How to Cite:
Jasim, A. M., & Alzurfi, S. K. L. (2022). Compared cadmium adsorption from biochar and magnetite biochar in water. *International Journal of Health Sciences*, *6*(S5), 11603–11621.
https://doi.org/10.53730/ijhs.v6nS5.11998

Compared cadmium adsorption from biochar and magnetite biochar in water

Ali Mohammed Jasim
Department of Ecology and Pollution, Faculty of Science, University of Kufa, Iraq

Sadiq Kadhum Lafta Alzurfi
Department of Ecology and Pollution, Faculty of Science, University of Kufa, Iraq
Email: sadiqk.alzurfi@uokufa.edu.iq

Abstract---Water safety is a prerequisite for sustainable global quantitative and qualitative development. Heavy metal pollution has become a major problem in our environment, where traditional heavy metal processing techniques were unsuccessful and expensive. In this study, biochar and magnetite biochar have been used as an efficient, low-cost, safe, and environmentally friendly method for heavy metal removal such as cadmium. The biochar has been prepared from palm fronds and then activated by sodium hydroxide before treatment with two concentrations (5 ppm and 10 ppm) of cadmium in the water. The biochar (BC) had a positive effect on improving the efficiency of removing cadmium (II). The percentage to remove cadmium was 98% when we added 0.5 g of biochar to the solution. On the other hand, we have prepared composite materials by mixing biochar with magnetite at the mole ratio of (2:1) to prepare magnetite-biochar (MBC). A property was added to the biochar prepared by adding Fe_3O_4 to the biochar, which led to the activation of the effective aggregates with a significant improvement in the adsorption performance of heavy metals while increasing the removal efficiency up to 100%. This explains the high adsorption performance of MBC. FTIR, EDX, and XRD analysis were used to distinguish BC and MBC treated with cadmium. These analytical results revealed that biochar contains effective groups of hydroxyl groups that can adsorb heavy metals. As for the magnetite biochar analysis, the results revealed that the compound contains magnetite in addition to the carbonyl, hydroxyl, and carboxylic groups. Analytical results showed that the BC used to treat the cadmium (II) contained cadmium ion among the remaining components after treatment. The results clearly showed that the use of biochar was effective in removing cadmium, thus reducing the risk of their occurrence and eliminating them in an easy, inexpensive, and environmentally friendly way.

Manuscript submitted: 9 April 2022, Manuscript revised: 18 June 2022, Accepted for publication: 27 July 2022

***Keyword*---**Biochar (BC), EDX, Magnetite-biochar (MBC), Palm, XRD.

Introduction

Water pollution by heavy metals and its purification technologies has been a global concern for decades. Most heavy metals are known not only to damage the environment but also to cause toxic effects on human health (Kim and Lee, 2017). Polluted water in the environment contains a large number of organic and inorganic pollutants as a result of the continuous discharge of pollutants such as heavy metals, surfactants, agricultural pesticides, industrial waste, and others (Zulfiqar et al., 2019). Most of these pollutants are closely related to the elements of the environment that they contain after release. Inorganic contaminants are removed via coagulation, flocculation, absorption, membrane filtration (Cevallos-Mendoza *et al.,* 2022), reverse osmosis (Rezakazemi *et al.*,2018), chemical precipitation, ion exchange (Clifford et al.,2011), electrochemical treatment, solvent extraction. (Vunain et al., 2019). One of the most serious pollutants to be cared for and treated is chemical pollutants such as heavy metals. Heavy metals are naturally occurring metals with elemental densities greater than 5 gm/cm^3 and atomic numbers greater than 20 (Ali and Khan, 2018).Rapid industrialization and unplanned urbanization have introduced heavy metals into the environment through improper dumping of industrial waste directly on land and into water bodies (Dixit et al., 2015). Heavy metals in the environment have become a big problem because of this (Hashem et al., 2017). Many traditional techniques are applied in different regions of the world to remove water pollutants (Vunain et al., 2019). One of the elements that increases the anxiety of researchers is cadmium, which is considered one of the water-polluting elements, which is an essential concern because of its movement and toxicity at relatively low concentrations. The main sources of the environmental disk are the main focus due to its transmission and toxicity with relatively low concentrations. The main sources of the environmental disk are humans, including agricultural sources such as chemical fertilizers and pesticides, as well as industrial and mining sources (Manzoor et al., 2019; Rizwan et al., 2018). Researchers have recently become increasingly interested in biochar as a result of its improved ability to absorb minerals and natural toxins when used in contaminant processing (Guillossou et al., 2019). Biochar is a carbon-rich solid created by high-temperature pyrolysis of biomass in the absence of oxygen (Lehmann et al., 2006 Hadi and Aljanaby, 2022). Biochar's ability to remove organic and inorganic contaminants from water is determined by its physical and chemical features such as initial composition, pore size, surface area, cation/anion exchange, etc. (Kaetzl et al., 2020). Therefore, this study was aimed at producing biochar from palm fronds and assessing its efficiency in cadmium removal from water.

Material and methods

Material

The palm fronds were collected from a palm plantation in Najaf, Iraq. It was cleaned, sieved, and processed for the creation of biochar after collection. Other chemicals were bought from Sigma-Aldrich, sodium hydroxide, hydrochloride acid, cadmium sulfate, ferrous sulfate, ferric chloride, and ethanol. Without any further treatment, the compounds were used as received (Medhat and Aljanaby, 2022)

Methods

The manufacture of biochar (BC) and magnetite biochar (MBC) were the two processes that made up the preparation process for the composite magnetite biochar-based adsorbent (Figure 1). To make biochar, raw palm fronds were initially pyrolyzed using various input variables, including pyrolysis temperature, heating time, and impregnation ratio (raw palm/NaOH:1.5M). After that, magnet materials were added to the resulting biochar to create a composite magnetite biochar. After the biochar and magnetite biochar were characterized, they were used in the Cd(II) adsorption process.

Biochar preparation

The palm fronds underwent a 24-hour drying process in an oven set at 105 C ° after being continually rinsed with distilled water to eliminate contaminants and dust from their surface. By running the dried sample through the appropriate sieves, the mesh size was reduced to the necessary 0.5 mm (Vibratory Sieve Shaker AS 200 Digit cA Model). After that, it was kept at room temperature in an airtight container until used it. Slow pyrolysis was used to create biochar from palm fronds. The preparation parameters were preoptimized in a tube furnace at a pyrolysis temperature of 550 °C, a reaction period of 180 min, and an impregnation ratio of 1:1 with 500 ml of sodium hydroxide (1.5M) (Saeed et al.,2021).

Magnetite Biochar Preparation

The co-precipitation method was used to prepare magnetite iron oxide (AL-Kazazz *et al.*,2016). MNPs 4O3Fe as follows:
Magnetite biochar was created by combining magnetite nanoparticles with Fe_3O_4 nanoparticles. It was precipitated using techniques utilizing ferric chloride ($FeCl_3.6H_2O$) and ferrous sulfate ($FeSO_4$), whose mole ratio is (2:1), respectively.

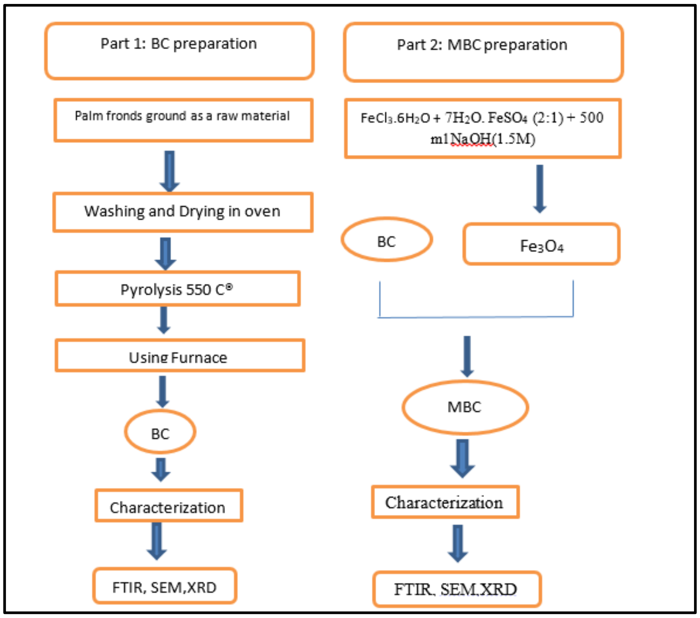


Figure 1: The steps to prepare active biochar (BC) and composite magnetite biochar (MBC)

Preparation of modified (magnetite) biochar

The produced Fe_3O_4 was then combined with palm charcoal by adding 5 gm MBC and 10 gm BC to 750 mL of deionized water over the course of two hours. Following multiple rounds of washing with ethanol and then distilled water, the magnetite biochar is dried in a 24-hour period at a temperature of 45°C (Baltrėnaitė ,*et al*., 2017).

Adsorption Study:

In order to make a 1000 mg/L Cd (II) stock solution, 1.8 g of cadmium sulfate were dissolved in deionized water. For batch experiments, the stock solution was then diluted to various concentrations (5, 10 ppm). To get the optimum adsorption performance, the solution underwent various treatments. Batch adsorption tests were carried out by adding biochar to a cadmium aqueous solution in an Erlenmeyer flask. The dose of the adsorbent (0.1 and 0.5) gm and the duration of the adsorbent were (15, 30 and 60) minutes. Syringe filters and Sartorius filter paper (0.45) µm were used to filter the material, and atomic absorption spectrometry was used to determine the absorbance (AAS, 210 VGP, USA). The removal ratio (R %) and adsorption capacity of magnetite biochar were determined using Equation 1.

$$R\% = \frac{(Ci-Cf)}{Ci} \times 100 \text{ ....(1)}$$

Statically Analysis

One-way an ANOVA was used to evaluate all the data. To demonstrate the statistical difference, a probability threshold of 5% (P 0.05) was chosen. Utilizing SPSS 26.0(IBM, Chicago, IL, USA)

Results and Discussion

Removal ratio

The first step of this study included the analysis of the capability of biochar to remove metal ions from the solutions with two initial concentrations of cadmium ion. Sorption capability is calculated using the formula (1) and expressed as a percentage of Cd(II) removal from the solution. In all analyzed cases, the removal (%) of Cd(II) (5 ppm) from the solution was higher than 97, where the recorded higher ratio was (99.55) in 0.1 g of BC at 30 min. and the lower ratio was (97.6) in 0.5 g of BC at 60 min. The tests of between-subject effects are non-significant between weight P 0.05 = 0.052 and time = 0.889. In addition, that, we used the concentration 10 ppm of Cd (II), the removal ratio (%) was higher than 92, where the recorded higher ratio was (93.4) in 0.1 g of BC at 30 min. and the lower ratio was (92.1) in 0.1 g of BC at 15 min. (Fig.2). The tests of between-subject effects are non-significant between weight P 0.05 = 0.37 and time = 0.57. Fig.3 shows the removal ratio of cadmium metal by MBC in a 5 ppm concentration where the higher ratio (%) was (99.78) in 0.5 g of MBC at 30 min. and the lower ratio was (99.2) in 0.1 g of MBC at 15 min. P 0.05 = 0.013 was found to be significant between weights and P 0.05 = 0.14 was found to be non-significant between times.

While in concentration, 10 ppm of cadmium metal was removed, the removal ratio (%) was higher than 97, where the recorded higher ratio was (99.4) in 0.5 g of MBC at 60 min. and the lower ratio was (97.8) in 0.1 g of MBC at 15 min.(Fig.4). The tests of between-subject effects were significant between weights P 0.05 = 0.00 and non-significant between times = 0.063.

It was noted through the results that appeared after using biochar in treating aqueous solutions contaminated with Cd (II) that biochar has the ability to adsorb Cd (II) from their aqueous solutions, which agrees with results of (Wu et al., 2019) that showed that biochar derived from walnut trees (W-Biochar), wild cherry trees (C-Biochar), and bamboo (B-Biochar) had the greatest adsorption capacity.

The results showed a decrease in Cd (II) concentrations from a concentration of (5) mg/L to (0.02) mg/L within (30) minutes at a constant temperature of (25-30) degrees Celsius. because of the availability of the surface area and the presence of active groups that help to bind cadmium ions on the surface of the absorbent material (Mall, et al., 2005). while the lowest adsorption rate of Cd (II) was (0.6) mg/liter at a concentration of (5) mg/liter of Cd (II) when weighing (0.5) g of activated biochar at a time of (60) minutes. which causes agglomeration of the micro-components of the absorbents, thus reducing the distance between the micro-components of the absorbent materials, which prevents the increase in efficiency (Putra et al., 2009).

In order to improve the adsorption efficiency and to obtain positive results and to note the differences in the adsorption efficiency, we added Fe_3O_4 prepared in the laboratory to biochar to remove heavy metals using cadmium from the standard aqueous solution to obtain a compound that can be controlled by a magnetite field. because the first is difficult to assemble and easy to pass through the filter paper. In addition to electrostatic adsorption, which is the main way magnetite biochar removes heavy metals, interactions with functional groups and ion exchange between heavy metals and adsorbents also help (Bagbi et al., 2016; Giraldo et al., 2013).

Thus, when we add magnetization to the activated biochar prepared for treatment, we notice an increase in the removal rates and a noticeable improvement in the results, as shown in Figure (2), for cadmium (II), where the highest adsorption of cadmium was recorded, where its concentration after treatment was (0.01) mg. because of the increase in the surface area of the sorbent material, the improvement of the absorbing surface of the material, and the abundance of sites for the active groups to polarize cadmium ions (Giraldo, *et al.*, 2013). Finally, it was observed that the adsorption process decreases when increasing the concentrations and weights used for treatment, whether for biochar or magnetite biochar for cadmium, due to the nature of the competition of cadmium ions for binding sites on the surface of the adsorbent material with the small area of the components of biochar and magnetite biochar. While the lower concentration provides a driving force that can overcome all the resistances that are transferred to the solutes between the solid (biochar) and liquid (aqueous solution) phases, As the driving force for mass transfer increases, the adsorption resistance (Cd) decreases (Putra *et al.,* 2009).

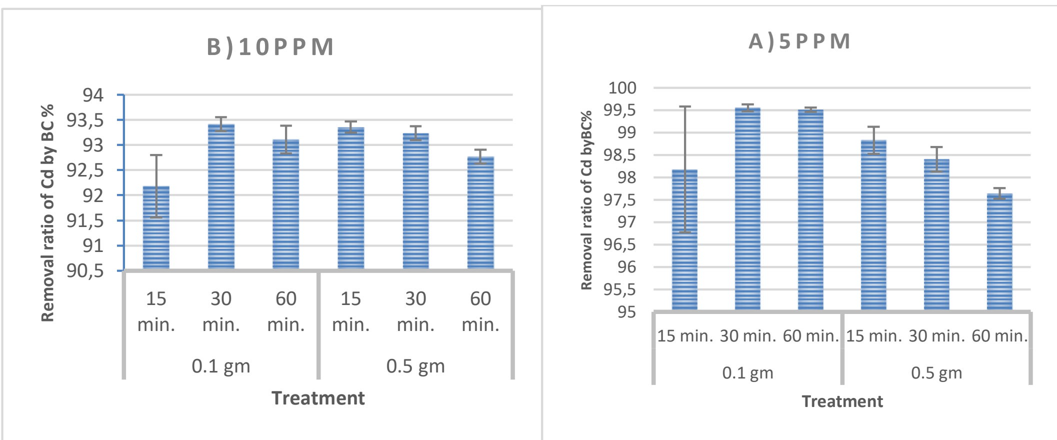


Figure 1: Removal ratio of Cd(II) A) 5 ppm B) 10 ppm by BC

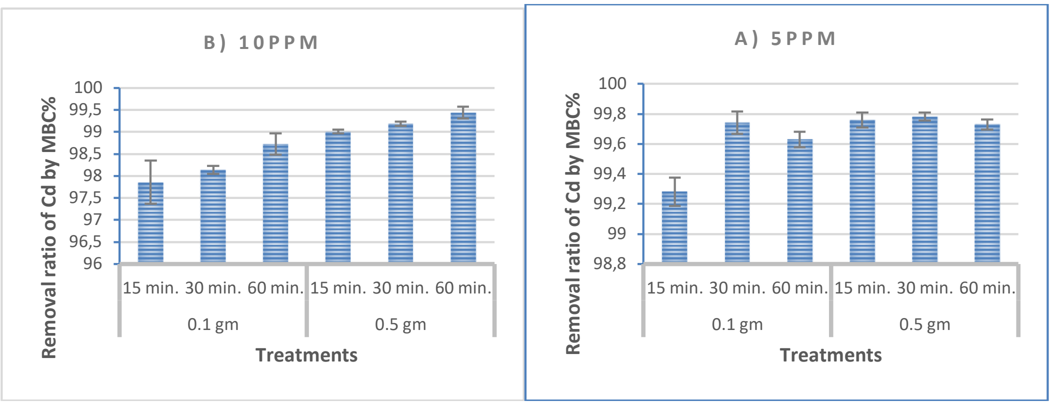


Figure 2: Removal ratio of Cd(II) A) 5 ppm B) 10 ppm by MBC

FTIR Spectra Analysis

FTIR examination of magnetite biochar (biochar with magnetite), which shows the appearance of the band (584 cm^{-1}) that belongs to the (Fe-O) band, and this indicates that the magnetite biochar contains iron due to the presence of Fe_3O_4 in its composition, with the appearance of other effective groups at the band (3410 and 3429 cm^{-1}) which belong to the (O-H) bond, and the reason for this is due to the activation of biochar with (NaOH) with the presence of iron oxide (magnetite) (Goodarzi *et al., 2004).* With the appearance of a bundle at (1095 cm^{-1}) that belongs to the (C = O) fascia (Trakal *et al.*, 2016). All figures show the presence of the (O-H) bond whose band is limited to (3412-3429 cm^{-1}) where the peak is kept at (13433 cm^{-1}) resulting from the expansion (O-H) resulting from the water in the sample or any other mineral derived from a group hydroxyl. Figure (7), which represents biochar after being treated with cadmium at a concentration of (5 ppm), shows the emergence of new bands compared to biochar before treatment, which is (744 and 766 cm^{-1}), which represents the (C-C) bond (Goodarzi *et al., 2004*), as well as the appearance of the band (1477 cm^{-1}), which represents an (O-H) bond, which indicates that cadmium has been associated with a (C-C) or (O-H) bond *(Goodarzi et al., 2004).* Note in Figure (8) that biochar represents after being treated with cadmium at a concentration (10 ppm), where the FTIR analysis shows in this figure the presence of a new absorption line for cadmium, which is the band (1735 cm^{-1}), which represents the bond (C=O) (Xu et al., *2006*). In addition to the presence of bundles (1379 cm^{-1}) that belong to the (C-O) joint (Denyes et al., 2014) and bundle (736 cm-1), which indicates the presence of the (C-H) joint (Chen *et al., 2011*). This indicates the participation of these groups in binding the cadmium element to the surface of the absorbent material, which leads to a decrease in the concentration ratio after the treatment process (Bai *et al.*, 2013).

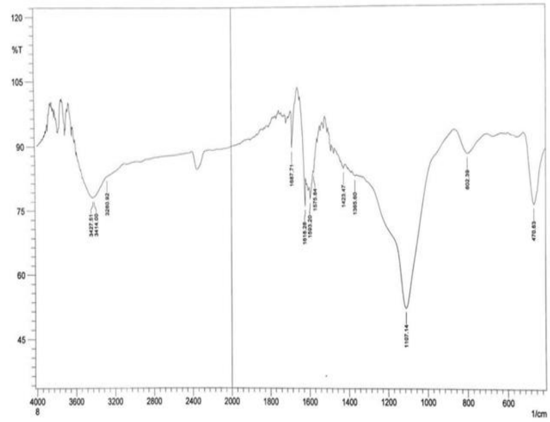


Figure 3:The (FT-IR) of biochar before activated

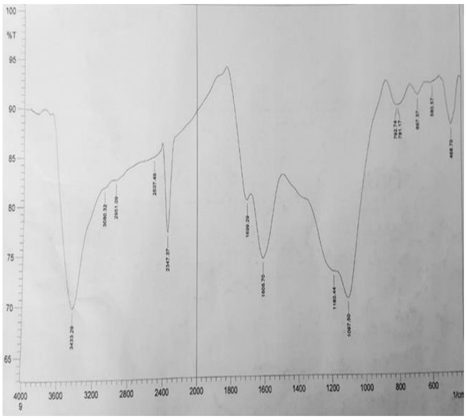


Figure 4:The FT-IR for activated biochar (BC)

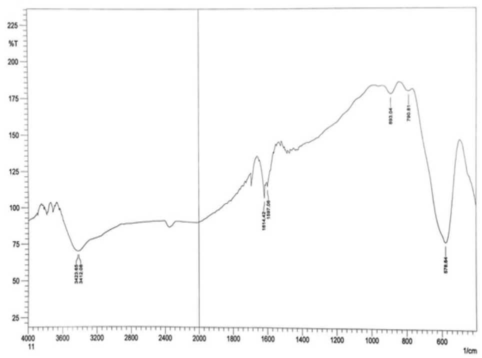


Figure 5: The FT-IR for iron oxide (Fe_3O_4) (magnetite)

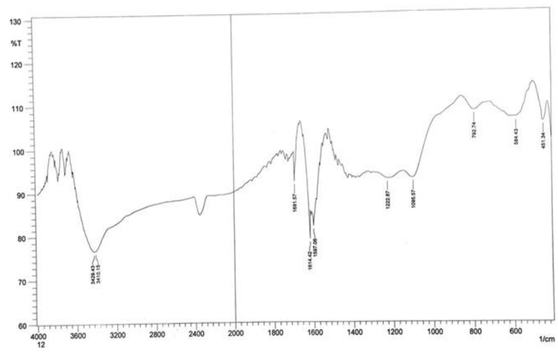


Figure 6: FT-IR magnetite biochar (MBC)

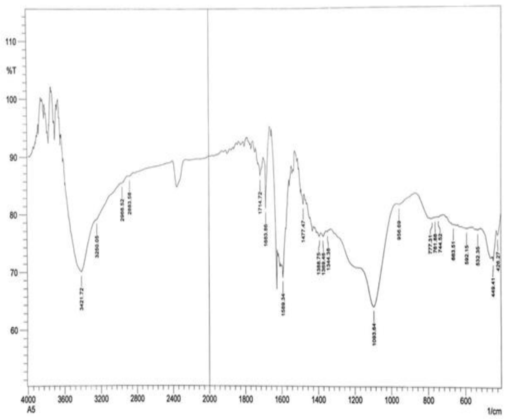


Figure 7: FT-IR for activated biochar treated with cadmium at a concentration of (5 ppm)

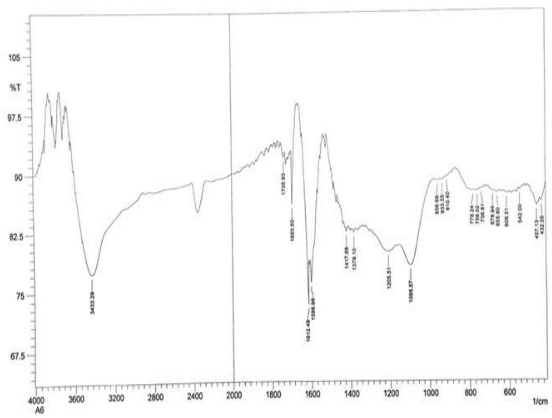


Figure 8: FT-IR for activated biochar treated with cadmium at a concentration of (10 ppm)

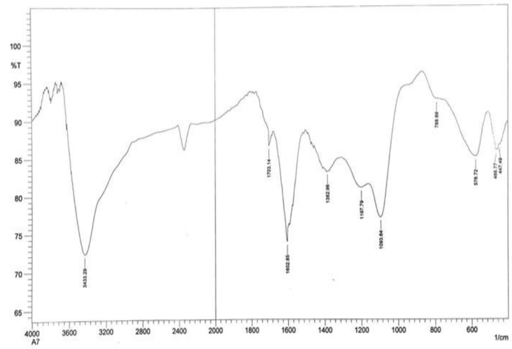


Figure 9: (FT-IR) magnetite biochar treated with cadmium at a concentration of (5 ppm)

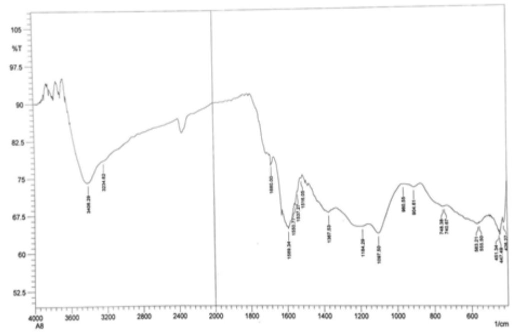
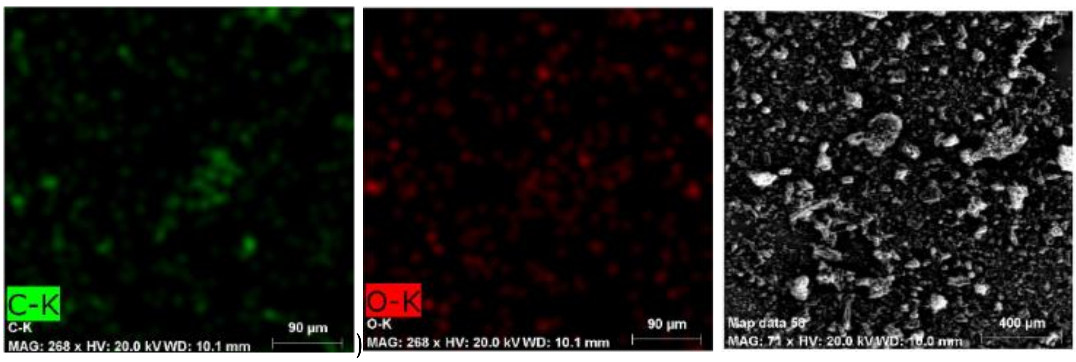


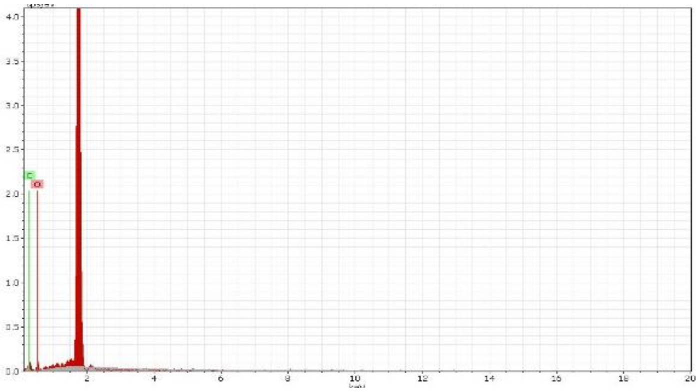
Figure 10: (FT-IR) magnetite biochar treated with cadmium at a concentration of (10 ppm)

SEM and EDX Spectra Analysis

EDX is used to identify the basic elements that make up the compound (there may be elements other than the materials that were used in the experiment and which are unwanted materials). EDX also determines the contents of each substance present in the compound, and through EDX it is possible to determine the homogeneity and its initial distribution in the compound's composition. The biochar was examined before and after activation resulting from palm fronds, and it was found that it is composed of basic elements such as carbon and oxygen, and this was shown by the (SEM) image that appears in figure (11,12) and the (EDX) analysis, which appears in Figure (13,14), where the red color indicates the presence of the element carbon and the green color indicates the presence of the element oxygen, where the analysis shows that the compound consists of two basic elements.

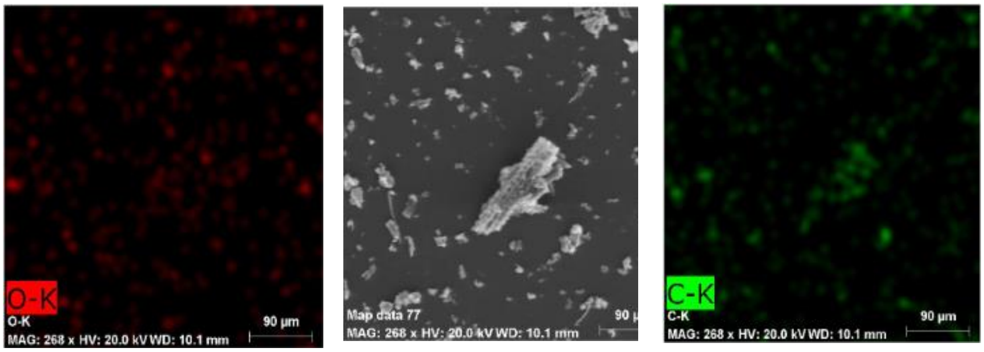


(A) (B) (C)

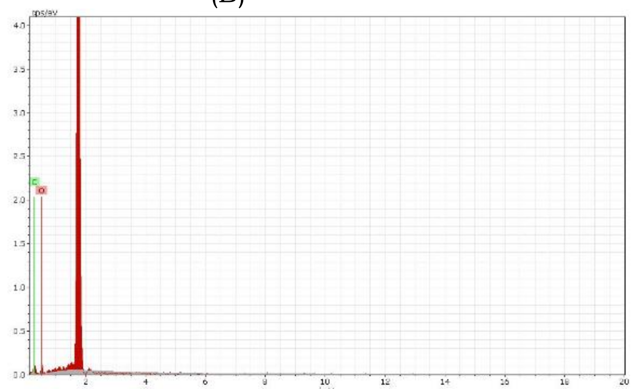


(D)

Figure 11: SEM (A) SEM biochar shows the oxygen element in green (B) Biochar shows the carbon element in red (C) (SEM) shows the composition of inactive biochar (D) EDX shows the elements from which inactive biochar is composed.

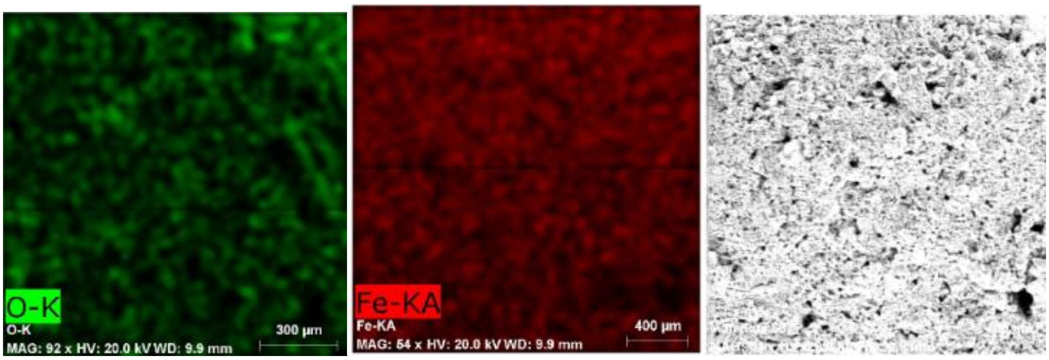


(A) (B) (C)

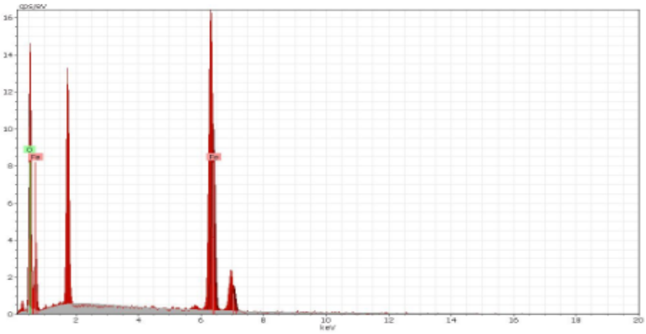


(D)

Figure 12: SEM (A) Biochar shows the carbon element in green (B) SEM biochar shows the oxygen element in red (C) (SEM) shows the composition of active biochar (D) EDX shows the elements from which biochar is activated composed.

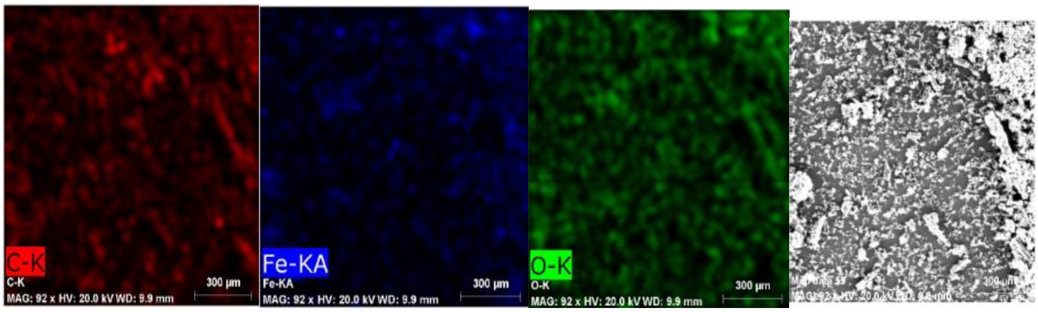


(A) (B) (C)

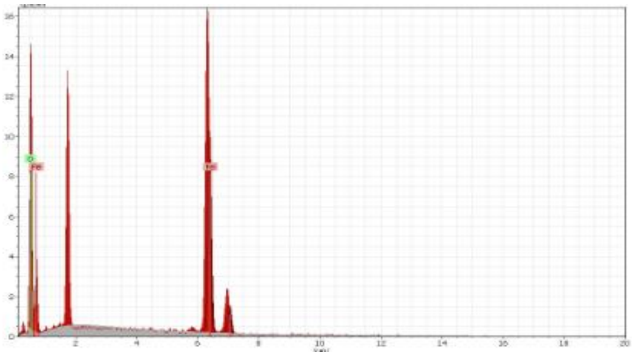


(D)

Figure 13: (A) SEM Iron oxide nanoparticles (magnetite) show iron in red (B) SEM Iron oxide nanoparticles (magnetite) show oxygen in green (C) SEM Iron oxide nanoparticles (magnetite) show magnetite compounds (D) EDX shows the Iron oxide nanoparticles (magnetite) composed.



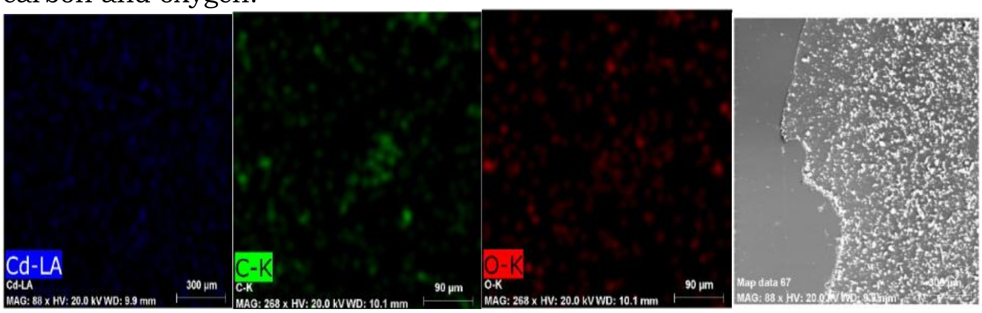
(A) (B) (C) (D)



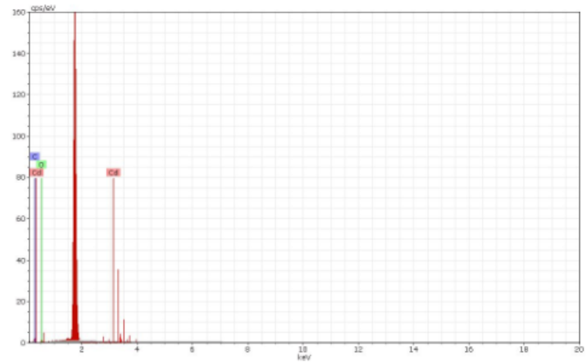
(E)

Figure 14: (A) SEM Magnetite biochar compound show carbon in red (B) Magnetite biochar compound show Iron in blue (C) Magnetite biochar compound show Oxygen in green (D) SEM Magnetite biochar compound show (Oxygen, carbon, iron) (E) EDX analysis shows the Magnetite biochar composed.

While Figure (15-16) shows SEM that shows the composition of the activated biochar elements, where cadmium appears along with carbon and oxygen, and the shows the (EDX) analysis of the activated biochar treated with cadmium, where the activated biochar was analyzed after the water treatment process containing cadmium in different concentrations (5, 10) ppm, where the figures show the presence of cadmium in the composition of activated biochar with carbon and oxygen.

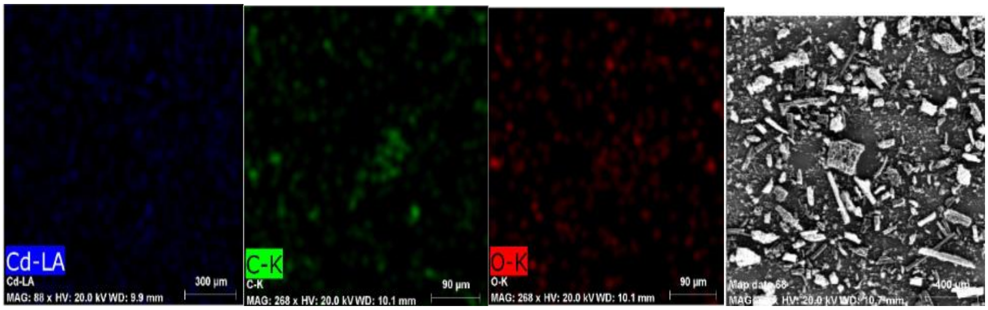


(A) (B) (C) (D)

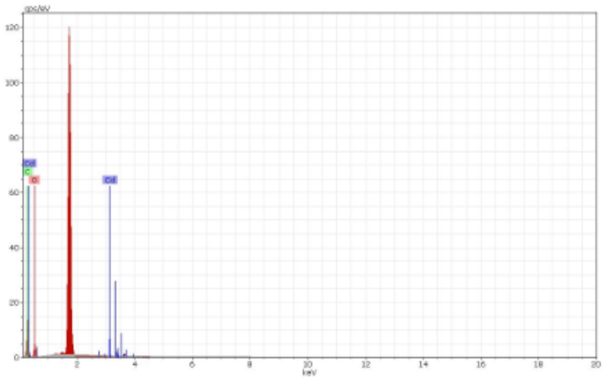


(E)

Figure 15: (A) shows the element cadmium in blue (B) shows the element carbon in green (C) shows the element oxygen in red (D) SEM of activated biochar treated with cadmium at (5ppm) (E) The (EDX) analysis of activated biochar treated with cadmium at (5 ppm).



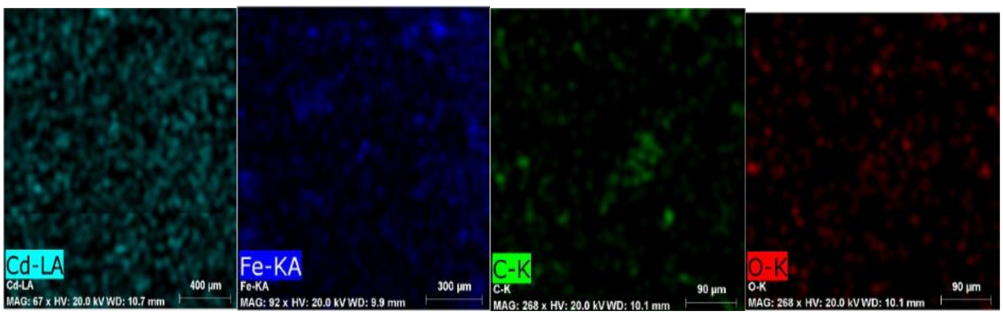
(A) (B) (C) (D)



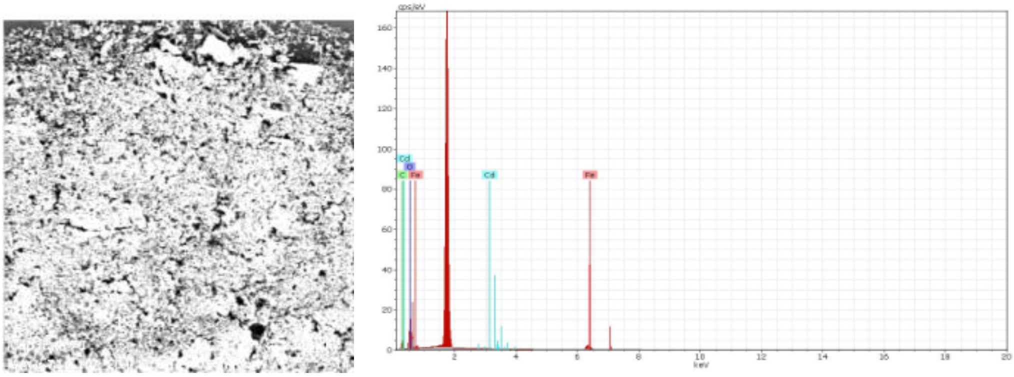
(E)

Figure 16: (A) shows the element cadmium in blue (B) shows the element carbon in green (C) shows the element oxygen in red (D) SEM of activated biochar treated with cadmium at a concentration of (10 ppm) (E) The (EDX) analysis of activated biochar treated with cadmium at a concentration of (10ppm).

While Figure (17 and 18) shows a (SEM) that shows the composition of the magnetite biochar elements, where cadmium appears along with iron, carbon, and oxygen. and shows the EDX analysis of magnetite biochar treated with cadmium, where the biochar was examined. The magnetite biochar produced after the water treatment process contained two concentrations of Cd(II) (5,10) ppm, where the figures show the presence of cadmium in the magnetite biochar composition with iron, carbon, and oxygen in the weight proportions of (0.07), (4.96), (66.79), and (28.18) respectively.

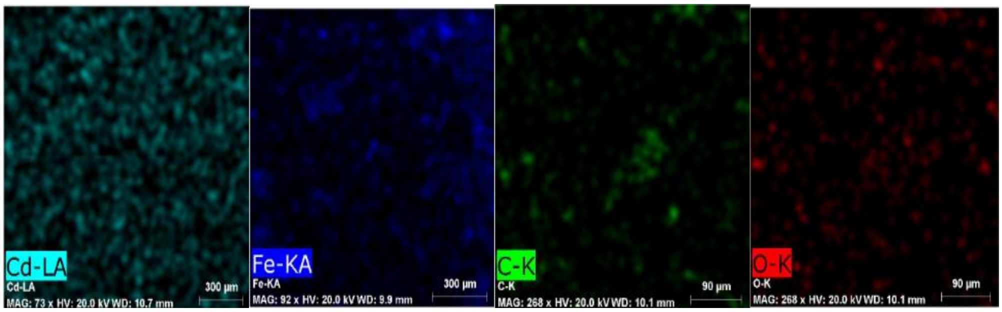


(A) (B) (C) (D)

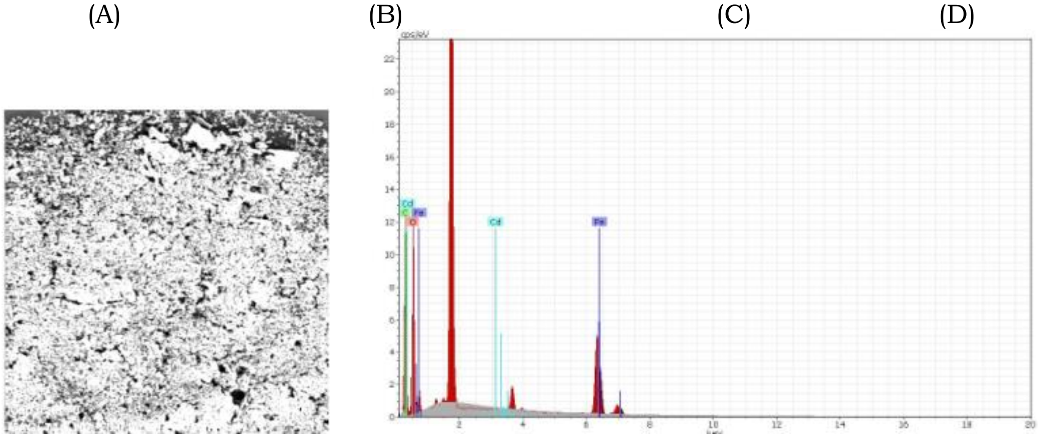


(E) (F)

Figure 17: (A) shows the element cadmium in blue (B) shows the element Iron in blue (C) shows the element carbon in green (D) shows the element oxygen in red (E) SEM of magnetite biochar treated with cadmium at a concentration of (5 ppm) (F) The (EDX) analysis of magnetite biochar treated with cadmium at a concentration of (5ppm)



(A) (B) (C) (D)



(E) (F)

Figure 18: (A) shows the element cadmium in blue (B) shows the element Iron in blue (C) shows the element carbon in green (D) shows the element oxygen in red (E) SEM of magnetite biochar treated with cadmium at a concentration of (10 ppm). (F) The (EDX) analysis of magnetite biochar treated with cadmium at a concentration of (10ppm)

XRD Spectra Analysis

The XRD analysis of biochar before and after the adsorption of cadmium shows that biochar is free of any compound containing cadmium (5 ppm), and in the figure (19), the red line of biochar after treatment (solids remaining from biochar) shows compounds containing cadmium, which confirms the absorption of cadmium by biochar derived from palm fronds, and the compounds that appear are represented by poor peaks (67.9°) due to the low concentrations used. While appearing at a concentration of (10) mg/liter, it is represented by (54.6°), (70.2°), and (29.54) (Figure 19: red line) (Wasna'a,2016). Whereas a large part of the uptake of cadmium by biochar derived from palm fronds followed the surface deposition mechanisms of the compounds (Singh et al., 2010; Liao et al., 2001; Abkari et al., 2016). The laboratory prepared nanoparticles of iron oxide (magnetite Fe_3O_4) nanoparticles were investigated using X-ray diffraction. which shows the XRD pattern of the final powder in Figure (21), where nanoparticles were investigated using X-ray diffraction. which shows the XRD pattern of the final powder in Figure (21), where XRD shows peaks corresponding to Fe_3O_4, marked by their indices (30°), (35.3°), (57°), and (62.6°). This is what was mentioned in previous studies for nanoparticles (Fe_3O_4). (Liao et al., 2001; Gong and Lin., 2003). In Figure (21, red line), the composition and components of magnetite biochar with cadmium 5 ppm for XRD analysis are shown. which shows the appearance of the laboratory-prepared Fe_3O_4 compound, and Cd in the poor peaks of it could be indexed at (54.4°), (68.73°), and Cd in the peak (30°). This indicates that Fe_3O_4prepared with the biochar matrix was well crystallized (Yan et al., 2015). We note in Figure (22) the presentation of the XRD patterns of the magnetite biochar sample used in the treatment of solutions contaminated with Cd (10 ppm) , through which several peaks of Fe_3O_4 can be seen, six peaks represented by (30°), (35.3°),(42.9°), (53.3),(56.99) ,and (62.5). The size of the nanoparticles of the compounds (Fe_3O_4) (Wasna'a, 2016; Liao et al., 2001).

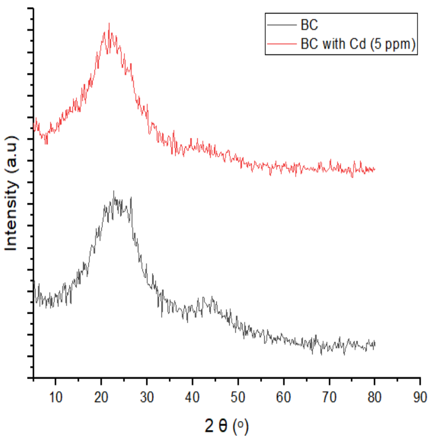


Figure19: XRD analysis of biochar treated with cadmium at 5ppm

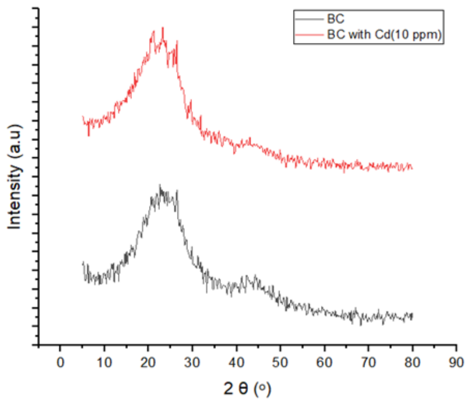


Figure 20: XRD analysis of biochar treated with cadmium at 10 ppm

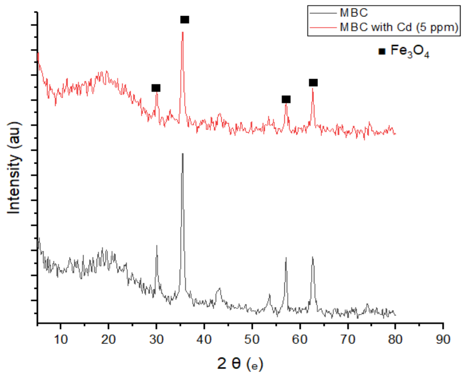


Figure21: (XRD) analysis of MBC treated with cadmium at 5ppm

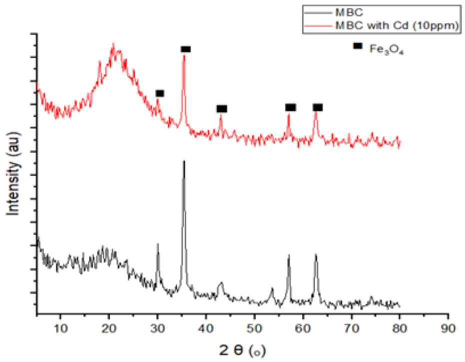


Figure 22: (XRD) analysis of MBC treated with cadmium at 10ppm

Conclusions

The removal efficiency is greatly influenced by the elemental concentration of the metal, the dose of the adsorbent, and the amount of the adsorbent. Due to a direct increase in the number of active adsorption sites accessible on the adsorbent surface, biochar was found to have a favorable impact on the removal efficiency of and the addition of magnetizing properties to biochar prepared by grafting improved the adsorption efficiency, with a removal efficiency of reaching 100%. The addition of the magnetizing property increased the number of active sites, expanded the surface area of absorption and provided an attractive material for metal ions, which explains the high absorption efficiency of magnetite biochar. Scanning electron microscopy (SEM) images of biochar (Palm fronds) showed a large difference in shape among samples, and the porous structures of both biochar and magnetite were nano scale. Due to the high porosity, the magnetite biochar has higher heavy metal removal. The FTIR spectra results showed the participation of carbonyl, carboxyl and hydroxyl groups in the palm fronds as the main binding sites for cationic ions on the surface of the adsorbent during the adsorption process.

Acknowledgments

We'd like to thank Dr. Ahmed Hussein in the Department of Chemistry in the College of Science at the University of Kufa for his wise comments. We'd also like to thank the Head of the Department of Environment and Pollution at the University of Kufa for making it easy to do experiments and use its labs.

References

Ali, H., Khan, E., (2018). What are heavy metals? Long-standing controversy over the scientific use of the term 'heavy metals'–proposal of acomprehensive definition. Toxicol. Environ. Chem. 100, 6–19.

AL-Kazazz, F.F., AL-Hakeim, H. k. and AL-Aobaid, H. K., (2016). "study the Interaction Between LH, FSH, and TSH with New synthesized Magnetite

Nanoparticles Coated with Dextran" Medical Journal of Babylon, Vol. 132, PP. 421-434.

Andayani, R. H. R., Luhpuri, D., Hakim, M. Z., & Fahrudin, A. (2022). Digital therapy in rehabilitation service for mental health patients during COVID-19 pandemic: Opportunity and challenges. International Journal of Health Sciences, 6(2), 1001–1012. https://doi.org/10.53730/ijhs.v6n2.9698

Bai H., Wang H., Sun J., Irfan M., Han M., Huang Y., Han X. Yang Q., (2013). Production, Production, purification and characterization of novel beta glucosidase from newly isolated Penicillium simplicissimum H-11 in submerged fermentation, Excli. J. 12, 528–540

Baltrėnaitė E, Baltrėnas P, Bhatnagar A, Vilppo T, Selenius M,Koistinen A, Dahl M, Penttinen O (2017) A multicomponent approach to using waste-derived biochar in biofiltration: a case study based on dissimilar types of waste. Int Biodeterior Biodegrad 119:565–57

Biasini, J. Ge, Y. Hu, M. Dong, C. Guo, W.p. Beyermann and Yin, Y.,(2007). "One-step synthesis of highly water-soluble magnetite colloidal nanocrystals" Chem, Eur. J., 13, 7153-7161.

Cai .W. and ,Wan.J.Q.,(2007). "Facile synthesis of superparamagnetite magnetite nanoparticles in liquid polyols" J. Colloid Interface Sci.,305.366-370.wih

Cevallos-Mendoza, J., Amorim, C. G., Rodríguez-Díaz, J. M., & Montenegro, M. D. C. B. (2022). Removal of Contaminants from Water by Membrane Filtration: A Review. *Membranes*, *12*(6), 570.

Chen B, Chen Z & LV S. (2011). A novel magnetite biochar efficiently sorbs organic pollutants and phosphate. Bioresour Technol 102: 716-723.

Clifford, D., Sorg, T. J., & Ghurye, G. L. (2011). Ion exchange and adsorption of inorganic contaminants. *Water Quality & Treatment: A Handbook on Drinking Water*, 12-1

DENYES M, PARISIEN MA, RUTTER A & ZEEB BA. (2014). Physical, chemical and biological characterization of six biochars produced for the remediation of contaminated sites. J Vis Exp e52183.

Dixit, R., Wasiullah Malaviya, D., Pandiyan, K., Singh, U.B., Sahu, A., Shukla, R., Singh, B.P., Rai, J.P., Sharma, P.K., Lade, H., Paul, D., (2015). Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes. Sustain 7, 2189–2212.

Gong, J.; Lin, X.(2003). Facilitated Electron Transfer of Hemoglobin embedded in Nano-sized Fe3O4 Matrix Based on Paraffin Impregnated Graphite Electrode and Electrochemical Catalysis For Trichloroacetic Acid. Microchem. J., 75, 51-57.

Goodarzi,A. Sahoo,Y. Swihart,M.T. and Prasad,Pn.N.,(2004). "Aqueous ferrofluid of citric acid coated magnetiten particles, Mater. Res. Soc. Symp. Proc.,789.129-134.

Gorda, A. A. N. O. S., & Anggreswari, N. P. Y. (2018). The implementation of participatory communication development: Bali Mandara program. International Journal of Social Sciences and Humanities, 2(2), 265–278. https://doi.org/10.29332/ijssh.v2n2.173

Guillossou, R., Le Roux, J., Mailler, R., Vulliet, E., Morlay, C., Nauleau, F., ... & Rocher, V. (2019). Organic micropollutants in a large wastewater treatment plant: what are the benefits of an advanced treatment by activated carbon adsorption in comparison to conventional treatment?. *Chemosphere*, *218*, 1050-1060

Hadi, H. I. & Aljanaby, A. A. J. (2022). Helicobacter Pylori-oncogenic protein cytotoxin-associated gene A and assessment of CD14 and CD163 in duodenal ulcer and gastric cancer patients. International Journal of Health Sciences, 6(S2), 839–851. https://doi.org/10.53730/ijhs.v6nS2.5134

Hashem, M.A., Nur-A-Tomal, M.S., Mondal, N.R., Rahman, M.A., (2017). Hair burning and liming in tanneries is a source of pollution by arsenic, lead,zinc, manganese and iron. Environ. Chem. Lett. 15, 501–506.

Kaetzl, K., Lübken, M., Nettmann, E., Krimmler, S., Wichern, M.,(2020). Slow sand filtration of raw wastewater using biochar as an alternative filtration media. Sci. Rep., 10, 1229.

Kim, H.T., Lee, T.G., (2017). A simultaneous stabilization and solidification of the top five most toxic heavy metals (Hg, Pb, As, Cr and Cd). Chemosphere 178, 479–485.

Lehmann, J., Gaunt, J., & Rondon, M. (2006). Bio-char sequestration in terrestrial ecosystems–a review. *Mitigation and adaptation strategies for global change*, *11*(2), 403-427

Liao, M. H., & Chen, D. H. (2001). Immobilization of yeast alcohol dehydrogenase on magnetite nanoparticles for improving its stability. *Biotechnology letters*, *23*(20), 1723-1727

Manzoor, M., Gul, I., Kallerhoff, J., & Arshad, M. (2019). Fungi-assisted phytoextraction of lead: Tolerance, plant growth—promoting activities and phytoavailability. Environmental Science and Pollution Research International, 26(23), 23788–23797.

Medhat, A. R., & Aljanaby, A. A. J. (2022). Assessment of some immune markers in typhoid-patients: A case control study . International Journal of Health Sciences, 6(S1), 4199–4210. https://doi.org/10.53730/ijhs.v6nS1.5592

Rezakazemi, M., Khajeh, A., & Mesbah, M. (2018). Membrane filtration of wastewater from gas and oil production. *Environmental Chemistry Letters*, *16*(2), 367-388.

Rizwan, M., Ali, S., Zia Ur Rehman, M., Rinklebe, J., Tsang, D. C. W., Bashir, A., Maqbool, A., Tack, F. M. G., & Ok, Y. S. (2018). Cadmium phytoremediation potential of Brassica crop species: A review. The Science of the Total Environment, 631-632, 1175–1191.

Saeed, A.; Harun, N.; Sufian, S.; Bilad, M.; Nufida, B.; Ismail, N.; Zakaria, Z.; Jagaba, A.; Ghaleb, A.; Al-Dhawi, B. (2021) .Modeling and Optimization of Biochar Based Adsorbent Derived from Kenaf Using Response Surface Methodology on Adsorption of Cd2+ . Water, 13, 999.

Son E., Poo K., Chang J., Chae K., (2018). Heavy metal removal from aqueous solutions using engineered magnetite biochars derived from waste marine macro-algal biomass. Sci Total Environ 615:161–168.

Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2022). Post-pandemic health and its sustainability: Educational situation. International Journal of Health Sciences, 6(1), i-v. https://doi.org/10.53730/ijhs.v6n1.5949

Trakal, L., Veselská, V., Šafařík, I., Vítková, M., Číhalová, S., & Komárek, M. (2016). Lead and cadmium sorption mechanisms on magnetiteally modified biochars. *Bioresource technology*, *203*, 318-324

Vunain, E., Masoamphambe, E., Mpeketula P., Monjerezi, M., Etale, A., (2019). Evaluation of coagulating e_ciency and water borne pathogens reduction capacity of Moringa oleifera seed powder for treatment of domestic wastewater from Zomba, Malawi. J. Environ. Chem. Eng., 7, 103–118.

Wasna'a, M. A. (2016). Synthesis and study the structure and optical properties of CdO polycrystalline thin film using electrochemical depositing method. *Int. J. Nano. Chem*, *2*(1), 21-25

Wu, J., Ren, D., Zhang, X., Chen, Z., Zhang, S., Li, S., & Fu, L. (2019). The adsorption properties of biochar derived from woody plants or bamboo for cadmium in aqueous solution. Desalin. Water Treat, 160, 268-275.

Xu F., Sun J., Sun R.; Fowler P., (2006). Baird, M.S. Comparative study of organosolv lignins from wheat straw. Ind. Crop. Prod.,23, 180–193.

Yan, L., Kong, L., Qu, Z., Li, L., & Shen, G. (2015). Magnetite biochar decorated with ZnS nanocrytals for Pb (II) removal. *ACS Sustainable Chemistry & Engineering*, *3*(1), 125-132.

Zulfiqar, M., Samsudin, M., Sufian, S., (2019). Modelling and optimization of photocatalytic degradation of phenol via Tio2 nanoparticles: An insight into response surface methodology and artificial neural network. J. Photoch. Photobio., 384, 112039.