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Effectiveness of Using Activated Carbon as Adsorbent for Copper Removal from Synthetic Wastewater

Anna Jesil, A.M. Saravanan*, Zainab Hassan Ahmed Al Kumzari

Department of Mechanical and Industrial Engineering, Caledonian College of Engineering, Sultanate of Oman

*Corresponding author email: amslogin@gmail.com

ABSTRACT

Adsorption is an attractive technology for the treatment of effluent from heavy metal industry. The removal of copper from synthetic wastewater by adsorption on activated carbon prepared from date palm seed was investigated at room temperature 25^0C. The optimum adsorbent dosage, stirring speed, initial concentration, temperature, contact time and pH was determined as 0.9 g/l, 120 rpm, 100 ppm, 25^0C, 75 min, and 5 respectively, which give removal efficiency in the range (80 - 90%). Experimental data was fitted with the Langmuir and Freundlich isotherm models. Freundlich model had higher correlation value (R^2) of 0.941 which fitted the equilibrium adsorption process more than Langmuir model for the experimental work. The BET surface area and total pore volume of activated carbon prepared by activation with phosphoric acid were identified to be 71.5674m^2/g and 0.024281 cm^3/g respectively.

Keywords: Optimization, $CuSO_4.5H_2O$ solution, Activated carbon, Adsorption, synthetic wastewater, isotherm.

1. INTRODUCTION

Nowadays the use of adsorption techniques for the removal of heavy metals has received global attention as most industrial processes generate wastewater containing certain heavy metals such as chromium, lead, mercury and copper that are classified as toxic effluents [1]. Adsorption using activated carbon is employed in the treatment of metal industry effluent.

Natural materials derived from agriculture waste find application in wastewater treatment in a most environmentally friendly manner [2]. Adsorption technique has been used since the 1950s for removing a wide variety of inorganic gases and many types of organic vapors. Besides scope of application of adsorption technique has been expanding recently due to a wide development in the design of the adsorption system [3]. Moreover, activated carbon may be reused by removing the adsorbed organic compound through various methods such as steam, thermal and physical/chemical methods [3].

This present investigation is to explore the potential of activated carbon prepared from date seed as adsorbent for copper removal from synthetic wastewater. The influence of various parameters, such as adsorbent dosage, initial concentration, contact time, stirring speed, pH, and temperature will be studied to determine the optimal adsorption conditions.

2. METHODOLOGY, DESIGN AND EXPERIMENTATION

Copper sulphate were procured through the college lab stores and was used without any further purification.Distilled water was used throughout the experiments which were carried out in 100 ml plastic bottles. The total volume of the reaction mixture was kept at 50 ml and phosphoric acid (H_3PO_4) is used for preparing the activated carbon. All experiments were carried out in the project lab of Caledonian College of Engineering.The equilibrium concentration were analyzed using 660 UV visible spectrophotometer after estimation of the optimum wavelength for copper analysis.

2.1 Preparation of activated carbon from date seed

Required quantity of date seeds were washed with distilled water several times to remove soluble impurities of water until a clear solution was obtained and then, dried in the sun for two days.

It was then soaked in H_3PO_4 acid. 300 g of date seeds were taken and immersed in 200ml of H_3PO_4 for one hour.

These seeds were then washed with distilled water. Later, the washed seeds were oven dried and then carbonized for 4 hours at 400 ^{0}C in the furnace. It was further washed by using distilled water till neutral pH was obtained and then dried at 100^{0}C for 2hours. Finally, it was ground into a fine powder and then sieved to use the appropriate size.

2.2 Synthetic effluent preparation

The stock solution of 1000 ppm copper was prepared from $CuSO_4.5H_2O$ by dissolving a suitable amount in distilled water. The stock solution was further diluted according to the requirements by using distilled water.

2.3 Method for copper analysis - UV Visible spectrophotometer

UV- Visible spectrophotometer has been used around for the past 35 years and during this period, it became one of the most important instrument in the analytical laboratory [1].There are many applications of this instrument which are applied in chemical industries because of the several advantages which are ease of use, accuracy, less time, and cost effectiveness. The working principle is based on the Beer Lambert law. The wavelength of copper is (660 nm) which is used to measure the absorbance of copper. It include, the relationship between absorbance and the intensity of the color which is directly proportional to its concentration [4].

3. RESULTS AND ANALYSIS

Batch adsorption experiments were carried out by shaking a certain quantity of the adsorbent with 50 ml of the solution containing copper at a known concentration at room temperature and at a particular pH. pH adjustment was done by using 0.1 N NaOH and 0.1N HCl.

The mixture was stirred in the rotary shaker for a time period, after the predetermined time period, the adsorbent was removed by filtration and the sample was analyzed for copper concentration by UV visible spectrophotometer. The parameters studied were:

1. Effect of adsorbent dosage
2. Effect of variation of pH
3. Effect of contact time
4. Effect of stirring speed
5. Effect of initial copper concentration

3.1 Effect of adsorbent dosage

Referring to the graph shown below (Fig. 1) it is observed that, the percentage removal of copper increases as the adsorbent dosage increases from 0.5 g/l up to 0.9 g/l due to the increased surface area available as the dosage increases. It is apparent that with a higher dosage of adsorbent there would be greater availability of adsorbant for the removal of copper. However, the removal efficiency of copper decreased when the adsorbent dosage was 1.1 g/l .The dosage at which maximum removal is attained taken as optimum dosage.

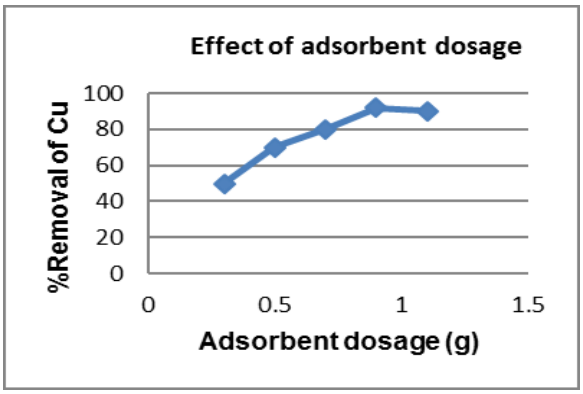

Fig. 1 Effect of adsorbent dosage on copper removal by chemically (H_3PO_4) activated carbon

3.2 Effect of pH

The percentage removal of copper from synthetic wastewater is strongly affected by the pH variation of the solution as illustrated in the graph (Figure 2). It is observed that the percentage removal of copper increases, when the pH increases from 2 to 5. This is because more negatively charged surface at higher pH causing greater attractive force towards the positive copper ions. Hence the percentage removal of copper at higher pH values is more as the adsorbent surface becomes more active due to the gathering of hydroxyl ions. It was observed that percentage removal of copper decreases slightly in the range of 6–8. This because at 6 pH, the zero electric discharge of the adsorbent is obtained. The pH at which maximum removal is attained, is taken as optimum pH. Hence the optimum removal efficiency of copper was obtained at pH 5.

3.3 Effect of contact time

Contact time has more influence than other parameters of the adsorption process. It can be observed (Fig. 3) that the percentage removal of copper increases with increase in contact time from 15 min to 75 min to some level at optimum adsorbent dosage and pH. Hence the

optimum removal efficiency of copper from synthetic wastewater was obtained at 75 min. As the contact time increases, more time for mass transfer of the copper ions to the adsorbent surface is available and hence the percentage removal of copper increases.

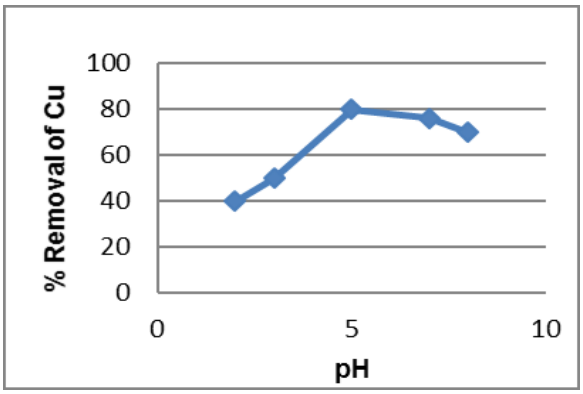

Fig. 2 Effect of pH on copper removal by chemically (H_3PO_4) activated carbon

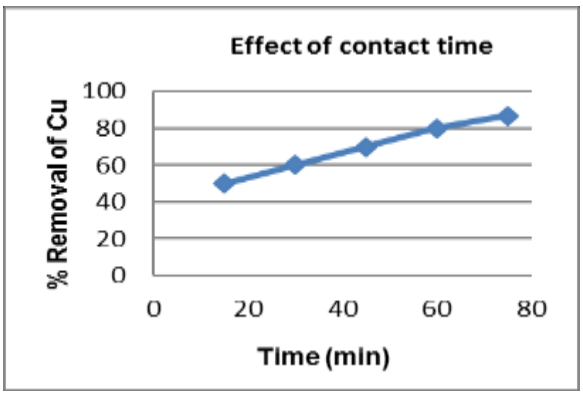

Fig. 3 Effect of contact time on copper removal by chemically (H_3PO_4) activated carbon

3.4 Effect of stirring speed

Fig. 4 illustrates the effect of stirring speed in the removal of Copper from synthetic wastewater. The percentage removal of copper increased with increase in stirring speed from 80 rpm to 120 rpm. After that the percentage removal of copper and the adsorption capacity decreases slightly in stirring speed range of 140 rpm to 160 rpm and obtained a maximum 90 % removal of copper at 120 rpm. However, at low stirring speed the percentage removal of copper was lower than optimum speed. At low stirring speed, the particles is not spread properly in the solution to provide active binding sites for adsorption of copper. The speed at which maximum removal is attained taken as optimum stirring speed. Hence the optimum removal efficiency of copper was obtained at 120 rpm.

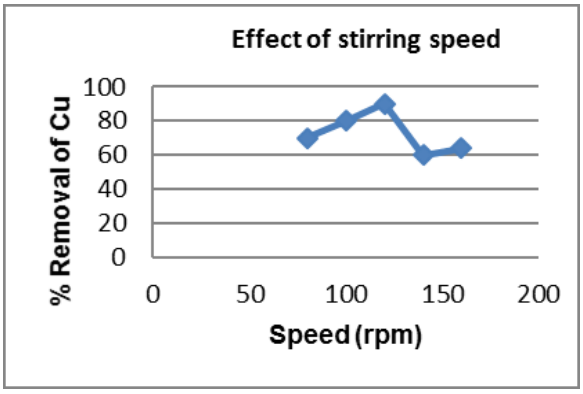

Fig. 4 Effect of stirring speed on copper removal by chemically (H_3PO_4) activated carbon

3.5 Effect of initial concentration

Fig. 5 illustrates the effect of initial concentration in the removal of copper from synthetic wastewater.

From the graph shown (Figure 5) it is observed that the percentage removal of copper decreases as the copper concentration increases from 100ppm to 300ppm the surface sites becomes available for the adsorption capacity decreases due to the higher electrostatic interaction between the copper ions and the limited active sites of absorbent. Moreover, the copper uptake is rapid during the initial period of adsorption and obtained a maximum removal (90 %) is achieved at 100ppm concentration for 150 µm size particle. On the other hand, at higher initial concentration of copper lead to an increase of the copper ions toward the active sites. Hence the optimum removal efficiency of copper from synthetic wastewater was obtained at 100 ppm.

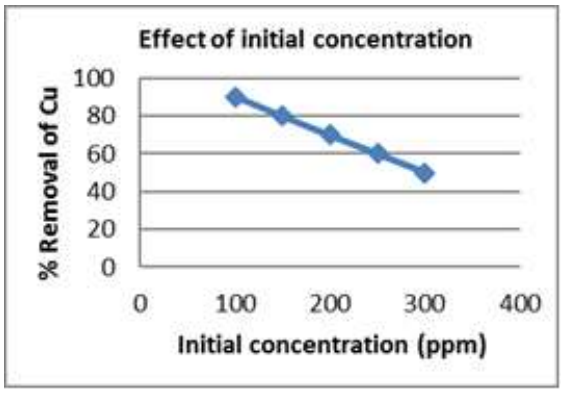

Fig. 5 Effect of initial concentration on copper removal

3.6 Equilibrium adsorption isotherm

Several models had been used in this project to examine the relationship between sorbed Copper (q_e) and equilibrium concentration (C_e) as and used as well to

describe the experimental data of adsorption isotherm (Auyb, 2014). As the Freundlich and Langmuir models are the most frequently employed for fitting the data, these two models were used in the present work. The Langmuir adsorption model assumes that maximum adsorption of metal ions occurs on the adsorbent surface by saturating monolayer with no lateral interaction between adsorbed ions, while the Freundlich adsorption model assumes multilayer adsorption over the heterogeneous surface by with non-uniform distribution of adsorption heat.

The equilibrium adsorption isotherm was studied by varying the initial copper concentration while keeping the adsorbent mass in each sample as constant and 5 hours of equilibrium periods for adsorption experiments were used to guarantee the equilibrium conditions.

4. CONCLUSION

The rapidly growing interest in the use of activated carbon adsorption technology for effluent treatment is reflected by the significant number of publications that have been produced during the last years. This project was conducted to study the effectiveness of activated carbon prepared from date palm seed to remove copper from synthetic wastewater. The activated carbon was prepared by the chemical activation method using Phosphoric acid. The BET isotherm method showed a specific surface area of 71.5674 m^2/g and pore volume of 0.024281cm^3/g. The optimum adsorbent dosage required for removal of copper from synthetic wastewater was 0.9 g/l, pH of 5, contact time of 75 min, stirring speed of 120 rpm, initial copper concentration of 100 ppm and a temperature of 25^0C which gave a removal efficiency in the range 80 - 90 %. Removal of copper from synthetic wastewater becomes possible by using activated carbon prepared from date palm seed which is abundantly available in Oman and hence can be used as a low cost adsorbent. Adsorption isotherm models Langmuir, Freundlich were studied, and out of these the best model fitted for the adsorption of copper on date palm seed adsorbent is the Freundlich model.

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