth to determine which adsorbent is more effective in removing the chromium.

Research objectives

1. Preparation of biochar from rice husk and water hyacinth (*Eichhornia crassipes*).
2. Characterization of biochar prepared from rice husk and water hyacinth (*Eichhornia crassipes*).
3. Evaluation of adsorption of chromium on biochar prepared from rice husk and water hyacinth (*Eichhornia crassipes*).

2. Materials and Methods

2.1 Materials, Instruments and Chemicals

In January 2017, rice husk and water hyacinth (*Eichhornia crassipes*) were taken at District Phagwara, Punjab, India. Preparation of Cr (VI) stock solution was done using potassium dichromate ($K_2Cr_2O_7$). All solutions were made in double-distilled water. The pH was fixed with 0.1 M HCl and 0.1 M NaOH, and nitric acid (67) was used to digest the sample before ICP-OES analysis.

2.2 Rice Husk and Water Hyacinth Biochar Preparation

Rice husk and water hyacinth were dried in a 105°C furnace in 1 h and pyrolyzed in a muffle furnace at low-oxygen concentration (600°C). The heating was carried on until the materials changed to uniformly black, which confirmed the formation of biochar (Figures 1 and 2). Rice husk biochar was procured in a needle shape and water hyacinth biochar was ground and sieved using a 0.150 mm sieve.

a

b

Figure 1. Preparation of rice husk

biochar: (a) raw rice husk before pyrolysis and (b) rice husk biochar after pyrolysis at 600°C

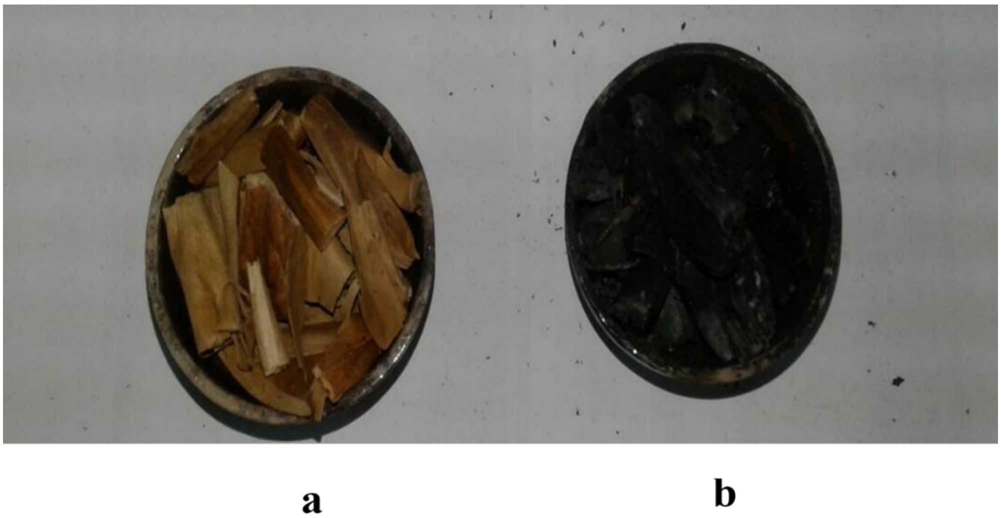


Figure 2. Preparation of *Eichhornia crassipes* biochar: **(a)** dried water hyacinth before pyrolysis and **(b)** water hyacinth biochar after pyrolysis at 600°C.

2.3 Physicochemical Characterization of Biochar

Biochars were characterised in terms of moisture content, pH, electrical conductivity (EC), ashing content, solid density, bulk density, porosity and cation exchange capacity (CEC). The moisture content was obtained after drying in the oven at 110+/-5. The pH, EC were determined with the help of 1% biochar suspension. Ash content was estimated by heating a sample at 760°C in 6 h. Standard methods were used to determine bulk density, solid density, and porosity, whereas ammonium chloride extraction, flame photometric analysis and titration analysis determined CEC.

2.4 Instrumental Characterisation

Surface morphology was examined using scanning electron microscopy (SEM). Functional groups were identified using Fourier transform infrared spectroscopy (FTIR), and structural characteristics were ascertained using X-ray diffraction (XRD).

2.5 Preparation of Chromium Stock Solution

A 1000 mg/L stock solution of A Cr (VI) was made by dissolving 2.8287 g (analytical-grade) in $K_2Cr_2O_7$, 1 L of double-distilled water in a 1000 mL volumetric flask. The solution was then thoroughly mixed by shaking the solution 2-3 min. To ensure that no foreign ions were present at the end of the solution, the solution was mixed with double-distilled water.

2.6 Batch Adsorption Experiments

The experiments of batch adsorption were performed under 3, 30°C and 150 rpm agitation. The original Cr (VI) level was 12 ppm. The dosage of rice husk biochar to 100 mL solution was 1, 5, 10 and 15 g and water hyacinth biochar to 50 mL solution was 0.5, 2.5, 5, and 7.5 g. Regular sampling was performed, filtered, nitric acid digested with the help of ICP-OES. The water hyacinth samples were centrifuged and then filtered.

2.7 Removal Efficiency and Breakthrough Curve Study

Similar experiments were performed with contact time with a collection at 30 min up to 4 h to assess the removal efficiency and breakthrough behaviour.

2.8 Adsorption Calculations

The amount of chromium adsorbed by biochar was calculated using:

$$q = \frac{(C_0 - C_e)V}{W}$$

where $q$is the amount of chromium adsorbed, $C_0$is the concentration initially, $C_e$is the equilibrium concentration, $V$is the volume of solution and $W$is the weight of adsorbent.

The percentage removal of chromium was calculated as:

$$\text{Removal (\%)} = \frac{C_{\text{initial}} - C_{\text{final}}}{C_{\text{initial}}} \times 100$$

3. Results

3.1 Preparation of Biochar

Biochar from rice husk and water hyacinth was organized effectively through pyrolysis at 600°C in a muffle furnace in low-oxygen atmosphere. There was uniformity in the colour of both materials turning black, which proved the formation of biochar. The biochar obtained was rice husk biochar in their activated form (needle-shaped) and water hyacinth biochar was ground and sieved using sieve with 0.150 mm diameter.

3.2 Physicochemical Characterization

The biochar preparations had different physicochemical characteristics (Table 1). Rice husk biochar had pH 7.36, moisture content 6.93%, ash content 46.2%, electrical conductivity 244.9 µS/ppm, bulk density 0.122 g cm^{-3}, solid density 0.22 g cm^{-3}, porosity 0.45, and CEC 34.48 c mol kg^{-1}. The water hyacinth biochar contained a pH of 9.81, moisture content 13.5, ash content 54.4, electrical conductivity 606.2 µS/ppm, bulk density 0.040 g cm^{-1}, solid density 0.102 g cm^{-1}, porosity 0.60, and CEC 42.24 cmol/kg.

Table 1. Physical and chemical characterization of water hyacinth and rice husk biochar

Parameter	Rice Husk Biochar	Water Hyacinth Biochar
Temperature	600°C	600°C
pH	7.36	9.81
Moisture content	6.93%	13.5%
Ash content	46.2%	54.4%
Electrical conductivity	244.9 µS/ppm	606.2 µS/ppm
Bulk density	0.122 g cm^{-3}	0.040 g cm^{-3}
Solid density	0.22 g cm^{-3}	0.102 g cm^{-3}
Porosity	0.45	0.60
CEC	34.48 cmol kg^{-1}	42.24 cmol kg^{-1}

3.3 SEM Analysis

SEM analysis revealed rice husk biochar as having wafer-like, porous, and fibrous particles with a particle size between 50 µm to 500 µm (Figure 3). The porosity of the rice husk biochar suggests that the physical spaces are available on its surface that could be used to adsorb chromium.

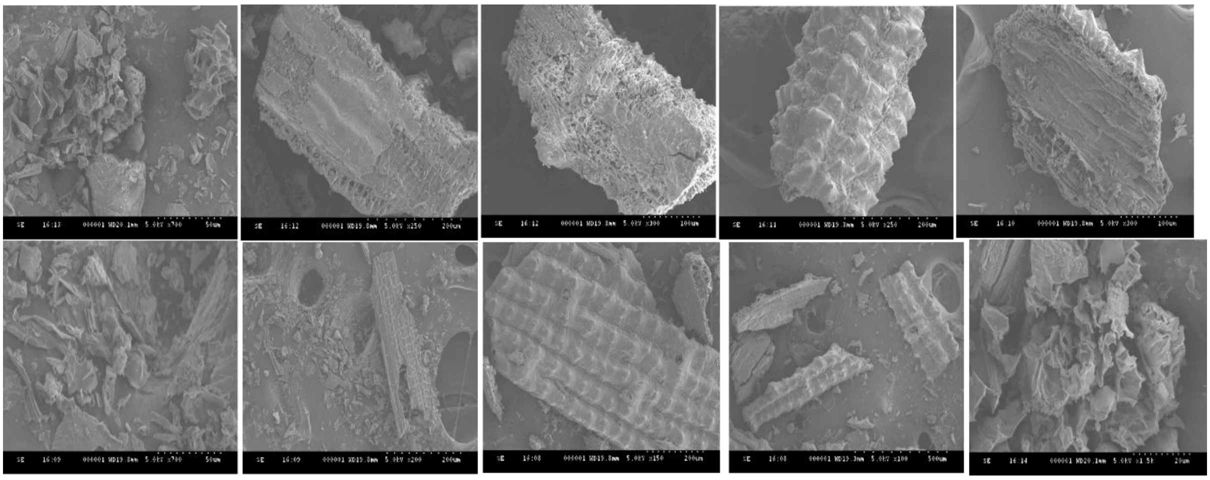


Figure 3. SEM micrographs of rice husk biochar showing wafer-like, porous, and fibrous surface morphology at different magnifications.

The porous and fibrous structure suggests that there are surface spaces which could have chromium adsorption. The water hyacinth biochar had irregular and foliage porous morphology that was coarse and granulated in the same size range (Figure 4).

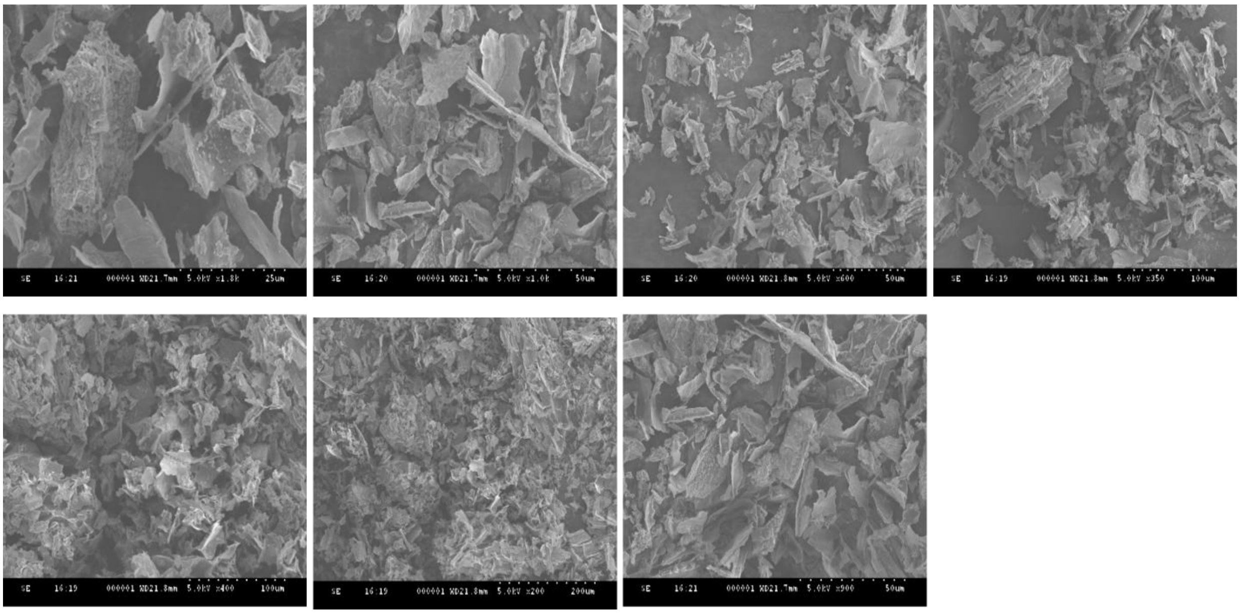
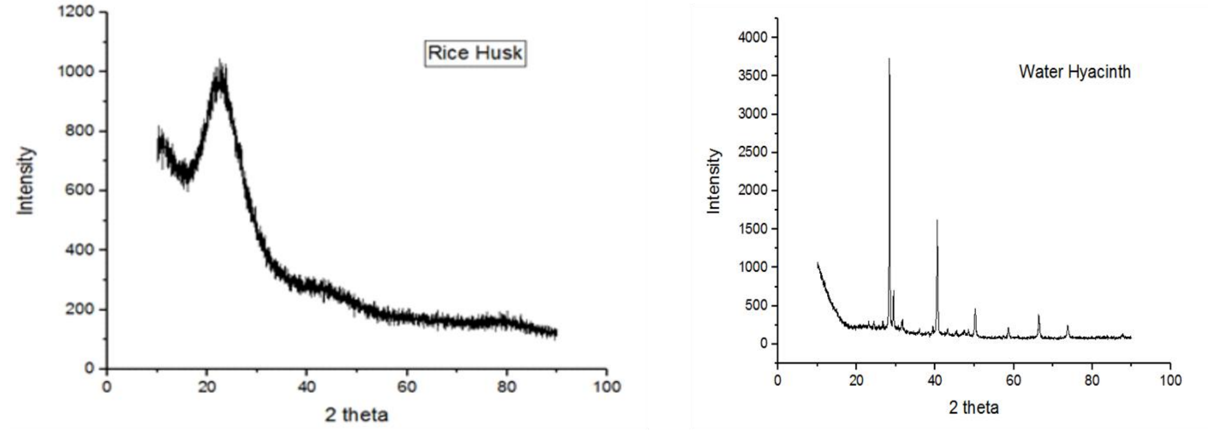


Figure 4. SEM micrographs of water hyacinth biochar showing irregular, porous, coarse, and granulated surface morphology at different magnifications

SEM findings have validated that both the biochars contain porous structures; nevertheless, the rice husk biochar seems to be more fibrous, whereas water hyacinth biochar has an irregular and granulated structure.

3.4 XRD Analysis

XRD patterns of biochar obtained from rice husk and water hyacinth were studied to assess their structural nature. In the case of rice husk biochar, three broad peaks around 10-15°, 20-30°, and 40-50°, where the peak around 20° was very dominant, indicated an amorphous nature (Figure 5a). On the other hand, water hyacinth biochar demonstrated multiple sharp peaks at various angles, indicating that it was comprised of crystalline phases (Figure 5b).



a

b

Figure 5. XRD patterns of (a) rice husk biochar and (b) water hyacinth biochar showing amorphous and crystalline characteristics

The broad peak seen in rice husk biochar means there is some disorder in the carbon, meaning that the surface irregularity is greater. On the other hand, the sharp peaks in water hyacinth biochar show that the carbon is more crystalline in nature. This implies that rice husk biochar has some amorphous properties, whereas water hyacinth biochar has crystalline and amorphous properties.

3.5 FTIR Analysis

Peaks at 2925, 1651, 1564, 1302, 879, and 618 cm^{-1} in the rice husk biochar's FTIR spectra indicated C-H stretching, C=C stretching, aromatic C=O stretching, and O-H stretching (Figure 6a). The FTIR spectrum of water hyacinth biochar showed peaks at 1590, 1501, 1301, 1122, 615, and 415 cm^{-1}, which corresponded to COO^- asymmetric stretching, carboxylic group/N-H bending, C=O stretching, carbonates, and O-H stretching, respectively (Figure 6b).

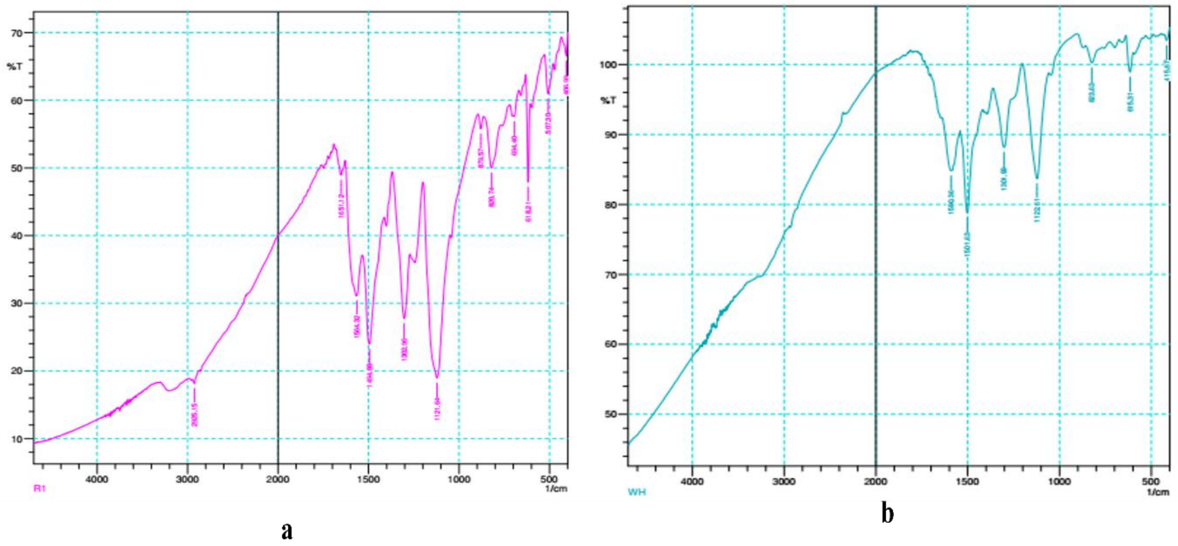


Figure 6. FTIR spectra of (a) rice husk biochar and (b) water hyacinth biochar showing major functional groups

The presence of oxygen functional groups in the biochars involved in the adsorption process was revealed by FTIR spectra process through mechanisms including electrostatic interaction and complexation.

3.6 Effect of Adsorbent Dosage on Cr (VI) Removal

The adsorbent dosage effect was studied at pH 3, 30°C, 150 rpm, contact time of 6 h for Cr (VI) removal. Due to the increased surface area and active sites, the removal efficiency rose as the adsorbent dose increased (Figure 7). Rice husk biochar was more effective in removing Cr (VI) than water hyacinth biochar. Rice husk biochar exhibited 88.4% Cr (VI) removal at 5% adsorbent and water hyacinth biochar showed 41% at 15% dosage of adsorbent.

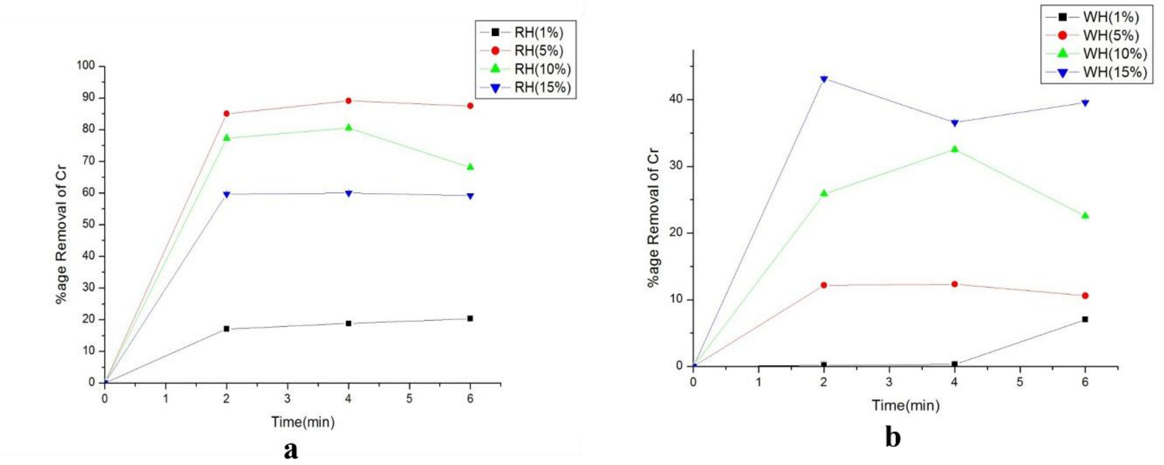
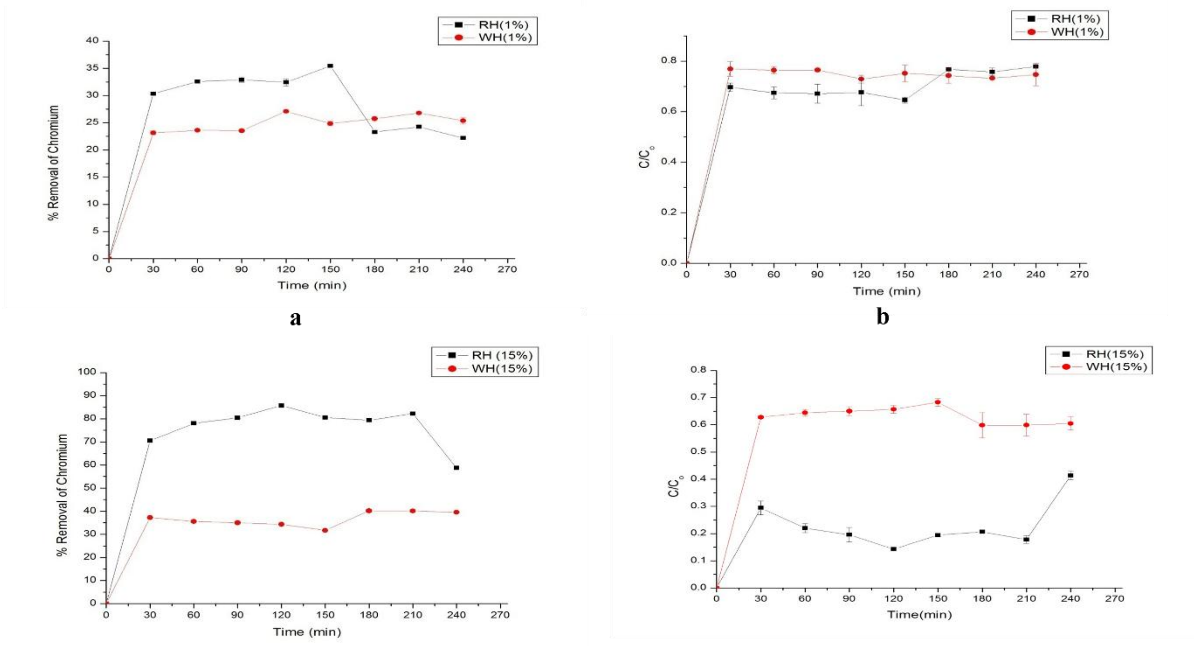


Figure 7. Effect of dosage of adsorbent on Cr (VI) removal using (a) rice husk biochar and (b) water hyacinth biochar

The optimal removal efficiencies were found at 5 g rice husk biochar and 7.5 g water hyacinth biochar. The better removal with rice husk biochar could be explained by having more appropriate surface groups and sites for chromium sorption.

3.7 Contact Time effect on Cr (VI) Removal

The influence of contact time on the removal of Cr (VI) was investigated at pH 3, 30°C and 150 rpm using a 12ppm initial Cr (VI) concentration with rice husk biochar (RH) and water hyacinth biochar (WH). The rate of Cr removal was high at first but then slowed and approached equilibrium (Figure 8a, 8c). The efficiency of removal of rice husk biochar was greater than that of water hyacinth biochar at 1% and 15% dosages. The faster removal in the beginning was because the initial sites were available, while the latter lower rate was due to the saturation of sites.



a b

c d

Figure 8. Contact time effect on Cr (VI) removal using rice husk biochar (RH) and water hyacinth biochar (WH): (a) percentage removal at 1% dosage, (b) breakthrough curve (C/C_0) at 1% dosage, (c) percentage removal at 15% dosage, and (d) breakthrough curve (C/C_0) at 15% dosage

The breakthrough curves (Figure 8b and 8d) show the variation of the concentration (C/C_0) with time. The rise in C/C_0 is due to the capacity of the adsorption sites. When the dosage increased (15%), the lower C/C_0 value for rice husk biochar indicates higher adsorption capacity than water hyacinth biochar.

4. Discussion

In this research, the adsorption capacity of biochar of rice husk and water hyacinth biochar was tested for the removal of Cr (VI) from water. The biochars showed ability of adsorption, with rice husk biochar being more efficient. These characteristics are related to differences in surface structure and morphology, and functional groups, which are crucial for adsorption processes. The SEM study showed that biochar of rice husk had a fibrous and porous structure, which allows for a higher surface area and accessibility of active sites for adsorption. By contrast, water hyacinth biochar had a more granular and inhomogeneous structure which may have compromised its adsorption capacity due to poor accessibility to active sites. Such findings have been reported where the adsorption efficiency of unmodified water hyacinth was found to be less than that of modified water hyacinth, highlighting the need for structural modification (Bapat & Jaspal, 2020). Additionally, the effectiveness of water hyacinth biomass is also dependent on the processing techniques as structural differences affect the adsorption capacity (Feng et al., 2017).

XRD analysis exposed that rice husk biochar was mainly amorphous whereas water hyacinth biochar showed a more crystalline structure. The amorphous structure is expected to have higher adsorption capacity due to more surface heterogeneities and active sites (Amir et al., 2025). This observation is supported by research that demonstrates improved biochar production for better adsorption performance by increasing surface irregularities and functional group availability (Amir et al., 2025). The functional groups identified by FTIR analysis, such as hydroxyl, carbonyl, and carboxyl groups, in both biochars also play a role in adsorption via electrostatic attraction and complexation. The adsorption studies demonstrated that Cr (VI) removal efficiency was influenced by the amount of the adsorbent used. This is because more binding sites are available for adsorption. But, after a certain point, the removal efficiency did not increase considerably because the active sites became saturated. A similar trend has been observed with biochar prepared from water hyacinth, where adsorption efficiency increased with increasing adsorbent dosage, but eventually plateaued due to a lack of active binding sites (Mulyatun, 2020). Furthermore, both raw and carbonized *Eichhornia crassipes* have exhibited adsorption capability, but with different efficiencies based on surface properties and carbonization process (Lima & Asencios, 2021).

The contact time results exposed that the process of adsorption was fast initially and eventually reached equilibrium. This initial fast process can be accredited to the high availability of active sites, with a slower process due to site saturation. A similar trend in the adsorption process has been reported for modified water hyacinth biochars, where surface properties were enhanced to increase adsorption efficiency (Mohanadevi & Dhanabalan, 2024). The improved presentation of rice husk biochar can be related to its structure, containing silica and carbon that improve metal ions binding. Earlier research has shown that rice husk-based materials are suitable for contaminant removal, owing to their structural and chemical characteristics, particularly in wastewater treatment (Sa'at et al., 2025). On the other side, while water hyacinth biochar has potential, it may need functionalization to enhance its performance. Recent studies suggest water hyacinth biochar has potential in advanced applications such as nano-enabled and biofertilizer materials, suggesting its performance can be improved by functionalization (Irewale et al., 2024).

Eichhornia crassipes is known to be a sustainable biomass feedstock with high growth rate and pollutant removal capacity. Biochar production from water hyacinth presents an effective way of waste management and green technology. Research has demonstrated the feasibility of using water hyacinth biomass for various purposes, such as soil conditioning and water treatment, highlighting its potential applications (Canning, 2025). Likewise, biochars from aquatic weeds have been shown to remove pollutants, including dyes and metals, depending on the methods used and the surface characteristics of the biochar (Viswanathan et al., 2024). Biochar properties are determined by pyrolysis. Pyrolysis of water hyacinth biomass has been reported to yield products that can be used for environmental and energy purposes, such as pollutant removal (Tran et al., 2021). In addition, biochar obtained from *Eichhornia crassipes* has been used for the removal of toxic metals, demonstrating the potential for biochar as a biosorbent (Li et al., 2018). Preparation conditions (temperature and residence time) can be optimised to improve the adsorption capacity of the biochar as shown in studies on metal removal using water hyacinth biochar (Zhou et al., 2019).

However, there are some limitations of the study. The study was performed in a controlled laboratory environment, using synthetic solutions, which may not be entirely representative of wastewater. Furthermore, only batch adsorption experiments were carried out, not continuous flow systems. The impact of co-existing ions, pH levels and biochar stability were also not thoroughly investigated. Studies should also be directed towards enhancing the adsorption properties of the two biochars through chemical and/or physical modifications. Real wastewater studies, column tests, and regeneration studies are needed to evaluate the feasibility of using these biochars. Also, the application of biochars for the removal of other heavy metals and pollutants can provide a greater potential in wastewater treatment.

5. Conclusion

The rice husk biochar and water hyacinth biochar are used as a cheap adsorbent for the removal of Cr (VI) from water, which was investigated in this study. The biochars were successfully produced by pyrolysis at 600°C and analysed using physical, chemical and instrumental methods. The findings displayed that the adsorption process was reliant on various parameters including the amount of adsorbent, contact time, the surface features and structure of biochar. Rice husk biochar was found to be a better adsorbent than water hyacinth biochar. This higher efficiency could be due to its fibrous and porous structure, amorphous structure, and the presence of carbon and silica, which can potentially serve as active sites for Cr (VI) ions. On the other hand, the water hyacinth biochar, while also porous, exhibited reduced adsorption efficiency, which may be attributed to its crystalline structure and alkalinity. The adsorption kinetics demonstrated initial fast uptake and equilibrium phases, suggesting good binding of Cr (VI) ions with biochar. In conclusion, the results suggest that rice husk biochar is a better and more eco-friendly adsorbent for chromium ions efficient removal, whereas water hyacinth biochar also has the potential to be modified for this purpose. This finding suggests that waste-derived biochar can be used as an environmentally safe option for wastewater treatment.

References

1. Abd Aziz, M. A., Hairunnaja, M. A., Bashari, N. A. F., & Isa, K. M. (2025). Recent advances in processed water Hyacinth (*Eichhornia crassipes*) for the removal of organic contaminants from water. *Controlling Environmental Pollution: Practical Solutions*, 269-283.
2. Amir, F., Cheng, Y. S., Tseng, S. C., & Kalam, M. A. (2025). Optimized production and functionalization of water hyacinth-derived biochar for biocatalysis and dye adsorption. *Process Safety and Environmental Protection*, *201*, 107519.
3. Bapat, S. A., & Jaspal, D. K. (2020). Surface-modified water hyacinth (*Eichhornia crassipes*) over activated carbon for wastewater treatment: a comparative account. *South African Journal of Chemistry*, *73*, 70-80.
4. Canning, A. (2025). A review on harnessing the invasive water hyacinth (*Eichhornia crassipes*) for use as an agricultural soil amendment. *Land*, *14*(5), 1116.
5. Doan, V. D., Tran, T. K. N., Nguyen, A. T., Tran, V. A., Nguyen, T. D., & Le, V. T. (2021). Comparative study on adsorption of cationic and anionic dyes by nanomagnetite supported on biochar derived from *Eichhornia crassipes* and Phragmites australis stems. *Environmental nanotechnology, monitoring & management*, *16*, 100569.
6. Elbehiry, F., Darweesh, M., Al-Anany, F. S., Khalifa, A. M., Almashad, A. A., El-Ramady, H., ... & Elbasiouny, H. (2022). Using biochar and nanobiochar of water hyacinth and black tea waste in metals removal from aqueous solutions. *Sustainability*, *14*(16), 10118.
7. Emenike, E. C., Adeleke, J. A., Iwuozor, K. O., Egbemhenghe, A., Bello-Hassan, M. T., Adu, A. O., ... & Adeniyi, A. G. (2025). Application of rice husks-based biochar for removal of pollutants from water and wastewater. *Separation & Purification Reviews*, 1-22.
8. Farzana, N., Masud, R. B., Himadry, T. R., & Islam, M. S. (2026). *Eichhornia crassipes*-derived biochar via slow pyrolysis for the removal of Reactive Yellow 176 dye from aqueous media: adsorption isotherm, kinetic and thermodynamic studies. *RSC Sustainability*.
9. Feng, W., Xiao, K., Zhou, W., Zhu, D., Zhou, Y., Yuan, Y., ... & Zhao, J. (2017). Analysis of utilization technologies for *Eichhornia crassipes* biomass harvested after restoration of wastewater. *Bioresource technology*, *223*, 287-295.
10. Flafel, H. M., Rafatullah, M., Lalung, J., Kapoor, R. T., Siddiqui, M. R., & Qutob, M. (2024). Enhancing the efficiency of phytoremediation using water hyacinth (*Eichhornia crassipes*) for 2, 4-dichlorophenoxyacetic acid removal with modified biochar as

an assisted agent. *Chemosphere*, *367*, 143591.

11. Irewale, A. T., Dimkpa, C. O., Elemike, E. E., & Oguzie, E. E. (2024). Water hyacinth: Prospects for biochar-based, nano-enabled biofertilizer development. *Heliyon*, *10*(17).
12. Kumari, K., Swain, A. A., Kumar, M., & Bauddh, K. (2021). Utilization of *Eichhornia crassipes* biomass for production of biochar and its feasibility in agroecosystems: a review. *Environmental Sustainability*, *4*(2), 285-297.
13. Li, Q., Tang, L., Hu, J., Jiang, M., Shi, X., Zhang, T., ... & Pan, X. (2018). Removal of toxic metals from aqueous solution by biochars derived from long-root *Eichhornia crassipes*. *Royal Society open science*, *5*(10).
14. Lima, H. D. P., & Asencios, Y. J. (2021). *Eichhornia crassipes* (Mart.) Solms (natural or carbonized) as biosorbent to remove pollutants in water. *SN Applied Sciences*, *3*(8), 750.
15. Mishra, S., & Maiti, A. (2017). The efficiency of *Eichhornia crassipes* in the removal of organic and inorganic pollutants from wastewater: a review. *Environmental science and pollution research*, *24*(9), 7921-7937.
16. Mohanadevi, M., & Dhanabalan, K. (2024). Enhanced Chromium removal from water using ball milled nano-biochar derived from *Eichhornia crassipes* (Water hyacinth).
17. Mulyatun. (2020, May). Synthesis of *Eichhornia crassipes* biochar: sustainable efficient adsorbent for reducing Cr (VI) metal ion. In *Journal of Physics: Conference Series* (Vol. 1539, No. 1, p. 012003). IOP Publishing.
18. Najmudeen, T. M., Febna, M. A. A., Rojith, G., & Zacharia, P. U. (2019). Characterisation of biochar from water hyacinth *Eichhornia crassipes* and the effects of biochar on the growth of fish and paddy in integrated culture systems. *Journal of Coastal Research*, *86*(SI), 225-234.
19. Negi, D., Bhadury, P., & Daverey, A. (2025). Comparative study of Acorus calamus and Cyperus alternifolius in rice husk biochar integrated constructed wetland systems for nitrogen removal. *Applied Water Science*, *15*(11), 274.
20. Okoya, A. A., Adegbaju, O. S., Akinola, O. E., Akinyele, A. B., & Amuda, O. S. (2020). Comparative assessment of the efficiency of rice husk biochar and conventional water treatment method to remove chlorpyrifos from pesticide polluted water. *Current Journal of Applied Science and Technology*, *39*(2), 1-11.
21. Sa'at, S. K. M., Jalil, N. A., & Jamailudin, M. S. (2025). Effect of Rice Husk and Rice Husk Ash in Phytoremediation of Livestock Effluent by Scirpus grossus. *Advanced and Sustainable Technologies (ASET)*, *4*(2), 421-428.
22. Tran, T. K., Kim, N., Leu, H. J., Pham, M. P., Luong, N. A., & Vo, H. K. (2021). The production of hydrogen gas from modified water hyacinth (*Eichhornia crassipes*) biomass through pyrolysis process. *International Journal of Hydrogen Energy*, *46*(27), 13976-13984.
23. Ullah, M. H., & Rahman, M. J. (2024). Adsorptive removal of toxic heavy metals from wastewater using water hyacinth and its biochar: A review. *Heliyon*, *10*(17).
24. Viswanathan, S. P., Njazhakunnathu, G. V., Neelamury, S. P., Padmakumar, B., & Ambatt, T. P. (2024). The efficiency of aquatic weed–derived biochar in enhanced removal of cationic dyes from aqueous medium. *Biomass Conversion and Biorefinery*, *14*(12), 12895-12910.
25. Zhou, R., Zhang, M., Zhou, J., & Wang, J. (2019). Optimization of biochar preparation from the stem of *Eichhornia crassipes* using response surface methodology on adsorption of Cd2+. *Scientific Reports*, *9*(1), 17538.