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Cr(VI) ION REMOVAL FROM PLANTING WASTEWATER USING ACTIVATED CARBON FROM SHEA BUTTER HUSK

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Abstract

Cr(VI) ion was removed from plating wastewater using developed activated carbon made from shea butter husk. The effects of adsorbent dosage, contact time and pH on the adsorption of Cr(VI) ion from wastewater were investigated in batch adsorption studies. At optimal condition of 60min of contact time, adsorbent dosage of 1.2 g and pH 6 had the highest removal rate Cr(VI) ion from wastewater with removal rates of 82.50%, 89.39%, and 82.28% respectively. The adsorbent was characterized using SEM and XRD analyses. The SEM images revealed the porous structure of the adsorbent.

Keywords: Cr(VI) ion, activated carbon, shea butter husk, plating wastewater, SEM.

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Introduction

The most valuable natural resource on earth is water, in actuality. When a body of water is impacted by massive amounts of material, water pollution results. When it is not save for use for the intended purposes, water is regarded as polluted(Kılıç, 2021). Water becomes contaminated when minerals, organic compounds, inorganic pollutants or solid waste are introduced into the water(Owa, 2014).Discharges from industries, household, hospital, agricultural and human activities causes water pollution.

The presence of pollutant such as heavy metals in water has been rising with the expansion of industry and human activity, such as the plating and electroplating industry, batteries, pesticides, mining industry, rayon industry, metal rinse processes, tanning industry, fluidized bed bioreactors, textile industry, metal smelting, petrochemicals, paper manufacturing, and electrolysis applications(Briffa et al., 2020). When wastewater containing heavy metals is released into the environment, it poses a threat to human life due to their toxicity and mobility in the environment, as well as their persistence and concentration(Sim & Palet, 2022).

Zinc (Zn), copper (Cu), mercury (Hg), lead (Pb) nickel (Ni), cadmium (Cd), chromium (Cr), and arsenic (As) are the most often used heavy metals. Even though traces of these heavy metals can be found, they are still dangerous. Table 1 provides a summary of a few heavy metals, highlighting their main sources, medical implications, and legal limits in drinking water. The metals mentioned above, along with others like silver (Ag), iron (Fe), manganese (Mn), molybdenum (Mo), boron (B), calcium (Ca), antimony (Sb), cobalt (Co), etc., are frequently found in wastewater and must be eliminated(Qasem et al., 2021b).

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Table 1: Health implications of heavy metals

Common heavy metals found in wastewater and their origins, in addition to the health problems brought on by excessive levels and the authorized levels in drinking water by WHO and US EPA

Heavy metals	Main Sources	Organ and system affected	WHO (ppm)	US EPA(ppm)
Zn	Aerosol deodorants, rubber goods, some cosmetics and brass coating	Skin irritations, vomiting, stomach cramps, nausea, anemia, and convulsions.	5.0	5.0
Cu	Electronic/ cables industry and Corroded plumbing systems,	hematological system, gastrointestinal system, lungs, brain, cornea, kidneys, Liver and brain	1.5	1.3
Hg	Runoff from landfills and agriculture, electrical, appliances, electrolytic production of chlorine and caustic soda, Industrial and control	Liver, brain, kidneys, immunological system, lungs, cardiovascular system, endocrine, and reproductive system	0.001	0.002

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	instruments, laboratory apparatus, and refineries.			
Pb	rust inhibitors, lead-based batteries, ammunition, glazes, solder, alloys, cable sheathing pigments and plastic stabilizers.	Brain, bones, kidneys, liver, lungs, spleen, cardiovascular system, immunological system, hematological system, and reproductive system.	0.05	0.015
Ni	nickel alloy production and stainless steel	Gastrointestinal distress, lung, kidney, pulmonary fibrosis, and skin.		
Cd	Paints, plastic industries, batteries ,steel industry, metal refineries and corroded galvanized pipes.	Cardiovascular system, kidneys, liver, bones, lungs, testes, brain and immunological system, .	0.005	0.005
Cr(VI)Cr(III)	Mills and tanneries steel and pulp	Gastrointestinal system, brain, skin,	0.05	0.05

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		lungs, kidneys, liver, pancreas, tastes, and reproductive system		
As	Glass and electronics production	Metabolic system, cardiovascular system, kidneys, skin, lungs, brain, immunological system, and endocrine.	0.05	0.01

Due to the severity of the issues brought on by heavy metal pollution, a number of traditional treatment procedures have been developed to reduce heavy metals in wastewater before they are released into the environment. Conventional treatments such as membrane separation(Matsuura & Ethylenediamine, 2018), reverse osmosis(Bakalár et al., 2009), flocculation(Abdessemed et al., 2018), ion exchange(Hussain et al., 2021), oxidation-reduction(Sai Krishna et al., 2018), chemical precipitation(Correia et al., 2020) and electrocoagulation(Qasem et al., 2021a).

However, the aforementioned treatment methods come with some environmental and financial drawbacks, such as high costs, operational delays, ineffective pollution removal, production of secondary pollutants, complex technical treatment, reliance on oxidizing agents, and lengthy operational times(Abdullah et al., 2019).

However, in recent years, researchers have used a variety of agricultural waste items to produce activated carbon that is used to clean wastewater because of its low cost, effectiveness, easiness of use, great adaptability

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and reusability. Some of these waste products include walnut shell, rice husk, corn cob, pecan nutshell, mango seed coat, mustard husk, coconut shell, almond shell, acorn shell, sunflower, corn bract, peanut shell and orange peel(Khalil et al., 2013).

Shea butter husk, a cheap sustainable ingredient, was chosen for this investigation and used to make activated carbon for adsorption of Cr(VI).

The shea butter tree (Vitellaria paradoxa) is a natural tree species that can be found in several Sub-Saharan African nations. Shea butter trees are members of the Sapotaceae family and are primarily found in areas with annual rainfall between 400 and 1800 mm. Nigeria has a large number of shea butter trees, with an annual production of over 250 000 metric tonnes.(Esther et al., 2019)

Traditionally, Shea butter husk is used to massage young children and pregnant women, protect the skin from the sun and harsh weather, dress hair, relieve aches and joint problems, and treat swellings, wounds, and bruising. Shea butter is also used to treat eczema, dermatitis, burns, and ulcers. As a result of the diverse use of shea butter, the husk is widely available for use in producing beneficial materials like activated carbon.

Literature Review

All metals with an atomic density higher than 4 g/cm³ are referred to as heavy metals. Some of these heavy metals, which are frequently released into the atmosphere by both industrial and residential processes, include cadmium, lead, zinc, nickel, copper and chromium(Sai Krishna et al., 2018).

Chromium ion which is one of the heavy metals is said to exists in several oxidation states ranging from 0 to +6. It occurs mainly in three forms. Metallic chromium (Cr [0]) is a steel gray solid used to make steel and other alloys. This form does not occur naturally but is produced from chrome ore. In nature it exists in two oxidation states; Cr (III) and Cr (VI)(Emmanuel et

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al., 2015). Cr (III) occurs naturally in rocks, soils, plants and animals. Hexavalent chromium Cr (VI) is produced industrially when Cr (III) is heated in the presence of atmospheric oxygen. The production of steel, leather, and textiles are human activities that increase the concentrations of chromium (III)(Nwaedozie et al., 2013).

Chromium is utilized in metal alloys for paper rubber, magnetic tapes, electroplating, stainless steel, and paint pigments. Chromite mining activity leads to various problems due to released Cr (VI) on the environment. Cr (VI) is the most toxic form of chromium, which enters the body of a person via breathing in air or consuming food. High-level inhalation exposure to Cr (VI) can result in cancer, coughing, shortness of breath, ulcers, irritation of the nasal mucosa, nosebleeds, and holes in the nasal septum(Balali-mood et al., 2021). Children toys imported into Nigeria irrespective of the country of manufacture, especially toys from China contain toxic heavy metals with chromium inclusive.

To mitigate the problems caused by these toys due their chromium content is beyond the scope of this work. However, a ban on the importation of such toys by the Federal government of Nigeria is recommended to reduce exposure of humans (children and parents) to chromium via such toys.

Also, industrial discharge of untreated wastewater to water bodies is another means of exposure of chromium to the environment. The enormous health problems associated with chromium exposure through wastewater discharge can be reduced by wastewater treatment, which is the aim of this research work.

Materials and Methods

Sample collection

Shea butter husk was procured from a farm located in Bida, Niger State Nigeria. The husk samples were washed with regular tap water to remove

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any potential foreign objects (sands and soil). After being cleaned, the samples were dried for two to five days in the sun. The sun-dried materials were sieved after being reduced in size using a mechanical crusher.

Preparation of activated carbon

The samples of crumpled shea butter husk were put in a crucible that had been cleaned, then they were put in a muffle furnace and carbonized for 15 minutes at 500°C for 15mins. After carbonization, 25 grams of the char were mixed with 50ml of 2.M concentrations of potassium chloride solution and allowed for 24hours at room temperature to soak. The obtained samples were oven dried for 30min at 100°C. The dried samples were transferred into a muffle furnace and activated at 600 °C for 45mins.

Characterizations

Surface morphology (SEM) of the prepared activated carbons (AC) was imaged by means of SEM, HITACHI, model (SU8230).and BET analysis was carried out using the Dubinin-Radushkevich (DR) method.

Batch adsorption studies

Using the recently developed adsorbent from shea butter husk, the impact of a few factors on the uptake of the Cr(VI) ion from electroplating effluent was investigated. Using a water bath shaker, the impacts of the following parameters are considered: contact time, adsorbent dosage, and pH.

Effect of contact time

The effect of contact time on uptake of heavy metal ions was studied for a time frame of 90 minutes. In six diverse conical flasks holding 50 ml of measured plating wastewater, 0.6g of the developed activated carbon was applied. With the help of a water bath shaker, the adsorption process was

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carried out at a temperature of 30 °C and at various contacting times, which ranges from 15 to 90 min.

Effect of adsorbent dosage

The produced adsorbents, varying in weight from 0.3 to 1.5 g, were added to five conical flasks with 50 ml of electroplating wastewater. The flasks were corked and shaken at 200 rpm for an hour at 30 °C. The agitation phase was followed by filtering. Following the agitation phase, the contents of each flask were filtered and subjected to an AAS analysis.

Effect of pH

A pH range of 3.0 to 7.0 was used to investigate the impact of pH on metal ion uptake. Five 250 ml conical flasks were filled with the measured 50 ml of electroplating wastewater. The pH was raised from 3.0 to 7.0 using a solution of HCI and NaOH, and then the ideal dosage (1.2 g) from an earlier study was added and swirled for an hour at 200 rpm. After filtering the solution with Whatman filter paper, the solution was analyzed using atomic adsorption spectroscopy.

Data Analysis

The amount of heavy metal ions adsorbed at equilibrium and the percentage (%) removal were calculated using the following formulas.

$$q_e = \frac{v(C_o - C_e)}{m} \quad 1$$

$$\%R = \frac{(C_o - C_e)}{C_O} \quad 2$$

where C_0 (mg/cm^3) = initial heavy metal ions concentrations qe, (mg/cm^3) = quantity of metal ions uptake, Ce, (mg/cm^3) = equilibrium concentrations of solution (wastewater), present in wastewater, V (cm^3) = volume of wastewater used and m (g) = adsorbent weight.

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Results and Discussion

Characterization of Activated carbon(ACM) for Shea butter husk

Surface area and pore size analysis

The surface area, pore volume and pore size were derived using the Dubinin-Radushkevich (DR) method. Table 1 shows the BET surface area (SBET) of the raw, and activated carbon derived from shea butter. The BET surface of the shea butter husk was 278.9560 m2/g, with a micro pore volume of 0.1097 cm3/g and pore size of 3.0150 nm while the obtained activated carbon derived from shea butter husk has a surface area of 1204.5100 m2/g, with a pore volume of 0.4597 cm3/g and pore size of 3.0980 nm. The surface area of activated carbon developed was increased compare to the raw shea butter husk , which was as a result of activation using potassium chloride which led to opening of the closed pores and removal of unorganized carbon. Normally, with increase in surface area of an adsorbent, the larger is the adsorptive capacity of the adsorbent

Table 1: Surface area and average pore size distribution of raw shea butter husk and activated carbon developed

Sample	S_{BET} (m^2/g)	Pore volume cm^3/g	Pore size nm
Raw Shea husk	**278.9560**	0.1097	**3.0150**
Activated carbon from Shea butter husk (ACS)	**1204.5100**	0.4597	**3.0980**

SEM analysis

Using a scanning electron microscope, the morphology and surface characteristics of activated carbon from shea butter husk is examined. The SEM micrograph of activated carbon developed show in figure 1, revealed evidence of pores responsible adsorption of Cr(VI)

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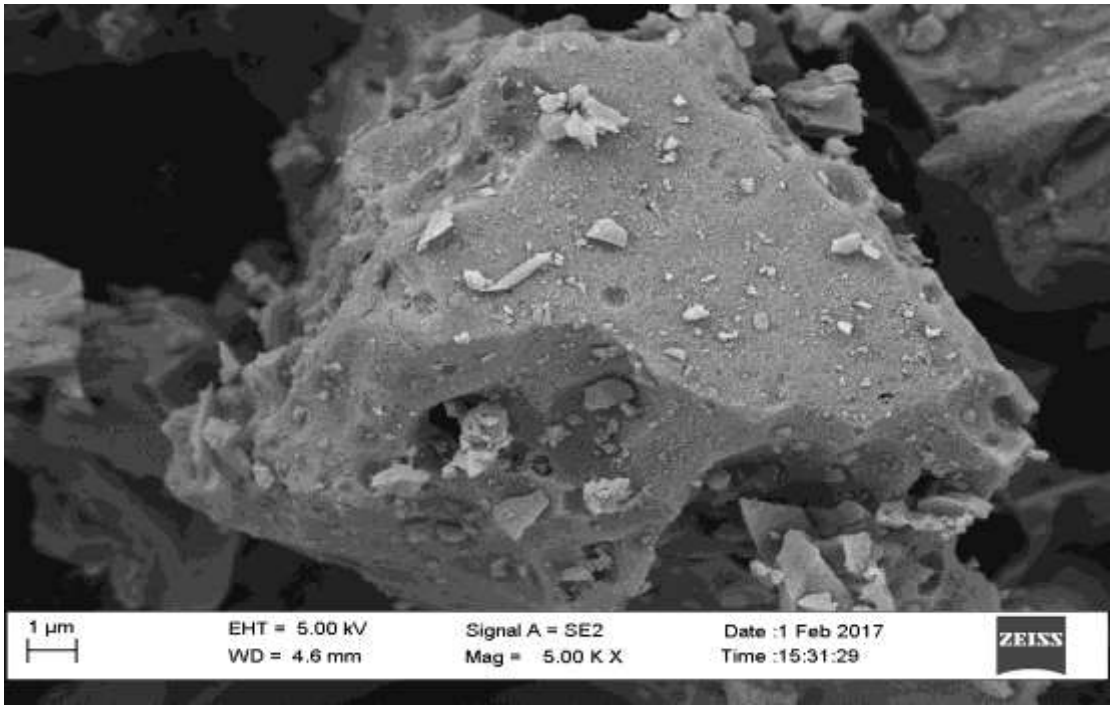

Figure 1: SEM image of activated carbon (from shea butter) at 5000X (a)

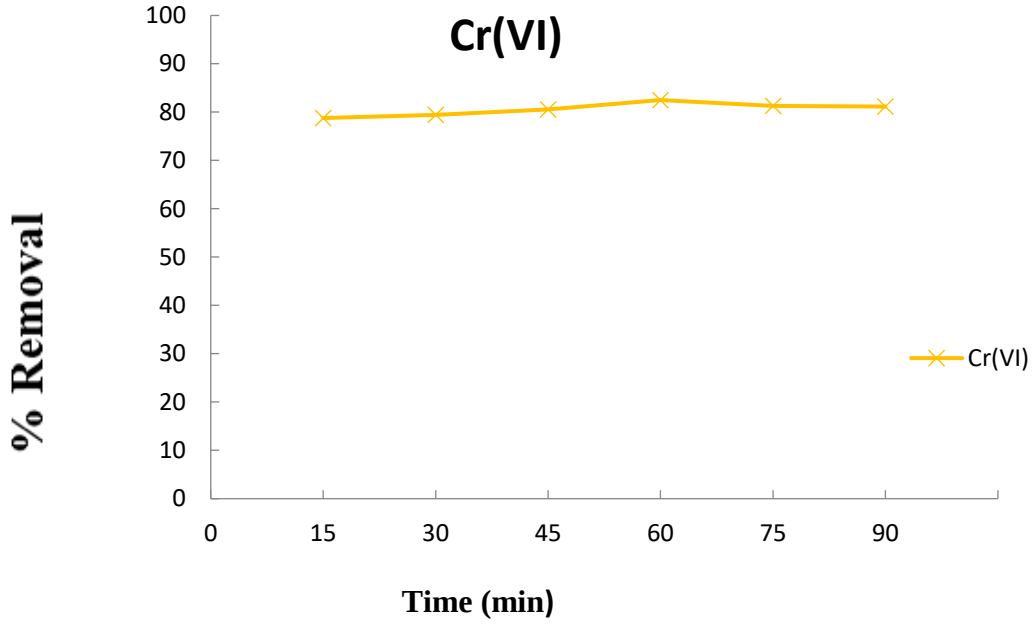

Figure 2: Effect of contact time on adsorption of Cr(VI) onto developed activated from Shea butter husk

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The removal of Cr(VI) on activated carbon developed increased as contact time was increased and achieved a maximum removal at 60 min with 82.50% removal of Cr(VI) as shown in figure 2. The increase in Cr(VI) ion removal as contact time increases may be due to the availability of adsorption sites on the surface of adsorbent. After 60min the system is seen to attain equilibrium with the saturation of the active sites of the absorbent.

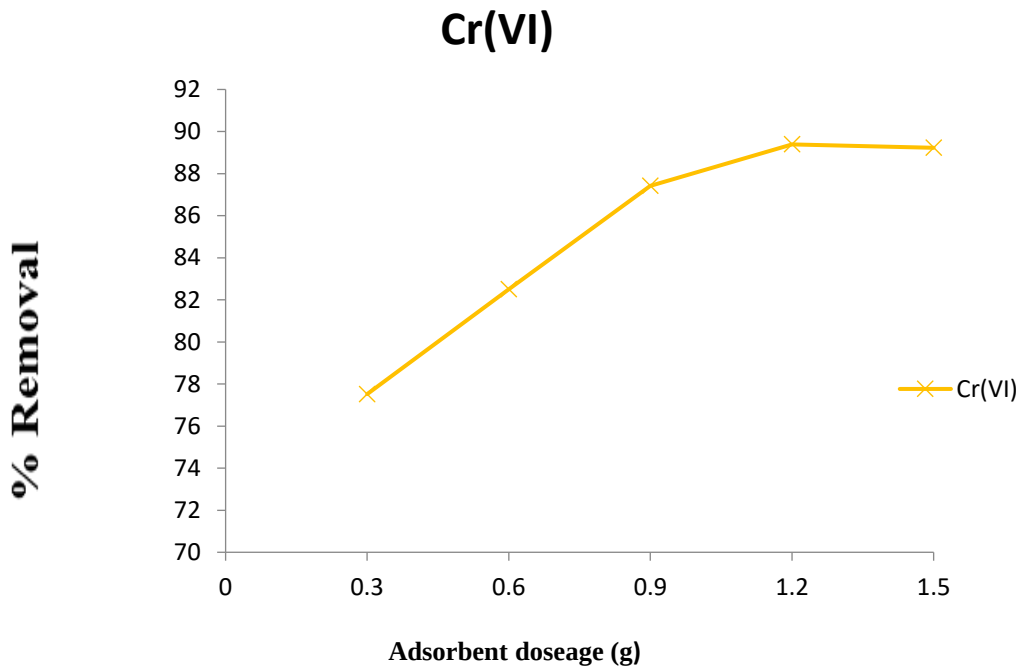

Figure 3: Effect of adsorbent dosage on adsorption of Cr(VI) onto developed activated from Shea butter husk

Figure 3 shows higher uptake of Cr(VI) on activated carbon developed with increase in adsorbent dosage. Maximum uptake of Cr(VI) ion was obtained at a dosage of 1.2 g with 89.39% removal. A larger percentage of metal ions are removed at high doses because the number of adsorption sites or surface area tends to grow based on the weight of the adsorbent(Adsorbent, 2019).

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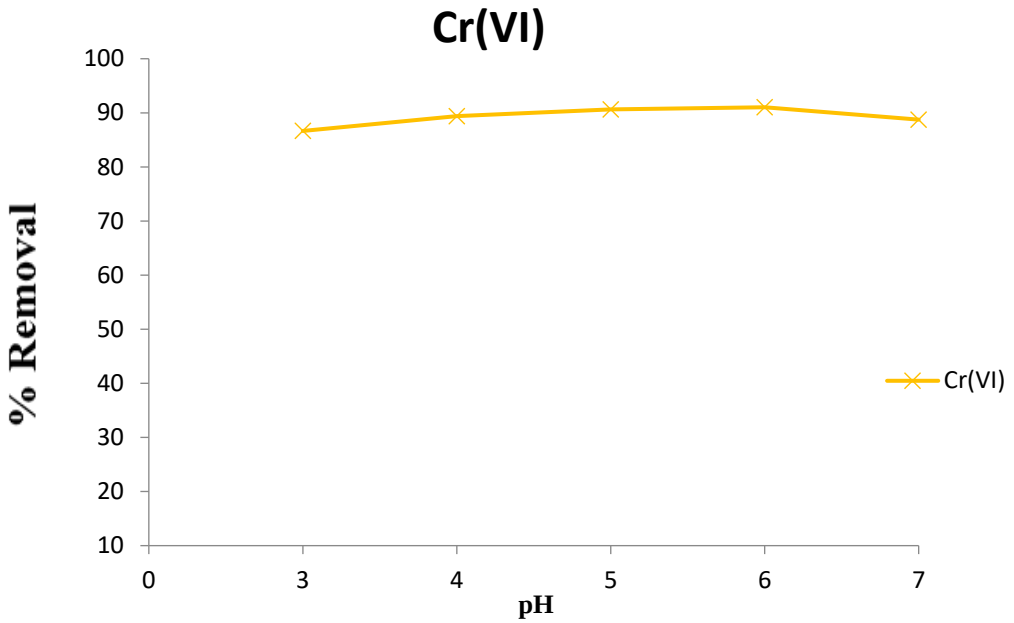

Figure 4: Effect of pH on adsorption of Cr(VI) onto developed activated from Shea butter husk

It can be seen from Figure 4 with activated carbon developed from shea butter husk used as adsorbent that the percentage removal of Cr(VI) ion was increased as the pH values increased. Maximum removal of Cr (VI) was at pH 6 with 82.28% removal. As the pH was increased from pH 3 to 6, more negatively charged surface becomes available thus facilitating greater Cr(VI) ion removal.

Conclusion

Activated carbon was prepared from shea butter husk and characterized. It was successfully applied to remove Cr (VI) ion from plating wastewater. Several factors affecting adsorption such as contact time, adsorbent dosage and pH were studied. The variation of contact time, adsorbent doseage and pH were optimum at 60min of contact time, 1.2g dosage and at pH of 6.

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Characterization using SEM image reveled the presences of pores responsible for adsorption of Cr (VI) ion on the adsorbent.

Reference

Abdessemed, D., Boumediene, T. H., & Aim, R. Ben. (2018). Treatment of wastewater by ultrafiltration Treatment of wastewater by ultrafiltration. *Desalination*, *9164*(November 1999), 1–5. https://doi.org/10.1016/S0011-9164(99)00149-6

Abdullah, N., Yusof, N., Lau, W. J., Jaafar, J., & Ismail, A. F. (2019). Recent trends of heavy metal removal from water/wastewater by membrane technologies. *Journal of Industrial and Engineering Chemistry*, *76*(April), 17–38. https://doi.org/10.1016/j.jiec.2019.03.029

Adsorbent, N. (2019). Adsorption Kinetic Study for Removal of Heavy Metal from Aqueous Solution by Adsorption Kinetic Study for Removal of Heavy Metal from Aqueous Solution by Natural Adsorbent. *DJ Journal of Engineering Chemistry and Fuel*, *4*(1), 12–26. https://doi.org/10.18831/djchem.org/2019011002

Bakalár, T., Búgel, M., & Gajdošová, L. (2009). Heavy metal removal using reverse osmosis. *Acta Montanistica Slovaca*, *14*(3), 250–253.

Balali-mood, M., Naseri, K., Tahergorabi, Z., & Khazdair, M. R. (2021). Toxic Mechanisms of Five Heavy Metals : Mercury , Lead , Chromium , Cadmium , and Arsenic. *Frontiers in Pharmacology*, *12*(April), 1–19. https://doi.org/10.3389/fphar.2021.643972

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heliyon Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, *6*(June), e04691. https://doi.org/10.1016/j.heliyon.2020.e04691

Correia, T., Regato, M., Almeida, A., Santos, T., Amaral, L., & Carvalho, F. (2020). Manual Treatment of Urban Wastewater by Chemical Precipitation for Production of Hydroponic Nutrient Solutions. *Journal of Ecological Engineering Volume*, *21*(3), 143–152.

Emmanuel, S. D., Adamu, I. K., Ejila, A., Ja, M. I., Amos, Y., & Abubakar, M. (2015). Biosorption of hexavalent chromium (chromium (VI) ion from industrial tannery effluent using filamentous fungi on modified rice husk medium / potato dextrose

medium (MRHM / PDM). *African Journal of Biotechnology*, *14*(13), 1143–1150. https://doi.org/10.5897/AJB2013.13553

Esther, B., Jimoh, A., Yahya, M. D., & Manase, A. (2019). Activated carbon prepared from Shea Butter Husk by Box-Behnken Box response surface methodology. *Research Journal of Chemical Science*, *9*(1), 1–10.

Hussain, S. T., Atalah, S., & Ali, K. (2021). Removal of Heavy Metal by Ion Exchange Using Bentonite Clay. *Journal of Ecological Engineering*, *22*(1), 104–111.

Khalil, H. P. S. A., Jawaid, M., Firoozian, P., & Rashid, U. (2013). Activated Carbon from Various Agricultural Wastes by Chemical Activation with KOH : Activated Carbon from Various Agricultural Wastes by Chemical Activation with KOH : Preparation and Characterization. *J. Biobased Mater. Bioenergy*, *7*(June), 1–7. https://doi.org/10.1166/jbmb.2013.1379

Kılıç, Z. (2021). Water Pollution : Causes , Negative Effects and Prevention Methods. *JJournal of the Institute of Science and Technology*, *1*(3), 1–4.

Matsuura, K. C. K. T., & Ethylenediamine, E. D. A. (2018). Removal of heavy metals and pollutants by membrane adsorption techniques. *Applied Water Science*, *8*(19), 1–30. https://doi.org/10.1007/s13201-018-0661-6

Nwaedozie, G., Mohammed, Y., & Nwaedozie, J. M. (2013). Environmental Impact of Toxic Metal Load in Some Military Training Areas within the One Division of Nigerian Army , Kaduna , Nigeria. *International Journal of Academic Research in Business and Social Sciences*, *3*(3), 180–189.

Owa, F. W. (2014). *Water pollution : sources , effects , control and management*. *3*, 1–6.

Qasem, N. A. A., Mohammed, R. H., & Lawal, D. U. (2021a). Removal of heavy metal ions from wastewater : a comprehensive and critical review. *Npj Clean Water*, *July*, 0–15. https://doi.org/10.1038/s41545-021-00127-0

Qasem, N. A. A., Mohammed, R. H., & Lawal, D. U. (2021b). Removal of heavy metal ions from wastewater: a comprehensive and critical review. *Npj Clean Water*, *4*(1), 0–15. https://doi.org/10.1038/s41545-021-00127-0

Sai Krishna, Y. V. S., Sandhya, G., & Ravichandra Babu, R. (2018). Removal of heavy metals

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Pb(II), Cd(II) and Cu(II) from waste waters using synthesized chromium doped nickel oxide nano particles. *Bulletin of the Chemical Society of Ethiopia*, *32*(2), 225–238. https://doi.org/10.4314/bcse.v32i2.4

Sim, D., & Palet, C. (2022). Agro-Industrial Waste as Potential Heavy Metal Adsorbents and Subsequent Safe Disposal of Spent Adsorbents. *Water*, *14*(Ii), 19.

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