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Comparison of Efficiency of Incinerated Biomedical Ash and Biochar as Adsorbent in Removal of Chromium (VI)

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ABSTRACT

Removal of heavy metals from wastewater is a challenging task. Tanneries play very important role in the economic growth of our country. However, they also discharge wastewater containing Cr (VI) which poses environmental hazards to the receiving water bodies. Though, many methods are available for the removal of heavy metals, adsorption is a widely used method. Conventionally, activated carbon is used as an adsorbent for treating Metal-ion contaminated wastewater due to its high efficacy rate but the problem with the usage of activated carbon is limited due to its high cost and difficulty in regeneration. A study has been carried out to determine the feasibility of biochar from garden litter and ash from biomedical wastes to remove chromium ions. The maximum removal of Cr(VI) was found to be 64.71% while using biochar and 77.45% while using Incinerated Biomedical Ash at a metal concentration 10 ppm with a contact time of 60 minutes. The R^2 value from the regression analysis for both the adsorbents showed a good fit between the experimental results and the model predictions.

Key words: *Biochar, Biomedical waste ash, Cr(VI)*

Introduction

Fresh potable water resources are important for all living organisms on earth. Increase in world population growth, droughts and developing industries has reduced the availability of the clean water. The annual global demand for water is increasing every year but the pollution has compromised potential water sources. In the developing countries, the impact of increased pollution is high increasing the inability for people to have consistent access to a clean drinking water which increases their likelihood to serious diseases. The pollution can be classified as biological particles, organic and inorganic. This study focuses on inorganic group of pollutants containing heavy metal ions.

The growth of industry and human activities like pesticides, batteries, metal rinse processes, plating and electroplating industry, metal smelting and paper manufacturing has increases the presence of heavy metals in wastewater which worsens the crisis for need for water (Kumar *et al.*, 2019). Industrial effluents contain a considerable heavy metal concentration in its effluent such as Nickel, Cadmium, Copper, Zinc, Mercury, Arsenic and Chromium. Heavy metal easily enters the human body by means of food chain because of it is easily absorbed in the vegetables and fishes. The nature of heavy metal

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ions is non-biodegradable it gets accumulated in an organ and causes serious threat to human health (Park *et al.*, 2012). Therefore, the removal of metal ions has to be done before discharging the treated effluent into the receiving waters because they are carcinogenic in nature and toxic substances should not be directly discharged in to the environment.

Numerous past studies in developing countries have investigated the prevalence of heavy metals in drinking water sources and reported their quantities, type, human exposure and removal methods (Rahman *et al.*, 2009; Chakrabarty *et al.*, 2011, Chowdhury *et al.*, 2016; Lydia *et al.*, 2023). The health effect due to this heavy metals are also studied by many researchers (Jaishankar *et al.*, 2014; Colak *et al.*, 2015; Bai *et al.*, 2016; Briffa *et al.*, 2020). Significant amount of research has been carried out on methods of removing heavy metals from, industrial wastewater, drinking water sources and other sources of water (Lesley *et al.*, 2019). Most of the research articles focus on the technologies and methods that will have high removal efficiency of heavy metals such as microbial remediation (Li and Tao, 2015), activated carbon adsorption (Ronan *et al.*, 2019; Walker *et al.*, 2000), carbon nanotechnology (Al *et al.*, 2018; Fahad *et al.*, 2021), membrane filtration (Abdullah *et al.*, 2019; Elorm *et al.*, 2020) and various other methods (Ahmady *et al.*, 2008, Aastha *et al.*, 2023). In the developing countries these methods are not cost effective. Technologies used in developing countries should be easily obtained and operating and maintenance cost must be low (Lesley *et al.*, 2019).

Many researchers have used different low cost materials for the removal of heavy metal like residuals from peanuts shells (Ahmad *et al.*, 2017), steel wool and Mg pellets (Yuen-Hua *et al.*, 2003), Rice husk (Jabbar *et al.*, 2016), Sugar beet pulp (Pehlivan *et al.*, 2006), Fly ash (Hala *et al.*, 2013), Dairy manure compost (Zhang *et al.*, 2011) ect. In the present study, two low cost adsorbents namely biomedical incinerated ash and biochar from garden litter were investigated for their efficacy rate and suitability in the removal of Cr(VI) ions.

Materials and Methods

Adsorbent - Biochar

Biochar is an environmental friendly and low cost alternative adsorbent for the removal of heavy metals from the waste water. Biochar is prepared by heating the biomass under absence of oxygen or low oxygen. Different approaches have been studied for efficient removal of heavy metals using biochar as adsorbent such as microbial biomass, shoot and root of *Plumbago zeylanica*, agricultural by products like peanuts shell, soya bean hulls, cotton seed hulls, sunflower husks,sugarcane bagasse, and walnut hulls (Arpita *et al.*, 2021). In this study, garden litter was collected, and the litter were subjected to pyrolysis to convert it to Char form. The pyrolysis method involves heating the sample in a closed oven and in the absence of oxygen at high temperature of 800 °C.

Adsorbent - Biomedical Incinerated Ash

The ash was collected from a biomedical waste processing unit. The Ash was subjected to microbial analysis to check for the presence of bacterial and fungi colonies by Pour plate method. The colonies of bacteria and fungi were TLTC (too low to count) which makes the biomedical incinerated ash safer to use.

Preparation of Stock solution for Cr(VI)

Stock solution of Cr(VI) was prepared by dissolving 2.82 g of potassium dichromate in 100ml of double distilled water to get a concentration of 1000ppm. The stock solution was further distilled to get a desired concentration of Cr(VI) solution.

Characterization of Adsorbents

The Morphology of the adsorbents, the surface area and the elements present in the adsorbents were studied by SEM and EDAX analysis.

SEM Analysis

Scanning Electron Microscopy uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The SEM analysis is done to determine the morphology, texture and size of the specimen. The specimens were observed in low vacuum in environmental SEM at a wide range of cryogenic or elevated temperatures with specialized instruments. The SEM images were captured at different microns. The Micrographs from SEM analysis shows that there is large number of pores both in activated carbon from biochar from garden litter and biomedical incinerated ash. The adsorbents are proved to be porous in the SEM analysis. The SEM images of the adsorbents at various wavelengths for biochar from garden litter and biomedical incinerated as hare shown in Fig. 1 and 2 respectively.

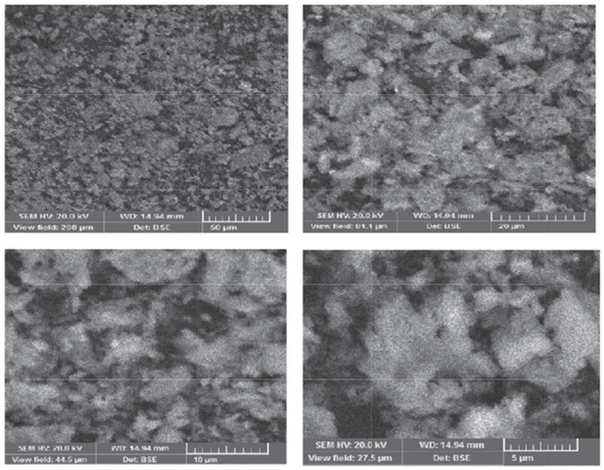

Fig. 1. SEM image of the Biochar at 5 μm, 10 μm, 20 μm, 50 μm.

EDX Analysis

Energy-dispersive X-ray spectroscopy (EDX) analysis was used to determine the chemical constituents of the adsorbents. An adsorbent is said to be as an ideal adsorbent if it contains carbon and oxygen as trace elements and nitrogen content should be totally nil (Daniel *et al*., 2017). The EDX analysis of Biochar and Incinerated Biomedical Ash indicates the peaks for carbon and oxygen. The EDX analysis also shows absence of nitrogen in both the adsorbents. The EDAX graph of the adsorbents are shown in Fig. 3 and 4.

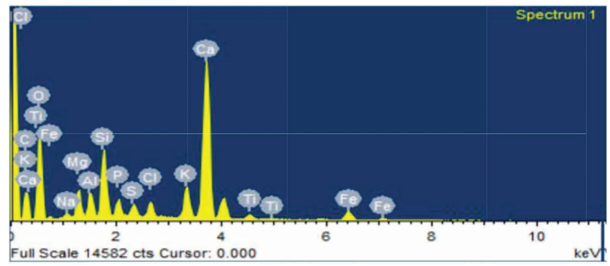

Fig. 3. EDX graph of Biochar

Adsorption Studies

The batch adsorption study was carried in 250 ml borosilconical flask by mixing a pre-weighed amount of the adsorbent (1g) with 100 ml of synthetically prepared Cr(VI) aqueous solution of various concentrations (10-50 ppm). The conical flasks were kept on a mechanical shaker for a time interval of 10- 60 minutes at a constant speed of 130 rpm. The conical flasks were taken out of the mechanical shaker for every 10 minutes and the optical density of the solution was observed by a UV-vis Spectrophotometer at a wavelength of 540 nm. The mass

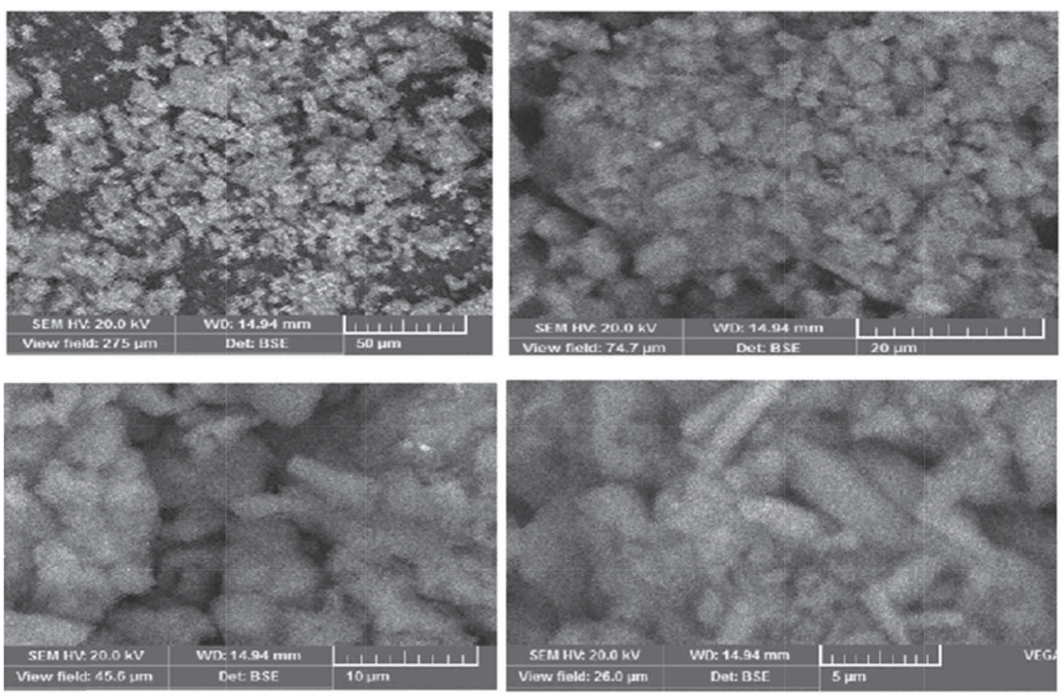

Fig. 2. SEM image of the Incinerated Biomedical Ash at 5 μm, 10 μm, 20 μm, 50 μm.

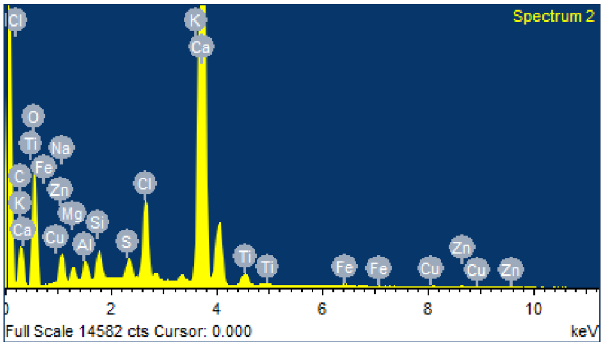

Fig. 4. EDX graph of Incinerated Biomedical Ash

balance of the adsorption was calculated by the quantity of solute adsorbed onto the solid. The removal percentage and adsorption capacity (q_e)is estimated using the following equation.

Removal Percentage = $(C_i - C_e) \times 100 / C_i$

Adsorption capacity (q_e) $=(C_i - C_e) \times V / m$

where, C_i and C_e are initial and final metal ion concentrations of the solution, V is the volume of the solution in litre and m is the weight of dry adsorbent in gram.

Results and Discussion

Effect of Adsorbent dose

The adsorbent dose of the adsorbent plays a major role in the evaluation of the adsorption properties of the adsorbent. The removal efficiency of adsorption increases up to 1g/100ml and attains equilibrium condition after that. This condition was observed for both the adsorbents. The increase in the percentage of the removal with the increase in the dosage of adsorbent is mainly due to the increase in the number of available adsorption sites for metal ions. The adsorption reaches the equilibrium condition after certain point owing to the presences of more number of adsorbent particles which leads to overcrowding and overlapping of adsorption sites. A removal of 77 % and 64 % were recorded for incinerated biomedical ash and biochar respectively at a dosage of 1g/ 100 ml each. The removal percentage is shown in Fig. 5. From the results obtained the optimum dosage of adsorbent for the removal of chromium is concluded as 1g/100ml for both the adsorbents.

Effect of Initial concentration and adsorption isotherm model

The effect of initial metal concentration on chromium removal was studied by batch adsorption experiments which were carried out for different initial metal ion concentrations from 10 ppm to 50 ppm. Fig.6. shows the effect of initial concentration of incinerated biomedical ash and biochar respectively. The result shows that the increase in initial metal ion concentration has decreased the percentage removal. This is mainly because of the decrease in the adsorption sites on the adsorption surface of the adsorbent. The maximum removal of Cr(VI) was found to be 64.71% while using biochar and 77.45% while using incinerated biomedical ashat a metal concentration 10 ppm.

Effect of Contact Time

Adsorption time is an important parameter that affect the adsorption process. In this study, the effect of time of contact of the adsorbent and adsorbate was studied by varying the contact time and was found that the adsorption process increased with increased time. The Cr(VI) removal efficiency while using biochar increased from 26% to 64.71% when the contact time was increased from 10 min to 60 min. Similarly, the Cr(VI) removal efficiency while using incinerated biomedical ash increased from 19.11% to77.45% when the contact time was increased from 10 min to 60 min. The maximum removal for both the adsorbents were recorded at 60

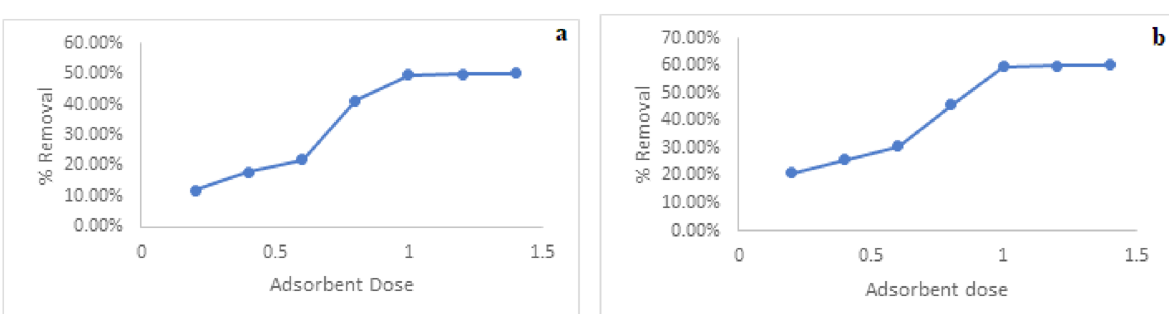

Fig. 5. Effect of Adsorbent dose for a) Incinerated Biomedical Ash b) Biochar

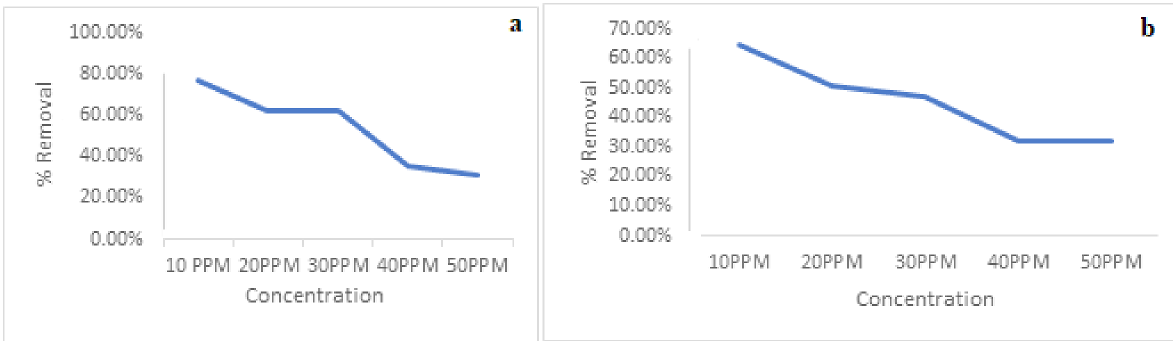

Fig. 6. Effect of Initial concentration of a) Incinerated Biomedical Ash b) Biochar

minutes after 60 minutes the rate of adsorption became more or less constant and reached equilibrium. The optimum time was fixed at 60 minutes. Fig. 7. shows the effect of contact time of incinerated biomedical ash and biochar.

Adsorption isotherm

There are many methods to model the experimental data of adsorption isotherm. The values obtained in the isotherm study helps to understand the interaction between the adsorbent and adsorbate. Langmuir Isotherm method has been used widely to describe equilibrium for practical application. The Langmuir isotherm is derived by assuming that the phenomena occurs at a homogeneous site and holds a monolayer molecule.

The Langmuir isotherm is obtained by the equation 1

$$1/(q_e) = 1 / q_m + 1/ K_a . q_m C_o \quad .. (1)$$

Where, q_e is the amount of Cr(VI) adsorbed per weight of adsorbent, C_e is the equilibrium concentrate of adsorbate, K_a is the rate of adsorption, q_m is the maximum adsorption capacity to form a monolayer.

The Langmuir isotherm is expressed in a dimensionless factor R_L in equation 2.

$$R_L = 1/ (1+ K_a .C_o) \quad .. (2)$$

Where, C_o is the Initial concentration, R_L is the separation factor. The applicability of the Isotherm depends upon the value of R_L. If $R_L > 1$, then the adsorption process is applicable and the existing conditions are favourable. If $R_L<1$, then the adsorption process cannot be applied and the conditions are unfavourable.

The plot of C_e/Q_e resulted in a linear relation indicating the applicability of the Langmuir equation for the removal of Cr(VI) using incinerated biomedical ash and biochar. The correlation coefficients were high for both the biochar ($R^2 = 0.983$) and incinerated biomedical ash (R2 = 0.9558), which suggest that the Cr(VI) ions on the absorbent is monolayer coverage. The R_L value which is lesser than 1, proved that the process fits the Isotherm model and can be used for practical applications. Fig. 8 shows the langmuir plot for adsorption of cr(vi) by incinerated biomedical ash and biochar.

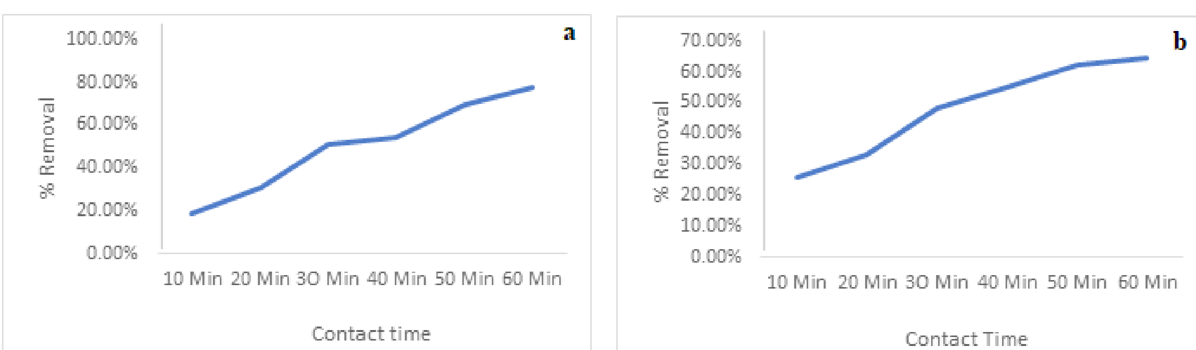

Fig. 7. Effect of contact time of a) Incinerated Biomedical Ash b) Biochar

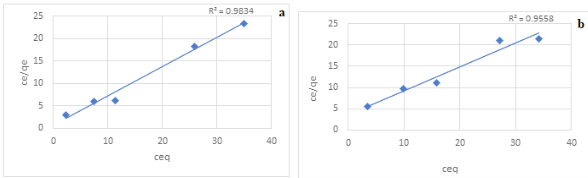

Fig. 8. Langmuir plot for adsorption of Cr(VI) by a) Incinerated Biomedical Ashb) Biochar

Conclusion

Increased scarcity of water and pollution has led to lack of drinking water in the developing countries. Among the water pollution, heavy metal contamination is a growing concern because of its effects on human health and ecosystem. There are various methods to remove the heavy metal but are not cost effective so significant amount of investigation is carried out by researchers to find cost effective method. This study is aimed at promoting low cost and sustainable adsorbents namely Incinerated biomedical ash and Biochar from garden litter to remove Cr(VI) ions from aqueous solution. The adsorbents were characterized using SEM and EDAX analysis. The adsorbents were effective in the removal of Cr(VI). The influence of parameters like adsorbent dosage, initial concentration, contact time on the percentage of removal were studied using batch method. The dosage was fixed at 1g/100 ml for both the adsorbents since equilibrium condition was attained beyond 1g/100ml. The percentage removal attained equilibrium at 60 minutes and the optimum time for adsorption is 60 minutes for both the adsorbents. The maximum removal percentage was 77.45% and 64.71% for incinerated biomedical ash and biochar respectively. The R^2 value from the regression analysis for both the adsorbents showed a good fit between the experimental results and the model predictions.

Conflict of Interest

The authors declare no conflict of interest.

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