Design an Adsorption Unit for Lake Water Treatment from Taylor’s University

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Abstract— Adsorption process is commonly known to treat water at low cost especially when the adsorbent used are biomass such as agricultural waste. In this study, rice husk was selected as the adsorbent due to the abundant availability in Malaysia and previous study shown the successful removal of different types of heavy metal and dye by adsorption process. Rice husk was prepared at different conditions to select the best for heavy metal removal in lake water in preliminary study. The study continued at column and result obtained was used to identify isotherm and kinetic model that fits the adsorption data.

Keywords— Adsorption; Rice Husk; Natural Adsorbent; Copper

1. Introduction

Wastewater treatment is one of the essential processes in industrial area especially when the waste produced from the process is toxic or containing heavy metal that will harm the surrounding if overexposed. Since the clean water source for human is obtained mostly from river, the proper wastewater treatment is needed before being released to the nearby river. However different processes need different kind of water treatment. Therefore a few water treatment processes are developed depending on the type of waste to be treated. The most common process that has been widely used recently is adsorption process. Adsorption method is preferable when compared to other separation such as membrane separation and coagulation/flocculation processes due to the recently use of biomass product as the natural adsorbent to replace the conventional adsorbent such as commercial activated carbon and silica gel [1]. This low cost and unconventional adsorbent can be made from agricultural wastes such as fruit peel [2], sugarcane and peanut shell [3]. Most of the natural adsorbent has been researched to successfully remove the heavy metal and dye from wastewater.

One of the attractions in Taylor’s University Lakeside Campus, Malaysia is the lake itself which located at the centre of the campus. The lake is a stagnant body where the main source of the water comes from rain water and the surface runoff from surrounding discharged the pollutants into the lake. The lake water is not polluted with large amount of heavy metal yet but the water still need to be treated to meet the clean water quality standard.

Thus a project is proposed to design an adsorption unit to be used in treating Taylor’s University lake water. The main objective of this study is to design an adsorption unit to treat contaminants in lake water by using natural based type adsorbent. A natural adsorbent is chosen based on literature review and the abundant availability in Malaysia in which rice husk is selected to be used in this study. Since adsorption is the main process in this study, a concentration to be study is needed to conduct the research. Based on previous Taylor’s University Lake Water 2010 Full Report, amount of copper content in lake water was higher than the Standard A and B for water quality in Malaysia. Thus copper is the heavy metal that will be treating in this study. A series of batch experiment is conducted to test different parameters such as contact time, adsorbent dosage and pH. The selected adsorbent and parameter are further tested in adsorption column and the equilibrium data is prepared to evaluate the adsorbent performance.

2. Methodology

2.1 Adsorbent Preparation

Rice husk (Type: Short Malinja Paddy R-16) was obtained from local rice mill located in Muar, Johor. The rice husk was sun-dried for 3 days to remove any water content. Preliminary experiment was conducted for water parameters with three different condition of rice husk were used. Rice husk (Type I) was crushed first with blender and sieved at 500 μm sieve (Model: RX-812-1) which is equivalent to 35 mesh size. The sample was stored in air tight container for future experimentation. (Type II) The crushed sample was pretreated with analytical grade H2PO4 for 24 hours to remove any impurities and colour pigments. Sample was filtered with Whatman No.1 Filter Paper oven dried at 110°C for 24 hours to remove remaining acid. (Type III) The raw rice husk was washed with distilled water several times to remove impurities and colour pigments. Oven dried at 110°C for 24 hours before being stored in dessicator for future use.

2.2 Batch Adsorption Experiment

2.2.1 Preparation of Copper Stock Solution

10 mg of analytical grade copper sulphate pentahydrate (CuSO4·5H2O) was dissolved in 500 ml of distilled water. Distilled water was added until the solution reached to 1 litre.

2.2.2 Effect of Contact Time, Adsorbent Dose and pH

pH of stock solution was adjusted with BP pH meter (Model: 3001 Trans Instrument) to 6.5 using either NaOH or HCl similar to the pH of lake water. 1 g of prepared adsorbent was added to six conical flasks. 200 ml of copper stock solution was transferred to the flasks and agitated at 150 rpm speed with WiseStir Magnetic Stirrer (Model: SMHS-3, DAIHAN Scientific Co., Ltd, Korea) at room temperature 25°C for different periods. The contact time was set to 10, 20, 30, 40, 60 and 90 minutes. The solution was immediately filtered with Whatman No. 1 Filter Paper to determine the final copper concentration with PinAAcle 900 AAS Spectrometer (Model: 900F, PerkinElmer Inc., USA). The impurity removed was calculated based on (1) and a graph was plotted for amount of impurities removed against contact time. Optimum contact time was obtained from the graph.

\[
q_e = \frac{(C_1 - C_2)W}{W} \tag{1}
\]

Different dose of adsorbent were added to six conical flasks (0.5 g, 0.7 g, 1.0 g, 1.5 g, 2.0 g and 2.5 g) contained 200 ml of stock solution. pH of stock solution was fixed at 6.5 and stirred at optimum contact time obtained from previous experiment.

pH of copper stock solution was adjusted to five different pH (pH 3, 5, 7, 8, 9) by calibrated with BP pH meter (Model: 3001 Trans Instrument) and 200 ml of stock solution was added to five conical flasks. All solution were stirred with WiseStir Magnetic Stirrer (Model: SMHS-3, DAIHAN Scientific Co., Ltd, Korea) at optimum contact time and adsorbent dosage obtained from previous study.
2.3 Column Experiments

Adsorption column was designed using acrylic column with internal diameter of 46 mm and height 460 mm (Height to Diameter Ratio = 10). The column was in down flow mode and peristaltic pump was used for pumping in the lake water. Three different flow rate and bed height were used (3, 5 and 7 ml/min) and (50, 100 and 150 mm) respectively. The effluent sample was collected at time interval of 10 minutes and breakthrough curve was plotted for each of the variables.

2.3.1 Adsorption Studies

The equilibrium data obtained from column experiment were used to determine the loading behavior of copper removal using rice husk by testing with Freundlich and Langmuir isotherm equations based on (2) and (3) respectively. Linear equations for both models were correlated and the adsorption capacity was obtained.

\[ q_e = K_f C_e^{1/n} \]  
\[ q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \]

2.3.2 Kinetic Studies

In this work, Thomas model were used and the expression for the model in adsorption column are as (4);

\[ C_t = \frac{1}{1 + \exp(k_{th} q_o m/v - k_{th} C_o t)} \]

Where \( k_{th} \) and \( q_o \) were obtained from linear graph plotted to determine the breakthrough curve of \( \frac{C_t}{C_o} \) against \( t \). \( q_o \) is the equilibrium Cu(II) uptake per g of rice husk adsorbent (mg/g) [4].

3. Result and Discussion

3.1 Rice Husk Preparation

Fig.1 Different Condition of Rice Husk Used for Preliminary Experiment

<table>
<thead>
<tr>
<th>Adsorbent Dosage (g)</th>
<th>Amount of Lake Water (ml)</th>
<th>Contact Time (minute)</th>
<th>Average Final Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>10</td>
<td>3.40</td>
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<tr>
<td></td>
<td></td>
<td>20</td>
<td>3.25</td>
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<td></td>
<td></td>
<td>30</td>
<td>2.68</td>
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<td></td>
<td></td>
<td>40</td>
<td>2.58</td>
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<td></td>
<td></td>
<td>60</td>
<td>3.04</td>
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<td></td>
<td></td>
<td>90</td>
<td>3.12</td>
</tr>
</tbody>
</table>

3.2 Preliminary Experiment using Rice Husk Type I

Table 1. Amount of Turbidity Removed at Different Contact Time using Rice Husk (Type I)

<table>
<thead>
<tr>
<th>Initial Turbidity (NTU)</th>
<th>Adsorbent Dosage (g)</th>
<th>Amount of Lake Water (ml)</th>
<th>Contact Time (minute)</th>
<th>Average Final Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
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<td>200</td>
<td>10</td>
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<td>90</td>
<td>3.12</td>
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</tbody>
</table>

Table 2. Amount of Turbidity Removed at Optimum Contact Time and Different Adsorbent Dosage

Type I rice husk had shown that the optimum contact time where the least value turbidity can be obtained at 40 minutes. However when the experiment continued for different adsorbent dosage, the average final turbidity showed inconsistent value and more turbid after the treatment. This caused by untreated rice husk as the sieved rice husk contained lots of colour pigments and impurities that needed to be removed before being used. Type I rice husk was not used for further column experiment.

For the column study, previous study had shown that removal of Cu(II) equilibrium sorption data using Rice Husk based Activated Carbon fitted Freundlich isotherm and Thomas model [4].

4. Conclusion

This study is still ongoing and based on the result obtained in the preliminary study, the sieved rice husk must be treated first before being used as rice husk contained a lot of impurities and release colour pigment once being crushed to smaller forms. However untreated rice husk gave better result for different contact time which showed the high possibility to be used in adsorption process by modifying the rice husk to obtain optimum efficiency. Application of rice husk gives beneficial in economy area by reducing cost in adsorption process and also in the biomass waste treatment.

References


