Heavy metal pollution removal from water using a cost-effective bio-adsorbent

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Abstract. One of the worldwide environmental issues is water contamination by toxic heavy metals. Copper is considered one of the most common heavy metals found in industrial wastes, and it has potential impacts on the ecosystem and human health. In order to remove copper from synthetic water, an economically effective adsorbent is required. Thus, this work evaluated the adsorption of copper by utilizing Westland Irish peat moss. The adsorbent was prepared by washing the Westland Irish peat moss using an acidic bath for half an hour with a continuous shaken process, then the mixture was centrifuged to separate the peat moss particles, which was washed using deionized water and dried using an oven. The dried sample was ground and sieved at 80 mesh screen before it was used as an adsorbent. The experiments were accomplished in a batch system as a function of initial solution pH, contact time as well as peat moss dosage. The maximum copper removal, 94.8%, was obtained at a pH of 6, optimum adsorption-equilibrium time of 80 minutes, and peat moss dosage of 7.5 g/L. Irish peat moss as an economically effective adsorbent was satisfactorily employed to remove copper from synthetic water.

1. Introduction

Copper (Cu) can be found in high concentrations in the different industrial waste streams, such as etching, plastics, electroplating, and metal finishing [1, 2]. Furthermore, its compounds are widely used in the agricultural sector in order to treat plant diseases [3-5]. When the copper is released to the environment, particularly water, it can be either bounded to particles suspended in the water, free form, or carried in the surface in copper compounds form. Because of copper toxic properties even with low concentration, the effluent should be properly treated before discharging to any water body. Individuals could be exposed to a considerable amount of copper in drinking water above the USEPA limit of 1.3 ppm when there is corroding copper pipe with low pH [6, 7]. Copper concentration between 0.001 and 0.01 ppm can have lethal impacts on a wide range of marine organisms such as scallops, clams, and isopods [8, 9]. Regarding human impact, the ingestion of copper results in stomach cramps as well as...
nausea vomiting. Moreover, other effects have been reported such as respiratory tract irritation, diarrhea as well as a type of contact dermatitis [1, 8]. Thus, copper concentration in the waste stream should be alleviated to meet the standard limits. The severe water crises in different countries due to the increasing pollution loads [10, 11], climate changes [12-15], increasing population [16-18], and also the uneven distribution of rain [19-21], and cities contributed to the water pollution [22-26].

Hence, different methods have been used to remove metals from water, such as industrial coagulants [27-29], natural coagulants [30, 31], microorganisms [32, 33], adsorption [34-36], electrochemical units [37-39], and hybrid methods [40, 41]. However, these removal techniques have some drawbacks such as expensive, incomplete removal, the possibility of secondary contaminations, or the production of large volumes of sludge [42-47]. The latter drawback was the focus of many studies, where the sludge was used in the production of construction blocks [48, 49], mortars [50, 51], or modified concretes [52-54]. There has been considerable attention among researchers worldwide toward adsorption techniques to remove heavy metals as it has benefits outweigh its drawbacks such as cost, more flexibility, better efficiency, easy to operate, and insensitivity to toxic pollutants. An economically effective adsorbent with low-cost is material that can be founded in nature abundantly or waste/by-products from the waste industry such as biomass (as activated carbon) and bioabsorbents [30, 35].

Sphagnum peat mosses are commonly utilized in Agriculture. They consist of 120 species with the ability of soil conditioning or potting medium to planting. The peat moss functional groups in lignin ease to trap the metals on its surface. Several studies have been shown that the success of peat mosses application in removing pollutants from aqueous solution with no-treatment and no-activation required. On the other hand, others were reported different cleanup solvent when employing peat mosses. Therefore, the treatment of peat moss was recommended to lessen any interferences resulted from the dissolution of matrix components. The treatment increases the sorbent surface adsorption via mitigating the preadsorbed components [30].

The aim of this study is to determine the copper removal from synthetic water by utilizing Westland Irish peat moss as an economically effective adsorbent under different experimental conditions. Furthermore, it explores the effect of different pH values, contact times, and various adsorbent dosage effects. Copper has been selected as it exists in natural water via different industrial waste.

2. Method
Peat moss preparation was carried out according to the stated methods in the literature. The experiments were performed in a batch system. The Westland Irish peat moss sample, 250 g, was initially washed using 400 mL 0.01 M HCl solution for 30 minutes; shaken continuously using an orbital shaker (model: SLA-OS-200). Then, the peat moss was centrifuged at 3000 rpm for 5 minutes, the separated particles were washed again using deionized water several times until the pH increased to 7. The washed sample was dried at a temperature of 60 °C for 24 hours using an electric oven (Lichen, model: 202-00T). The dried sample was ground using a laboratory grinder (Model: HS-400Y) and about 100 g of Irish peat moss was sieved via 80 mesh screen. The average surface area of the produced peat moss was 204 m²/g that was measured using Macsorb surface area analyzers (model: HM-1210). Analytical grade CuSO₄ (supplied by Sigma-Aldrich) was dissolved in deionized water to have the desired concentration of Cu. Copper concentration was determined using a Thermo atomic absorption spectrophotometer (model: ICE-3300).

3. Results and discussion
3.1. Effect of pH
The pH value of the metal aqueous solution highly affects the adsorption mechanism [31]. It evaluates the surface charge of peat moss and the speciation of metal. The impact of the pH value on the copper adoption was investigated by adding 5 g/L of peat moss dose in 20 mg/L Cu with a temperature of 20 °C. The agitation speed was 150 rpm and the contact time was 60 minutes. The pH values were adjusted between 2 and 6 using 0.1 M HCl or 0.1 M NaOH. This range of pH was selected to prove that the
adsorption process is responsible to remove the copper since the copper ions could be withdrawn by precipitation as copper hydroxides for pH more than 6. Figure 1 is presented the removal efficiency of copper versus the pH values. Overall, the removal efficiency tends to increase with rising pH value. The copper removal was quite low (16.3%) at a pH value of 2. The low removal percentage of copper at this pH value could be explained by the peat moss surface was positively charged, which leads to electrostatic repulsion between both the surface and the copper charge. Another reason for low removal efficiency could be explained by the competition, in terms of adsorption sites, between hydrogen ions and copper ions. The copper removal was noticed to increase by rising pH values. This is because the negative charge of peat moss gradually increased, allowing the metal adsorption. The pH values from 3 to 5 showed the removal percentage of copper was maximized until it was stabilized at a pH of 6.

![Figure 1](image1.png)

**Figure 1.** Copper removal percentages (%) versus pH values.

### 3.2. Effect of contact time

The impact of the contact time between the Irish peat moss and a copper aqueous solution with a concentration of 20 mg/L and a pH of 6 is demonstrated in Figure 2. The peat moss dosage was 5 g/L at a temperature of 20 °C and the agitation speed was 150 rpm. As it can be observed that the removal efficiencies of copper increased rapidly with the contact time up to 80 minutes, after that, the removal efficiencies become slower, and maximum removal efficiency was obtained. At the end of the experiment, it was noticed that there was a slow adsorption rate. This could be explained by the saturation of the available adsorbing sites that have been reached which leads to a decrease in the number of vacant sites in the peat moss.

![Figure 2](image2.png)

**Figure 2.** Copper removal efficiency versus contact time.
3.3. **Effect of dose**

To investigate the impact of peat moss concentrations on copper adsorption, a solution of 20 mg/L of copper was placed into contact with various peat dosages (2.5, 5, 7.5, 10, and 20 g/L) at a pH of 6 with a temperature of 20 °C. Moreover, the contact time was 80 minutes and the agitation speed was 150 rpm. The copper removal efficiencies were plotted versus the dosage of peat moss as shown in Figure 3. The copper removal percentages were 38.9%, 78.6%, and 94.8% for 2.5, 5, and 7.5 g/L of peat, respectively, and particularly 100% for 10 and 20 g/L of peat. Therefore, the copper amount adsorbed onto peat moss increased with the rising of adsorbent dosage and Cu adsorption was essential total when the peat dosages were 10 and 20 g/L. The increase in copper removal efficiency could be explained by increasing the surface area of the peat moss and volume binding sites. According to findings, an optimum adsorption concentration of 7.5 g/L of the peat moss was chosen in the experiments.

![Graph showing copper removal percentage versus peat moss dosages.](image)

**Figure 3.** Copper removal percentage versus peat moss dosages.

The results obtained showed that the removal of heavy metals is influenced by the treatment time and other parameters, therefore it is necessary to monitor these parameters to optimize the removal of copper. Accordingly, the use of smart units could help to achieve this goal; smart units are usually provided with sensing systems [55, 56], therefore a suitable type of sensors could be used in this study, such as electromagnetic sensors [57, 58].

4. **Conclusions**

Copper removal from synthetic water via Irish peat moss as an economically effective adsorbent was evaluated. The experiments were implemented in a batch system as a function of initial solution pH, contact time, and peat moss dosage. The maximum copper adsorption capacity was optimum at a pH value of 6 with 80 minutes as the best contact time. Peat concentration of 7.5 g/L showed the highest copper removal efficiency of 94.8%. The findings of this work demonstrated that the Irish peat moss can be utilized for copper removal as a low-cost abundantly and locally available adsorbent. The results obtained showed that the removal of heavy metals is influenced by the treatment time and other parameters, therefore for future studies, it is necessary to monitor these parameters to optimize the removal of copper. Accordingly, the use of smart units could help to achieve this goal; smart units are usually provided with sensing systems, therefore a suitable type of sensors could be used in this study, such as electromagnetic sensors.
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