Removal of Copper From Aqueous Solutions by Adsorption Technique onto Low Cost Material

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Abstract—Environmental pollution due to the development in technology is one of the most important current problems and of the future. Heavy metals such as copper, lead, …etc in wastewater are hazardous to the environment. These metals cannot be degraded or readily detoxified biologically and have tendency to accumulate in living materials. Also, heavy metals in the wastewater discharged to main water bodies can be toxic to aquatic life and render natural waters unstable for human consumption.

Copper (*Cu*) is a priority metal pollutant introduced into water bodies from many industrial processes such as metallurgical industry, fertilizers manufacture, paint manufacture and petroleum refining. An effort has been made in the present study to evaluate the potential of locally prepared activated carbon (LPAC) prepared from oil cake waste as an adsorbent (a low cost material) to remove *Cu* from aqueous solutions by adsorption technique. The effect of various parameters such as initial concentration of *Cu*, contact time, and solution pH on adsorption efficiency were studied during batch experiments at room temperature. The experimental results obtained during the study fitted well with Langmuir isotherm better than Freundlich isotherm. The maximum adsorption capacity of LPAC was high, that indicated the suitability use of LPAC. The percentage removal of *Cu* from aqueous solutions was high especially for solutions that had initial concentrations less than 100 *ppm*. The results obtained from this study show that, the LPAC can be used as low cost material for reliable removal of *Cu* from water and wastewater effluents.

Keywords— Adsorption Isotherm, Activated Carbon, Copper, Wastewater Treatment.

I. INTRODUCTION

Activated carbons, made from a wide range of natural and synthetic precursors have a long history of use in adsorption technology. The use of these inert materials as adsorbents utilizes their large surface area and pore volume size for superior adsorption and avoids complications associated with leachate of plasticizers and other toxins from polymer based systems [1,2]. Recently, the development of activated carbon from locally available materials has gained considerable attention in wastewater treatment strategies.

Effective activated carbons can be prepared from easily available plant wastes which generally create disposal problems. The adsorption capacity of materials can be increased by activation processes that enlarge the pore diameter leading to a significant increase in pore size. During activation, the textural properties of the materials may also change. The most commonly employed activation processes are chemical activation (liquid phase) and physical activation (gas phase). In chemical activation process, carbonization and activation are carried out in a single step by the thermal decomposition of the raw material treated with certain chemicals such as H_3PO_4, $NaOH$, KOH, $ZnCl_2$, $MgCl_2$, K_2CO_3 or Na_2CO_3. These chemicals may act as templates for the creation of microporosity. The physical activation involves oxidation and gasification of the material at higher temperatures. The temperatures used in chemical activation are also lower than those used in physical activation process. Therefore the material gets a better pore structure after a chemical process [3]. The enhanced pore volume and pore diameter of activated carbons may help increase in adsorption of solute from aqueous solutions. Earlier researchers in this direction produced high efficient activated carbons from waste materials for the treatment of anionic pollutants from wastewaters.

The present work deals with the utility of local prepared activated carbon (LPAC) prepared from local oil cake waste, low cost as well as nonhazardous material for the removal of copper (*Cu*) from aqueous solution. Batch adsorption experiments were performed to evaluate the effect of pH, initial copper concentration, contact time, adsorbent dose and ionic strength for the adsorption of *Cu* onto LPAC. The isotherm plots were determined experimentally by conducting equilibrium adsorption studies and the results are presents in this work.

II. MATERIALS AND METHODS

A. Preparation and properties of LPAC

The LPAC were beneficiated by using $ZnCl_2$ solution. After dried under sunlight, wastes crashed, grounded and screened, the wastes blending with KOH solutions were oxidant and surfactant at the activated temperatures. The characteristics of LPAC are: surface area 417-500 m^2/g and bulk density 270.5 kg/m^3.

B. Adsorption Experiments

The adsorbate use for all adsorption studies was obtained by preparing a stock solution of copper (1000 mg/l) using distilled water in a borosil made standard flask. Experimental solutions of copper having known initial concentrations were prepared by diluting the stock solution in stoppered conical flasks. The pH of the experimental solution was adjusted by adding different concentrations of HCl or $NaOH$ solutions. Batch adsorption experiments were conducted. The concentrations of residual Cu were measured using a spectrophotometer equipment (UV-Visible spectrophotometer Unicam 8700). The effect of pH on copper adsorption was studied using an initial concentration of 60 mg/l. The pH of each sample was adjusted between 3 and 7 (because the copper solutions would deposit at the pH>7). The pH adjusted solutions were kept for a contact time of 2 hrs at an agitation speed of 300 rpm in a temperature controlled water bath shaker at 30 ^oC. The residual copper concentration of each sample was measured. The optimum pH for the adsorption process was confirmed from the above experiment. Isotherm studies were performed to evaluate the adsorption capacity and energy of adsorption. All experiments were carried out in duplicate and showed differences less than 3%.

III. RESULTS AND DISCUSSION

A. Effect of PH on Copper Adsorption

Initially batch adsorption studies performed to study the influence of pH on the adsorption of copper onto LPAC from aqueous solutions. The copper adsorption was conducted using an initial concentrations of 60 mg/l over a pH range of 3-7 at 30 ^oC. Fig.1 shows that as the pH increases the amount of copper adsorption increases up to pH 5 in which the maximum removal of copper is 91% . In the case of LPAC a pH range of 4-6 is more suited for the quantitative removal of copper from aqueous solution. The variation in the amount of adsorption clearly indicated the influence of pH on adsorption process. Therefore pH=5 was selected as optimum value for conducting further adsorption experiments.
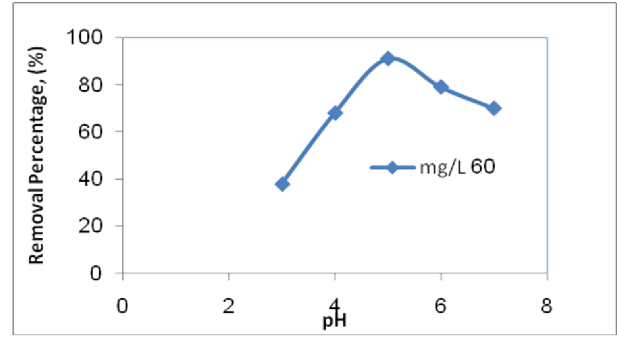

Fig.1 Removal percentage of Cu versus pH for batch process, at (30 ^oC temperature, agitation rate 300 rpm, adsorbent dose =1 g/l, contact time= 2 hrs and initial conc.=60mg/l)

B. Effect of Contact Time and Initial Concentrations

Adsorption of Cu by LPAC was carried out at (30 ^oC, 300 rpm and pH=5) with various initial concentrations are shown in Fig.3. The amount of Cu adsorbed by LPAC increased with increase in contact time and attained equilibrium at 5 and 10 min. for initial concentrations ranged between 60-120 mg/l. The curves shown in Fig.2 present the initial portion of the curve rises linearly and is changed into a curve and levels of 30 min. of contact time in the case of LPAC, after which there is no clear change in adsorption. The pleatue portion of the curve corresponds to pore diffusion and the linear portion of the curve reflects surface layer diffusion.

The effect of initial concentrations on the adsorption of copper on LPAC is depicted in Fig.2. The amount of adsorption increased with increase in initial concentration of Cu, however, the percentage adsorption decreased. At higher concentrations the ratio of the initial number of moles of Cu to the available adsorption sites is high; hence the fractional adsorption becomes dependent on initial concentration.
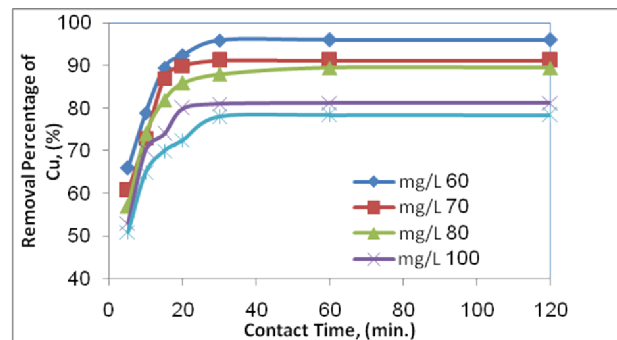

Fig.2 Variation of Cu Removal percentage versus contact time at (30 ^oC, agitation rate 300 rpm, pH=5 and adsorbent dose=1 g/l)

C. Adsorption Isotherm

Equilibrium studies were performed to evaluate the best fit isotherm model for explaining the adsorption of Cu onto LPAC. Isotherm studies were meant for evaluating the adsorption capacity and energy of adsorption of activated carbons. The equilibrium data were analyzing using the

following linearized formula of Langmuir and Freundlich isotherm models;

$$\frac{C_e}{q_e} = \frac{C_e}{Q_0} + \frac{1}{Q_0 b} \qquad (1)$$

$$\log(q_e) = \log(K_F) + \frac{1}{n}\log(C_e) \qquad (2)$$

The equilibrium adsorption studies were conducted using various initial concentrations of *Cu* at pH=5 and 30 ^oC. The isotherm of Langmuir and Freundlich models were obtained by plotting C_e/q_e versus C_e and $logq_e$ versus $logC_e$ as shown in Figs (3) and (4) respectively.
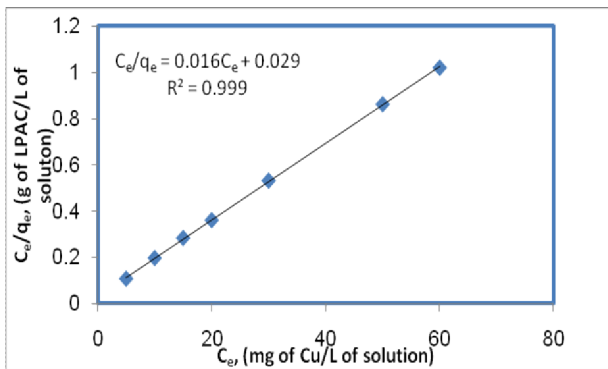

Fig.3 Langmuir isotherm for adsorption of *Cu* by LPAC at (30 ^oC, agitation rate 300 rpm, pH=5, adsorbent dose=1 *g/l* and initial conc.=60 *mg/l*)

The values of correlation coefficients for the adsorption of copper on LPAC from the system are presented in Table.1 from which Langmuir isotherm model found to well fit to experimental data more than Freundlich isotherm.
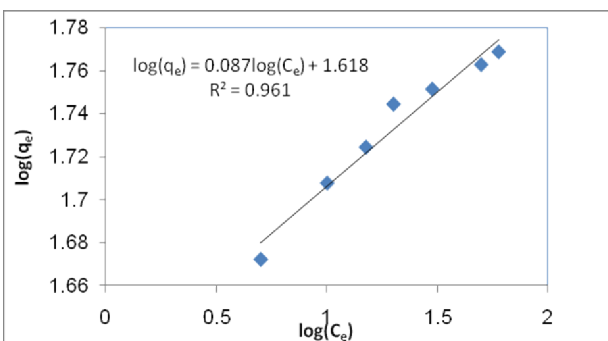

Fig.4 Freundlich isotherm for adsorption of Cu by LPAC at (30 ^oC, agitation rate 300 rpm, pH=5, adsorbent dose=1 *g/l* and initial conc.=60 *mg/l*)

IV. CONCLUSIONS

Activated carbon prepared from oil cake waste was found to be a suitable adsorbent material for the removal of copper from water and wastewaters. The removal process is highly pH dependent and best results were obtained at pH=5. The equilibrium in the solid-solution interface was best explained by Langmuir adsorption isotherm and the adsorption capacity of LPAC for the removal of *Cu* was found to be 62.5 *mg/g* at 30 ^oC. So, the present study shows the feasibility of the practical use of as an adsorbent LPAC as a low cost adsorbent for the effectively removal of *Cu* from aqueous solutions.

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