Removal of Cu^{+2} from Electroplating Industrial Wastewater by using Microwave Assisted Activated Carbon

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Abstract— **Rapid growth of industrialization infixes toxic materials engendering significant environmental problems. Removal of various heavy metals is efficiently carried out by using commercial activated carbon but its high cost restricts its widespread use upto certain extent. Therefore, use of waste agricultural material based activated carbon has drawn considerable attention of many researchers. In the present investigation, copper is removed from electroplating industry waste water by using Acacia scrap wood based activated carbon. The carbon was prepared through carbonization technique followed by microwave activation and characterized by using BET surface area analyzer, Scanning Electron Microscopy, CHN analyzer and Fourier Transform Infrared Spectroscopy. The activated carbon is found to have a high surface area and total pore volume of 695 m^2/g and 0.5 cc/g respectively. It was found that 99.9 % of Cu(II) removal efficiency and 98.63% of COD removal efficiency was achieved within first 80 min of the batch adsorption study with an initial concentration of 100 mg/L, adsorbent concentration of 1 g/L, pH of 6, temperature of 30 °C, particle size of 105 μm and agitation speed of 200 rpm. The kinetics of the adsorption follows the pseudo second order rate kinetics.**

Keywords— **Activated carbon; Effluent; Adsorption; Waste water.**

I. INTRODUCTION

Water pollution by various heavy metals is one of the major environmental problems worldwide. The presence of these heavy metals causes several harmful effects to aquatic (Li and Bai, 2005) and non-aquatic life. Copper is one of such heavy metal which is most commonly present in the effluents from brass manufacture, petroleum refining, electro-plating, mining and different agrochemical industries. The maximum permissible limit of copper in surface water and drinking water are 3 and 1.5 mg/L according to the World Health Organization (Rao et al., 2006). Excess intake of copper ions by human beings causes serious health hazards including hepatic and renal damage, mucosal irritation, widespread capillary damage and problem in central nervous system (Larous et al., 2005). Therefore, it is essential to remove this metal from various water bodies.

Removal of various heavy metals is efficiently carried out by using commercial activated carbon but its high cost restricts its widespread use upto certain extent. Therefore, use of waste agricultural material based activated carbon has drawn considerable attention of many researchers. In the present investigation, copper is removed from electroplating industry waste water by using Acacia scrap wood based activated carbon.

II. EXPERIMENTAL

A. Materials

Wastewater from copper plating industry was collected from Leather Links, Kolkata, India, was diluted to 2.5 times to reach the initial concentration at about 100 mg/L and then the solution was further diluted as per requirements. The hydrochloric acid (35% pure), sodium hydroxide (97% pure) and commercial activated carbon were procured from Merck Specialities Private Limited, Mumbai, India. All the chemicals used in the present study were of analytical grade.

B. Procedure

For the kinetic study, 0.1 g of adsorbent with 100 mL solution of Cu(II) were taken into a series of 250 mL conical flasks. The required pH of the solutions was maintained by adding 0.1 M NaOH or HCl. The flasks were shaken in a mechanical shaker (Thermocon, India) and the samples were collected at various intervals of time and were filtered. These samples were then analyzed for the determination of Cu(II) concentration.

For the equilibrium study, 100 ml of Cu(II) solution of different initial concentrations were taken in a series of 250 ml conical flasks and 0.1 g of adsorbent was added to the flasks. The flasks were shaken in a mechanical shaker till equilibrium was attained. After equilibrium was reached, the samples were collected, filtered and were analyzed by using an atomic adsorption spectrophotometer (Perkin Elmer AAnalyst 300, USA). The adsorption isotherm models were analyzed by using Origin Pro software (Version 8).

III.   RESULTS AND DISCUSSIONS

C. Characterization of the effluent

The wastewater sample was characterized to determine the composition. The composition of the wastewater sample is shown in Table 1.

TABLE I
The Characterization of Waste Water

Composition	Value
pH	8.6
Conductivity, mho/cm	0.0001
Total solids, mg/L	18.32
Total alkalinity, mg/L	1.15
Cu(II), mg/L	250
Ni(II), mg/L	0.05
COD, mg/L	160

The characteristics of the effluent shows that COD value 160 mg/L is well below the permissible limit (300 mg/L) as per Indian Standard Specification (Rajalakshmi, 2010). Whereas, the Cu(II) concentration is too high. Therefore, the present activated carbon (AC750NMW5) has been used for removal of Cu(II) from this effluent.

D. *Effect of parameters*

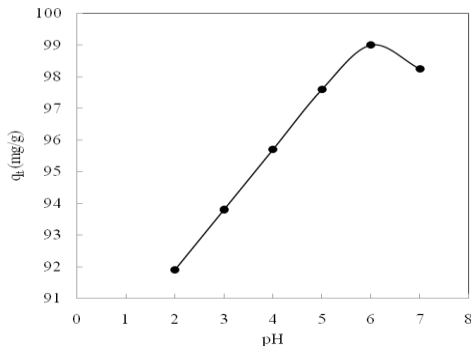Effect of pH: The effect of solution pH on Cu(II) adsorption is shown in Fig. 1.

Fig. 1: The effect of solution pH on the adsorption of Cu(II)

The results show that the pH of the solution is an important parameter for Cu(II) adsorption. The effect of pH was studied over a pH range of 2 to 7 at 30 °C and with a constant initial concentration, adsorbent concentration, particle size and agitation speed of 100 mg/L, 1 g/L, 105.5 μm and 200 rpm respectively. It is noted from Fig. 1 that the adsorption of Cu(II) increases with increase in solution pH from 2 to 6 and the maximum adsorption of Cu(II) occurs at a vicinity of pH 6.

The adsorption of Cu(II) decreases slightly at above 7. The possible reason may be at acidic pH due to high concentration of H+ ions, a competitive adsorption takes place between the hydrogen ions and Cu(II) ions. On the other hand, at higher solution pH the adsorbent surface become negatively charged with OH- ions which facilitates the adsorption of Cu(II) ions (Tumin et al., 2008).

Effect of initial concentration of copper effluent: The four different concentrations 40, 50, 75 and 100 mg/L were chosen to study the effect of initial concentration on the adsorption of Cu(II). The pH was maintained at 6 and other parameters were kept constant as earlier experiments. The plots of amount of copper adsorbed versus time in Fig. 2 show that the adsorption capacity increases from 39.81 to 99 mg/g as the metal concentration increases from 40 to 100 mg/L at 120 min. The driving force the concentration gradient increases with increase in initial concentrations which also enhances the adsorption capacity (Benaïssa and Elouchdi, 2007; Al-Asheh et al., 2003).
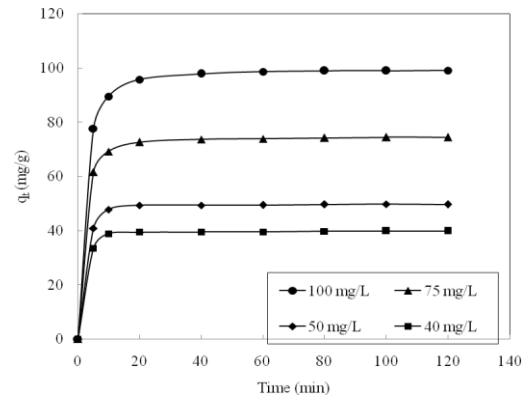

Fig. 2: The effect of initial concentration on the adsorption of Cu(II)

Effect of adsorbent concentration: To study the effect of adsorbent concentration, the adsorbent concentration was varied from 1 to 2 g/L keeping other parameters constant, as solution pH of 6, initial concentration of 100 mg/L, temperature of 30 °C particle size of 105.5 μm and agitation speed of 200 rpm respectively. The effect of adsorbent concentration is shown in Fig. 3. It is seen from the figure that the amount of Cu(II) adsorption increases from 49.53 to 99 mg/g after 120 min with decrease in adsorbent concentration from 2 to 1 g/L. The amount of Cu(II) adsorbed per gram of adsorbent decreases with increase in adsorbent concentration. This may occur due to creation of a dense layer outside the adsorbent particle which also prevents the adsorption of Cu(II) ions (Pons and Fuste, 1993).
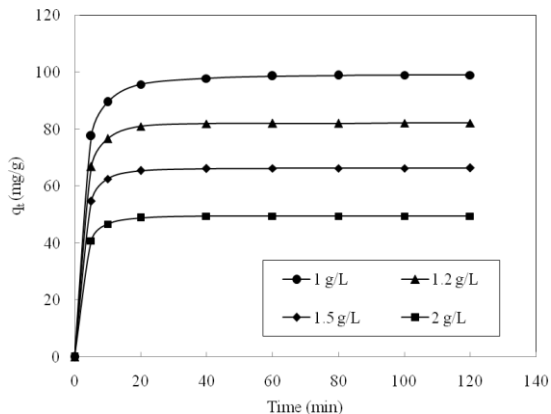
Fig. 3: Effect of adsorbent concentration on the adsorption of Cu(II)

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Effect of temperature: The effect of temperature on Cu(II) adsorption was investigated at four different temperatures. For this study, the solution pH, initial concentration, adsorbent concentration, particle size and agitation speed were kept constant at 6, 100 mg/L, 1 g/L, 105.5 μm and 200 rpm respectively. The effect of temperature on copper adsorption is shown in Fig. 4 by plotting adsorption capacity at 120 min as a function of temperature. It is evident from Fig. 4 that the adsorption of Cu(II) increases with decrease in temperature. At higher temperature, weakening of the attraction force between the adsorbate molecules increases which leads to decrease in adsorption capacity.
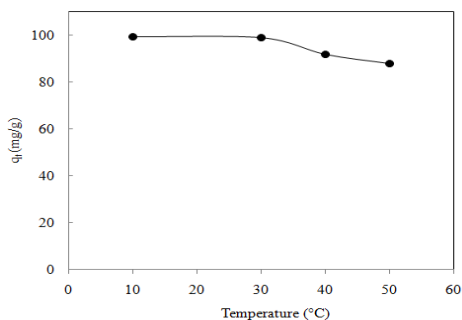

Fig. 4: Effect of temperature on the adsorption of Cu(II)

Effects of particle size and agitation speed: The effects of particle size and agitation speed on the adsorption of Cu(II) from the effluent were studied at constant solution pH, initial concentration, adsorbent concentration and temperature of 6, 100 mg/L, 1 g/L and 30 °C respectively. The particle size was varied from 105.5 to 375 μm (Fig. 5).
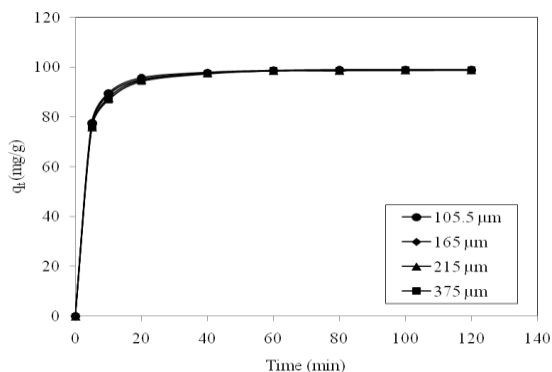

Fig. 5: Effect of particle size on the adsorption of Cu(II)

It is observed from Fig. 5 that the particle size does not have any significant effect on Cu(II) adsorption. It confirms that internal mass transfer is negligible. Therefore, successive experiments were conducted using particle size of 105.5 μm.

The effect of agitation speed on the adsorption of Cu(II) from the effluent was studied at a constant particle size of 105.5 μm and by varying the agitation speed from 100 to 400 rpm (Fig. 6). The adsorption of Cu(II) is found to be increased from 96.66 to 97.1 mg/g with increasing the agitation speed from 100 to 200 rpm. As the agitation speed increases no significant adsorption is observed as shown in Fig. 6. Similar trend was also observed in the previous literature (Khattri and Singh, 2009). Therefore, 200 rpm was kept constant for this study.
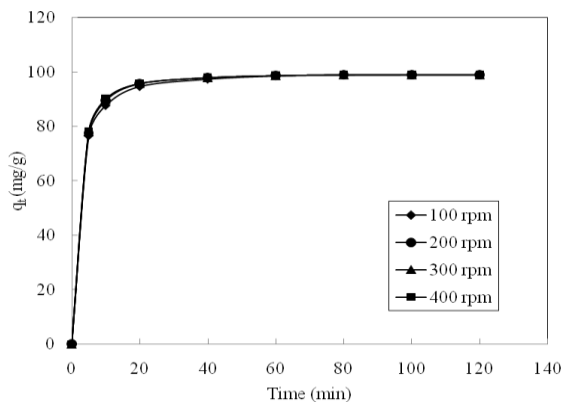

Fig. 6: Effect of agitation speed on the adsorption of Cu(II)

E. Kinetic study

The pseudo-first-order and pseudo-second-order kinetic models were used for the kinetic analysis. The values of the adsorption parameters at three different temperatures are shown in Table 2.

TABLE 2
Kinetic Study at Different Temperatures

Model	Parameters	Temperature (°C)		
		10	30	50
Pseudo-first-order	q_e (mg/g)	89.331	87.7	75.162
	k_1(min-1)	0.237	0.233	0.23
	R^2	0.977	0.969	0.947
Pseudo-second-order	q_e (mg/g)	100	100	90.909
	k_2 (g/mg-min)	0.016	0.017	0.015
	R^2	0.995	0.995	0.999

The applicability of the models is determined through comparing the values of correlation coefficient (R2). It is noted from the comparison (shown in Table 2) that the experimental data fits well with the pseudo-second-order model as it has comparatively higher values of correlation coefficient (R2 = 0.999) for all the three temperatures. The result obtained is in well agreement with previous literature (Bouhamed et al., 2012).

IV. CONCLUSION

In the present work, the adsorption of Cu(II) ions from industrial waste water was efficiently done by using microwave assisted activated carbon. The effects of different experimental parameters on Cu(II) adsorption were investigated. After series of batch studies it was found that the residual Cu(II) concentrations were below the WHO prescribed limit of 1.5 mg/L.

The maximum removal of Cu(II) was noted at pH 6. The adsorption kinetic data was satisfactorily fitted with the pseudo-second-order kinetic model. The adsorption of Cu(II) was found to increase with decrease in temperature confirming the process of adsorption to be exothermic in nature.

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