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Copper Removal from Synthetic Water by Using Rice Husk Activated Carbon

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Abstract: One of the most efficient ways of replacing the existing traditional technique is the application of low-cost adsorbent. Rice husk (RH) is an abundant and inexpensive material and can be processed for various applications into activated carbon (AC). In the past couple of years, AC has also been used as an adsorbent. In addition, AC has wider used, such as removing water and wastewater from different contaminants. In this analysis, the raw rice husk for removing copper from synthetic water is treated and modified as activated carbon for copper (II). Using alkaline sodium hydroxide solution, NaOH, which has a different adsorbent dosage, rice husk was prepared. The parameters to be tested before and after the absorption process are pH, turbidity, total suspended solid, and dissolved oxygen (DO) of the synthetic water. The result obtained indicates that different dosages of adsorbent have different effects on the consistency of the water. The adsorbent dose used was 0.6g, 1.6g, 2.6g, 3.6g, and 4.6g, respectively. In short, an effort has been made on using rice husk as an adsorbent, as the major parts of the adsorbent were lignin and silica, which encouraged the adsorption process. Based on the previous rice husk activated carbon results, this has been verified that the activated carbon intensity will extract copper from the water sample.

Keywords: Rice husk, raw rice husk, activated carbon, heavy metal, copper adsorption, wastewater, dissolved oxygen, pH

1. Introduction

Agricultural waste is a waste that is generated by a variety of farming processes. This includes farm muck and other waste, harvest waste, fertilizer run-off and pesticides are entering the water, air, or soil. [1]. The low cost of agriculture waste can be used to eliminate heavy metal from wastewater and that has been investigated by many researchers [2]. The agriculture waste that will discuss in this paper are rice husk ash. The solid layer that overlays rice grains is the rice husk, and it will be separated from the grains during the milling process. The husk is produced from hard materials, including silica and lignin, in needed to shield the seed during the rice season. A husk for humans that is usually indigestible. The husk is separated from the grain by the milling process to form brown rice. The brown rice is then processed, and the bran layer would've been removed for becoming white rice [3]. The significant amount of waste available in all rice-producing nations is rice husk and contains between 30% and 50% organic carbon [4].

Rice husk has been one of the lowest agricultural by-products acknowledged as being the most efficient heavy metal removal solution. Due to the special biochemical structure, sustainable and more successful removal of heavy metal, rice husk is economically eco-friendly [8]. The dry husk consists of 70-85% of lignin, sugars, and cellulose in organic matter. The rest will stay as silica that is found in the cell membrane [5],[2].

The objective of this study are to produce a low-cost adsorbent by using rice husk activated carbon and improve the water quality. Next, to understand the ability of rice husk activated carbon for the removal of copper by using the

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absorption method and to investigate the effectiveness of modified rice husk by using different adsorbent dosage. Lastly, to characterize rice husk's chemical composition and surface morphology, activated carbon as an adsorbent after the adsorption process.

1.1 Modified Rice Husk for Copper Removal

Rice husk has good chemical strength, high mechanical durability and is highly soluble in water and has a granular composition. Therefore, rice husks are potential to be a good absorbent element for treating heavy metal such as copper from wastewater [8].

The adsorption of Cr(III) and Cu(II) by rice husks was reported to be significantly dependent on pH, rice husk dosage, contact time and initial concentration of metal ions [9]. 5.0-6.0 were the optimal initial pH for the removal of Cr(III) and Cu(II). However, this will depend on the rate of increase with a decrease in initial concentration, increases retention time and rice husk dosage. The scale from 100–800 mg/L was studies for the concentration removal of Cu(II) and Cr(III). It was clearly shown that the removal efficiency of Cu(II) is higher that Cr(III) from the initial reading until the last reading. The first reading for 100mg/L is recorded 60% for Cu(II) while 50% for Cr(III). This can be referred to the saturation from the sorption sites toward adsorbents.

1.2 Adsorption Process

Adsorption process can be defined as the process of mass transfer, which a substance for example heavy metal is a transfer from the liquid phase to a solid or can be known as absorbent and will bound by chemical or physical interaction [10]. Adsorption process can be commonly in a simple formula below:

$$X + Y = X.Y \tag{1}$$

Where X is the heavy metal or pollutant (absorbate), Y is the adsorbent and X .Y is the adsorbed compound in which the heavy metal will attach or adheres to the solid surface of the adsorbent [11].

2. Materials and Methodology

This section discusses the preparation, equipment, and chemicals as well as method of adsorption. This experiment divides into three stages which include the first stage is the preparation of raw rice husk (RRH) and treatment of rice husk (TRH) for further used. Second stage that will be focus is on activated carbon produced from rice husk and the last stage aims to perform adsorption studies and the capacity of Cu(II) [12].

2.1 Preparation of Synthetic Water

3.931g of copper sulfate and equal to 1g of copper in a 250ml Erlenmeyer flask using a rotary shaker set at 150rpm of stirring speed, and all the samples were stirred for 120 minutes. Using a filtration pump set, the sample was then filtered through filter paper and measured the residual metal concentration in each sample by performing a turbidity test.

2.2 Preparation of Raw Rice Husk

Raw rice husk was collected in Alor Star Kedah, Malaysia and was wash with distilled water for a few times to remove useless products. Then, the rice husk was evaporated to 24 hours in the oven at 60°C. This method includes extracting the moisture content and all volatile compound that contain in the rice husk. After that, dry rice husk is granulated, and they are sieved to obtain a 1.18mm of RRH.

2.3 Treatment of Rice Husk

1.0M sodium hydroxide, NaOH was prepared for the treatment of rice husk. 800g of RRH will be mixed with 800ml of 1.0M NaOH in 1000mL beaker. Next, further treatment was carried out for 24 hours and stir continuously using a magnetic stir. This process is to increases the contact time between agent activation and RRH. Equation 2 is the reaction between silicon oxide and sodium hydroxide to produce sodium silicate (Na_2SiO_3). After 24 hours, the sample is sieved to obtain chemically TRH. This process was repeat by rinsing with distilled water until pH is in the range of 6-7. Finally, TRH was evaporated in the oven to 24 hours and weights using a measuring scale.

$$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O \tag{2}$$

2.4 Preparation of Rice Husk Activated Carbon (RHAC)

Next is for the preparation of rice ash activated carbon. The TRH is put into the crucible and sealed with the lid. The crucible containing rice husk is place in the furnace and heat to a temperature of carbonization at 500ºC for 2 hours. The sample is taken out and cooled at room temperature. The activated carbon rice husk will mark as RHAC is weighed by using a weighing scale.

3. Results and Discussions

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives.

3.1 Batch Adsorption Studies

The batch experiments were carried with 3.931g of copper sulfate and equal to 1g of copper in a 250 ml Erlenmeyer flask using a rotary shaker set at 150rpm of stirring speed, and all the samples were stirred for 120 minutes. Studies of batch adsorption, including dosage effects (0.6g, 1.6g, 2.6g, 3.6g, and 4.6g), have been investigated. Using a filtration pump set, the sample was then filtered through filter paper and measured the residual metal concentration in each sample by performing a turbidity test.

3.2 Effect of Adsorbent Dosage

The effect of the dosage of adsorbent on the removal of Cu(II) was Studied by changing the dose of RHAC to 0.6, 1.6, 2.6, 3.6, and 4.6g/100 ml is shown in the Fig. 1 below. The results showed that increasing adsorbent dosage resulted in a decrease in the percentage of turbidity removal. By increasing the adsorbent dosage, this condition can be understood by providing more active sites that seem to be saturated and not sufficient for turbidity removal. 0.6g of RHAC record 64.7% of turbidity removal and this is the optimal adsorbent dosage while the highest adsorbent dosage, 4.6g RHAC recorded 47.5% turbidity removal and at the same time recording the lowest reading for this experiment.

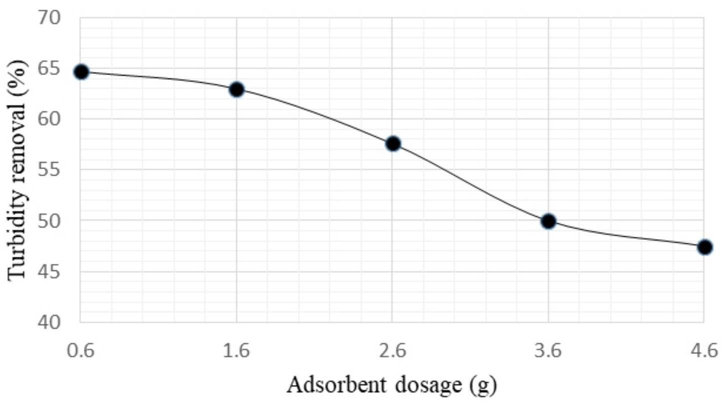

Fig. 1 - Graph of % Turbidity removal vs adsorbent dosage with agitation speed 150rpm

3.3 Turbidity

Each of the water samples in this experiment will undergo a turbidity test to assess how much turbidity is extracted and is reported in nephelometric turbidity units (NTU) (see Table 1). The small amount of RHAC can improve the turbidity reading from copper solution. This is due to the fact that the adsorbent dosage will become saturated and not efficient if the amount are increases.

Table 1 - Turbidity test of copper solution with rive husk activated carbon after adsorption

Adsorbent dosage (g)	Initial turbidity (NTU)	Final turbidity (NTU)
0.6	17.1	6.03
1.6	17.0	6.29
2.6	17.0	7.20
3.6	17.0	8.50
4.6	17.2	9.03

3.4 pH

Based on their high ion migration rate and high ion concentration in the solution, hydrogen ions could be absorbed more easily than copper ions. The pH solution impacts the ionization on the adsorbent surfaces of the functional groups (see Fig. 2). Since silica is an important component of the rice husk, Cu(II) absorption can occur by substituting silanol group protons on the surface with copper ions in the solution via cation exchange reactions [14].

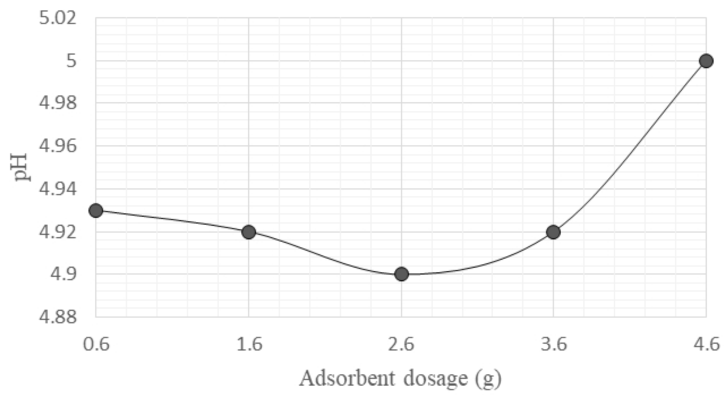

Fig. 2 - Graph of pH vs adsorbent dosage

3.4 Dissolved Oxygen

Higher the value of dissolved oxygen on the water sample, the better its efficiency. The dissolved oxygen level before adsorption and filtration ranged from 9.10mg/L to 9.12mg/L. On the other hand, dissolved oxygen after adsorption and filtration is recorded in table 2 below. The value was between 8.83mg/L and 8.90mg/L. Based on the experiment that was carried out, the dissolved oxygen at a 0.6g adsorbent dose is higher compared to the other result obtained. It is inversely related to turbidity and dissolved oxygen. The higher the degree of turbidity, the lower the concentration of oxygen dissolved in the sample taken. Table 1 and 2 shows that the higher turbidity and lower dissolved oxygen was at 4.6g adsorbent dosage.

Table 2 - The concentration on dissolved oxygen after adsorption and filtration

Adsorbent dosage (g)	Initial Dissolved oxygen (mg/L)	Final Dissolved oxygen (mg/L)
0.6	9.12	8.90
1.6	9.11	8.87
2.6	9.10	8.87
3.6	9.11	8.86
4.6	9.10	8.83

3.5 Total Suspended Solid (TSS)

Initial total suspended solid for this experiment are between 0.087mg/L until 0.089mg/L, while the final total suspended solid that have been obtained are in a range between 0.083mg/L to 0.098mg/L. The optimum TSS is located at a 0.6g adsorbent dosage, showing a reduction of 0.011g from the initial TSS. The result starts to increase at 3.6g of adsorbent dosage and indicates the higher TSS value (see Fig. 3). The reduction in TSS is due to the uptake of Cu(II) present in the solution, which decreases the turbidity of the sample. 0.6g of adsorbent dosage provides the best performance of turbidity, dissolved oxygen and total suspended solids.

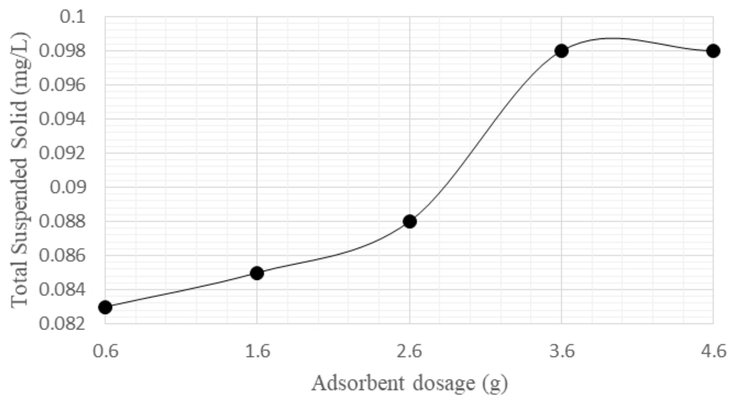

Fig. 3 - Graph of Total suspended solid vs adsorbent dosage

3.6 Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

FTIR is an important analytical method for detecting functional groups and characterizing details about the covalent bond. In addition to adsorption process, FTIR data were collected to provide on a molecular scale information on Cu(II) at the activated carbon rice husk surfaces. Fig. 4 show the FTIR analysis between different of 4.6g and 0.6g adsorbent dosage. The peak absorbance for 0.6g dosage located at 1186cm^{-1} which represent C-O functional group with class of organic compounds containing a hydroxyl functional group. The third highest peak was at 1640cm^{-1} represent C=C functional group indicative of unsaturated carbon or aromatic ring and 2095cm^{-1} which illustrates that rice husk activated carbon has alkynes compound class with weak C≡C group. 2967cm^{-1} peak represent a C-H functional group while 3312cm^{-1} show O-H bonds in the adsorbent. 0.6g rice husk activated carbon has peak at 1483cm^{-1} with C=C bonds. The graph also shows peak of 1703cm^{-1} which illustrate strong bond of C=O with carbonyl compound and 2658cm^{-1} which was strong O-H bonds. Meanwhile, 3290cm^{-1} represent a weak bending C-H functional group.

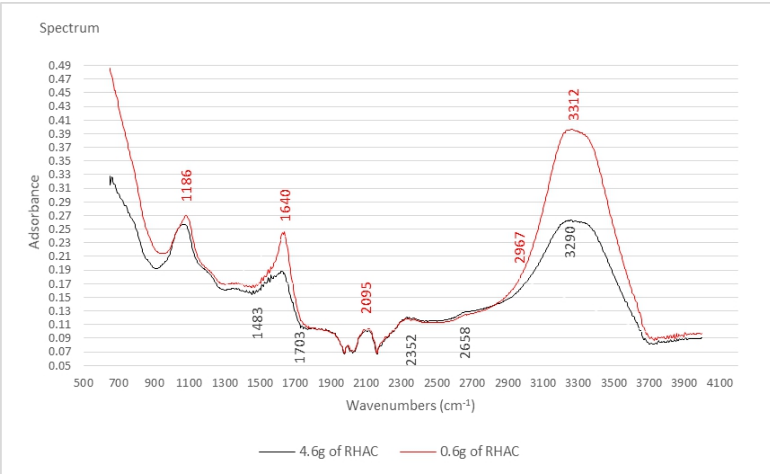

Fig. 4 - FTIR analysis for different adsorbent dosage

3.7 Scanning Electron Microscope (SEM)

The morphology of the surface of the rice husk was analyzed by electron microscopy scanning (SEM) before and after adsorption process. The surface morphology of SEM has changed from plane to irregular surface. This has been shown in Fig. 5 and Fig. 6 below. After the adsorption process, it clearly shows the formation of uneven surface, highly porous structure, and swollen of the surface of RHAC. Treatment of NaOH exhibited larger sorption surface since it can be seen in SEM analysis of RRH and RHAC. The findings indicate significant changes in adsorption morphology after RHAC, with an increased number of surface cavities allowing for a greater sorption capacity.

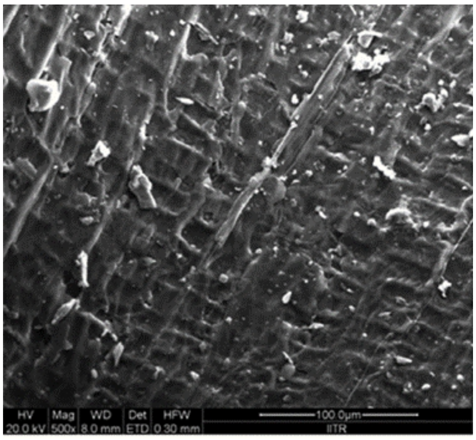

Fig. 5 - SEM image for raw rice husk (RRH) before adsorption process [15]

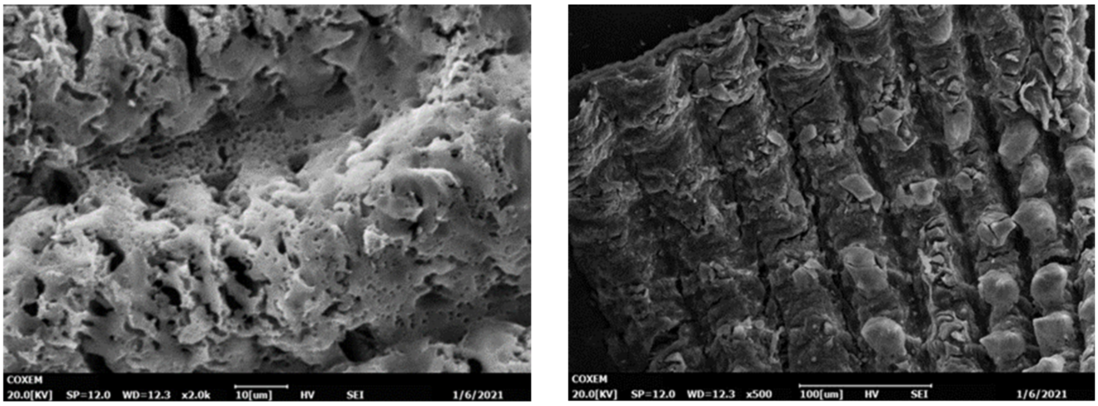

Fig. 6 - SEM image for rice husk activated carbon (RHAC) after adsorption process

4. Conclusion

In this research, batch adsorption studies have been conducted to eliminate Cu(II) from synthetic solutions produced using modified rice husk activated carbon as low-cost, readily accessible adsorbents. These findings are very useful for developing efficient wastewater treatment methods. For this purpose, different parameters for the elimination of Cu(II) by rice husks were examined.

Adsorption of Cu(II) increases with the decreasing of adsorbent dosage. The value of dissolved oxygen was inversely related to the reading of total suspended solids. This finally proves that the least adsorbent dosage is the most effective for Cu(II) removal.

Rice husk is an essential material for extracting Cu(II) from an aqueous solution in my research. There are some advantages to the use of Cu(II) rice husk from contaminated wastewater. The first is rice husk, which is often destroyed as residue, abundant and available at a much lower price. The recovery of Cu(II) is also significantly more economical than the existing process technology. This technique is environmentally sustainable and eliminates the great amount of illegal effluent discharges due to the small industry's concerns. It can provide the medium-scale industry with affordable technology.

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