Copper removal from water using carbonized sawdust

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Abstract. The occurrence of heavy metals in water sources is grave worldwide concerns for many reasons, firstly because the heavy metals could remain in the water for very long periods because they cannot be degraded by the microorganisms. Secondly, the heavy metals can be accumulated in the bodies of plants and other living cells to toxic levels and could affect humans through the food chain. Finally, the contaminated water by heavy metals causes severe health problems for consumers, such as kidney and brain diseases. Therefore, the development of effective water treatment methods for remediation of water from heavy metals is a vital concern for scientists nowadays. The present work uses sawdust as a chemically activated adsorbent to remove copper. The adsorption experiments were employed in a batch system to investigate the impact of different parameters such as contact time, solution pH, and adsorbent dose. The favorable pH for maximum copper removal was at neutral. After performing the batch experiments, an optimum contact time of 150 min was adopted. The findings indicated that the sawdust dosage of 2 g/L removed about 79% from the copper concentration in the aqueous solution. Sawdust has been successfully utilized as low-cost sorbents for copper removal.

1. Introduction

Heavy metal water pollution is the main worldwide concern for water and wastewater treatment plants because the heavy metals could remain in the water for very long periods because they cannot be degraded by the microorganisms [1, 2], and they could be accumulated in the bodies of plants and other living cells to toxic levels and could affect humans through the food chain. Besides, the consumption of contaminated water by heavy metals causes severe health problems for consumers, such as kidney failure, liver damages, brain diseases (such as Alzheimer), and abortions [3-5]. Heavy metals such as Cu, As, Ni, Cr, Co, Se, V, Zn, Cd, Pb, and Hg are toxic and impact the living organisms by causing diseases and disorders [6-9]. They are usually discharged to the ecosystem by many industries, such as batteries, mining, tanneries, agrochemicals, paper industries, etc., [10-13]. Even a low concentration of these metals is able to harm humans as they are considered the most hazardous ones [14-17]. Thus, removing heavy metals from waters is vital to protect human health and wildlife. Copper is one of the toxic heavy metals that accumulate in human bodies via the food web and leads to several physiological disorders [18-22]. Copper is utilized in a
wide range of industries such as fertilizer paint, pigment industries, electroplating, and wood manufacturing [23]. The World Health Organization has set a concentration of 1.5 ppm of copper in drinking water [23, 24]. Moreover, according to GB25467-2010, China has set a copper concentration of 0.5 ppm in industrial effluent. The increased copper concentration can cause serious toxicological concerns as it is able to impact the liver, skin, brain, as well as pancreas which, in turn, lead to liver and kidney failure, headache, vomiting, respiratory difficulties, nausea, and diarrhea.

Several removal techniques for heavy metals removal, such as flotation [25], electrocoagulation [26, 27], electrodialysis [28, 29], bio-based units [30, 31], chemical precipitating [32], coagulating and flocculating [22], and adsorption [33-36]. The majority of these techniques require a long contact time, costly or ineffective at high concentrations of pollutants [2, 6]. For example, the adsorption technique is limited by the cost of the industrial adsorption materials. Thus, selecting sorbent is important to develop a simple, environmentally friendly, and cheap method.

According to past literature, researchers have widely investigated the adsorption technique in their studies to remove pollutants from waters by employing different natural materials such as waste materials from food and agricultural by-product [17]. These materials are corn stalk, tree bark, almond shells, sunflower stalks, peat, tea leaves, sawdust [16, 17]. The used natural sorbent materials can be employed with or without modification for purpose of improving the adsorption capacity [16]. Wooden materials such as sawdust, peats, straw, tree bark, etc., are considered inexpensive sorbent and the best replacement for industrially produced sorbents. The advantages of applying these sorbents in removing heavy metals are determined by several aspects such as their adsorption capacity, the possibility of regeneration as well as removal selectivity.

Sawdust is defined as a by-product of waste from the timber industry. It is also considered as a low-cost adsorbent material for removing some acid, unwanted compounds, dyes, and heavy metals. The composition of sawdust affects its adsorption properties. It is composed of carbohydrates, phenolic compounds, lignin, cellulose, and hemicellulose. Utilizing sawdust as a low-cost adsorbent in removing heavy metals also benefits the timber industry in addition to its advantage of protecting the environment. Finally, it must be emphasized that human needs efficient water treatment methods more than any time before because of the increase in the discharge of industrials and agricultural wastewaters that contain high concentrations of heavy metals, and also because of the global warming the affects water availability [37-40], and water pollution [41-44].

This work is mainly focused on assessing the performance of carbonized sawdust for copper removal from aqueous solutions. It also investigates the influencing of operating conditions such as contact time, solution pH as well as sawdust dosages.

2. Method

In order to remove any dust and other contaminants, sawdust was firstly washed with tap water and then with deionized water. Then, sawdust was sun-dried to use it as activated carbon. Secondly, the chemical activation step was implemented by mixing 1 weight unit of the sawdust with 1.8 weight unit of concentrated H₂SO₄. Then, the sample was subjected to a temperature of 150°C for one day for drying purposes. To ensure removing the free acid, the carbonized material was washed with deionized water several times and then dried at a temperature of 105°C. In the current work, this carbonized material was utilized for the adsorption of copper. The particle size of the adsorbent was in the range of 0.5–0.8 mm. A stock solution of copper (100 mg/L) was prepared by dissolving the required amount of copper (II) nitrate in 250 mL of deionized water. Copper dilution was made suitably from the stock solution. All experiments were implemented by utilizing a 100 mL of copper solution and adding a known dose of the sawdust. The experiments were employed at a temperature of (20 ± 1 °C) and the samples were shaken by a rotary shaker with 150 rpm.
3. Results and discussion

3.1. Effect of contact time

The impact of contact time on the efficacy of copper adsorption on carbonized sawdust is implemented to investigate copper removal [6]. The pH solution was 4 and the agitation speed was 150 rpm. The copper concentration was constant with a concentration of 5 mg/L and a sawdust dose of 2 g/L. It can be observed from Figure 1 that the removal efficiency of chemically activated sawdust increased with rising the contact time until it remained constant at the saturation. The removal efficiency increased from 25% to 68% when the contact time increased from 10 to 150 min. The removal efficiency of both 150 min and 180 min of contact time was 68%. Thus, it was suggested that 150 min of contact time was chosen in this work for further experiments.

![Figure 1. Copper removal efficiency versus contact time.](image)

3.2. Effect of pH

pH is considered as a major parameter influencing the metals adsorption process which is also supported by past literature [2, 6]. This is because of the fact that the pH of an aqueous solution affects the functional groups of the adsorbents and chemical speciation of the target metal ions.

To investigate the effect of pH of copper adsorption on sawdust, the pH range in the experiments was from 2 to 9. The adjustment in pH values was accomplished by using H2SO4 to stock solution. The copper concentration was kept constant with 5 mg/L and the contact time was an optimum value of 150 min. Moreover, sawdust dosage was 2 g/L and the agitation speed was 150 rpm. Figure 2 describes the copper removal efficiencies versus pH values. It can be noticed that adsorption increased when rising pH value from 2 to 7 and then decreased slightly. The maximum removal efficiency was 79% which took place in neutral pH. The removal efficiency was low at low pH values which can be clarified by the increased competition between H+ and copper ions for the available adsorption sites since the sawdust surface required positive charges with inducing repulsive forces. At a pH of 8 and 9, the removal efficiency started to slightly decrease which could be because of the formation of both soluble hydroxyl complexes as well as Cu(OH)2 precipitation.
3.3. Effect of sawdust dose

The influence of adsorbent dosages, ranging from 1 to 4 g/L, onto copper adsorption is illustrated in Figure 3. The agitation speed in the experiments was set at 150 rpm. Moreover, a constant copper concentration in the aqueous solutions with neutral pH was 5 mg/L and the contact time was 150 min. With increasing sawdust concentration, particularly at 3 and 4 g/L, the available surface is also increased proportionally. This, in turn, resulted in increasing the adsorption which was 100% for high sawdust dosages (3 and 4 g/L). This was led to a lower copper concentration in the aqueous solution. Using lower sawdust concentration means obtaining smaller adsorption which is explained by the reaching to saturation stage when no more copper ions could be adsorbed. The optimum dosage was obtained at 2 g/L of sawdust with the removal of 79% of copper.

Figure 3. Copper removal efficiency versus dosage.

A number of the previous studies challenged that the cost-effectiveness and accuracy of the adsorption methods because the depleted media must be disposed into landfills that requires high construction and
maintenance costs [45-49]. These drawbacks could be overcome by recycling the depleted media in construction applications, such those in the literature [50-55], while the accuracy could be enhanced by applying computerized sensors, such those in the literature [56-59].

4. Conclusion
Sawdust as a low-cost material was examined for adsorption as an unexpansive method to remove copper. The adsorption of copper is highly dependent on time contact, amount of sawdust, and pH of an aqueous solution. Results indicated that copper removal increases when solution pH is increased from 1 to 7 and then decreased. At neutral pH, the copper removal was optimum and 150 min had ideal contact time. It was found that increasing the dosage of sawdust resulted in increasing adsorption degree which was because of increased the number of available sites to adsorb copper ions. A dose of 2 g/L of sawdust removed 79% from the copper concentration in the aqueous solution. Sawdust was found to be an effective bio-sorbent for copper removal in an aqueous solution.

More studies are needed to overcome the main drawbacks of the adsorption methods, where a number of the previous studies challenged that the cost-effectiveness and accuracy of the adsorption methods because the depleted media must be disposed into landfills that requires high construction and maintenance costs. Therefore, more studies are needed to investigate the possibility of recycling the depleted media in construction applications, and the applicability of computerized sensors to enhance the accuracy of the adsorption method.

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