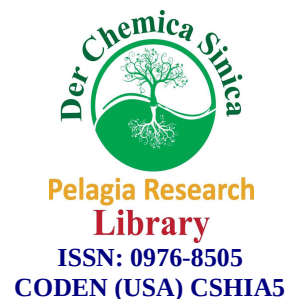




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The removal of copper from aqueous solution using commercially activated carbon

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ABSTRACT

In the present study, commercially activated carbon was investigated as a adsorbent for the removal of copper ions from aqueous solutions. Batch adsorption studies showed that commercially activated carbon was able to adsorb Cu(II) ions from aqueous solutions in the concentration range of 100 – 200 mg L⁻¹. The adsorption was favoured with maximum adsorption at pH 5, whereas the adsorption starts at pH 1. The effects of contact time, initial concentration of metal ions and adsorbent dosage have been reported. The applicability of Langmuir and Freundlich isotherms were tried for the system to completely understand the adsorption isotherm processes. Among these two isotherm models, the adsorption of Cu(II) ions on SUC fits very well with Langmuir adsorption isotherm which indicates the monolayer adsorption process. The commercially activated carbon was found to be cost effective and has good efficiency to remove copper ions from aqueous solution.

Keywords: Activated carbon, Adsorption, Copper, Aqueous solution

INTRODUCTION

The presence of toxic heavy metals in industrial effluents has become a matter of environmental concern. Copper(II) is known to be one of the heavy metals and widely used in many industries including metal cleaning and plating, paper board, printed circuit board, wood pulp, fertilizer, paints and pigments, etc.[1].The effluents in these industries usually contain a considerable amount of copper, which spreads into the environment through soils and water streams and accumulates along the food chain, resulting in a high risk to human health, as high concentrations of copper will cause stomach upset and ulcer, mental retardance, liver and brain damage, and so on. As copper(II) does not degrade biologically, the control of Cu(II) pollution has special importance for both organisms that live in waters and those that benefit from waters.

Different methods of treating wastewaters containing heavy metal ions have been developed over years which include coagulation, ion- exchange, membrane separation, reverse osmosis, solvent extraction, chemical precipitation, electro flotation, etc. Among these methods, adsorption is a much preferable technique for the removal of heavy metals from polluted waters compared to others due to ease of operation and cost- effective process.

In recent years, considerable attention has been focused on the removal of copper from aqueous solution using adsorbent derived from low-cost materials. Several adsorbents such as saw dust, silica and iron oxide, sewage sludge ash, anatase-type titanium dioxide, olive mill residues, inorganic colloids, blast furnace sludge and activated carbon have been used for the treatment of Cu(II)-rich effluents at the solid-solution interface. The material selected for

adsorption of copper (II) ions in this study is commercially activated carbon. It is purchased commercially from a scientific company. Commercially activated carbon is a low cost adsorbent material. The present paper investigates, in detail, the adsorption of copper by activated carbon. In this study the name of the adsorbent is abbreviated as AC.

MATERIALS AND METHODS

2.1 Purchasing of Adsorbent

Activated carbon is purchased commercially from Precision Scientific Company, Tiruchirappalli, Tamilnadu, India.

2.2 Adsorbate Solution

A stock solution of Cu(II) (1000 mgL^{-1}) was prepared by dissolving $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in distilled water. The solution was further diluted to the required concentrations before use.

2.3 Batch Adsorption Experiments

Adsorption experiments were carried out in batches of 50 ml of 200 mgL^{-1} of copper(II) solution with 0.2g of commercially activated carbon. pH of the solution was kept at 4 for all experiments unless otherwise mentioned. The pH values of solutions were adjusted with dilute HCl or NaOH solution by using Systronics digital pH meter 335 with combined glass electrode. The temperature of the experiments was maintained at $305 \text{ K} \pm 1$. The solutions were shaken in a mechanical rotary shaker at 225 rpm for 60 minutes to study the effect of pH, carbon dosage and concentration and then filtered using whatmann no. 40 filter paper and copper concentration was measured by using Systronics spectrophotometer.

To examine the effect of pH, adsorption experiments were conducted at different pH ranging from 1 to 5 at 200 mg L^{-1} of Cu (II) solution. The optimum pH was determined from this study. [4] The adsorption studies were also conducted in batch experiments as function of adsorbent dosage (0.1g to 0.8g) and metal ion concentrations ($50, 100, 150, 200, 250, 300 \text{ mg L}^{-1}$) for maximum adsorption.

The percentage of Cu(II) ions adsorption by SUC was computed using the equation:

$$\% \text{ adsorption} = \{C_i - C_e / C_i\} * 100 \quad \text{-----}(1)$$

Where C_i and C_e are the initial and equilibrium concentration of Cu(II) ions (mgL^{-1}) in solution. Adsorption capacity was calculated by using the mass balance equation for the adsorbent

$$q = (C_i - C_e) V / W \quad \text{-----}(2)$$

where q is the adsorption capacity (mg/g), C_i is the initial concentration of metal in solution (mg L^{-1}), C_e is the equilibrium concentration of metal in solution (g L^{-1}), V is the volume of metal ion solution (L) and W is the weight of the adsorbent (g).

RESULTS AND DISCUSSION

3.1 Effect of pH

pH of the solution is the most important parameter affecting metal ion adsorption. This is because hydrogen ion competing with the positively charged metal ions on the active sites of the adsorbent[2]. The effect of pH on the adsorption of Cu(II) ions on AC has been studied by varying it in the ranges of 1 to 5 as shown in fig (1). As shown in fig (1), the uptake of Cu(II) ions depends on pH, it increases with the increase in pH reaching the maximum adsorption at pH 5. Above pH 5 precipitation of Cu(II) ions occurred.

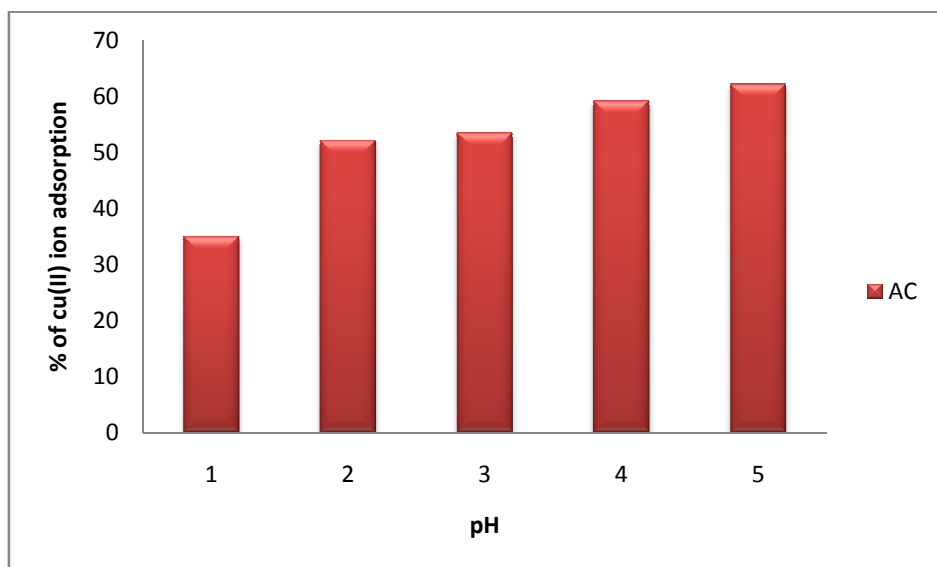


Fig. 1. Effect of pH on the adsorption of Cu(II) ions (initial concentration = 200 mg L^{-1} , temperature = 305 K , contact time = 60 min and adsorbent dosage = 4.0 g/L)

3.2 Effect of Adsorbent Dosage

The adsorption studies of Cu(II) ions on AC were done at $305 \pm 1 \text{ K}$ temperature by varying the quantity of adsorbent from 0.1 to 0.8 g while keeping the volume of the metal solution constant at pH 4 . The influence of adsorbent dosage in percent adsorption of Cu(II) ions is shown in fig (2).

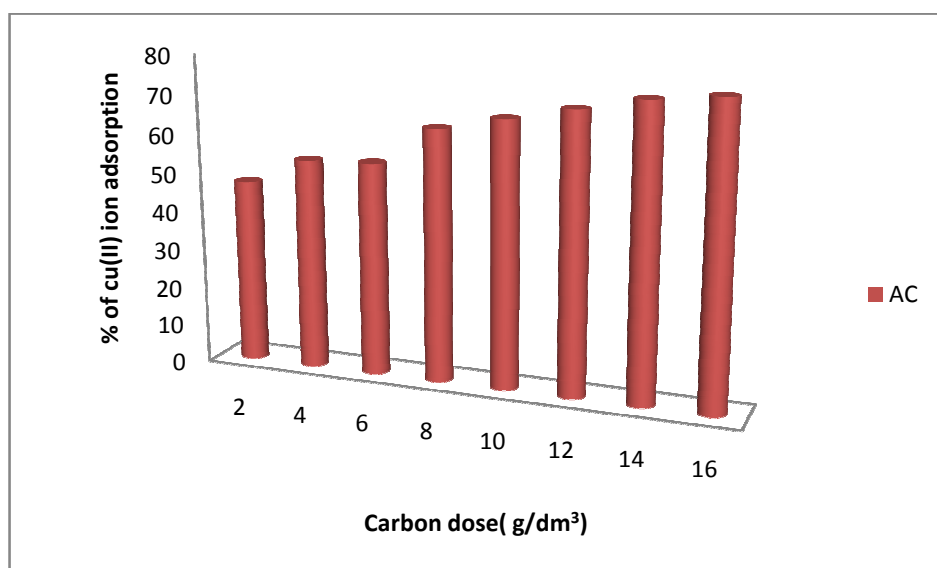


Fig. 2. Effect of adsorbent dosage on the adsorption of Cu(II) ions (initial concentration = 200 mg L^{-1} , temperature = $305 \pm 1 \text{ K}$, contact time = 60 min and pH 4.0)

The results from fig 2 indicates that the adsorption increased with the increase in the dose of the adsorbent. The increase in the adsorption percentage is due to the increase in active sites on the adsorbent and thus making easier penetration of the metal ions to the adsorption sites.

3.3 Effect of Initial Cu(II) ion Concentration

In batch adsorption processes, the initial metal ion concentration of metal ions in the solution plays a key role as a driving force to overcome the mass transfer resistance between the solution and solid phase^[2]. The effect of initial metal ion concentration ranging from 100-300 mg/L⁻¹ on AC was studied by taking different concentrations of CuSO₄ solutions at pH 4, while keeping the dosage of the adsorbent 4g/L constant and temperature at 305 ± 1 K. This result is shown in fig (3)

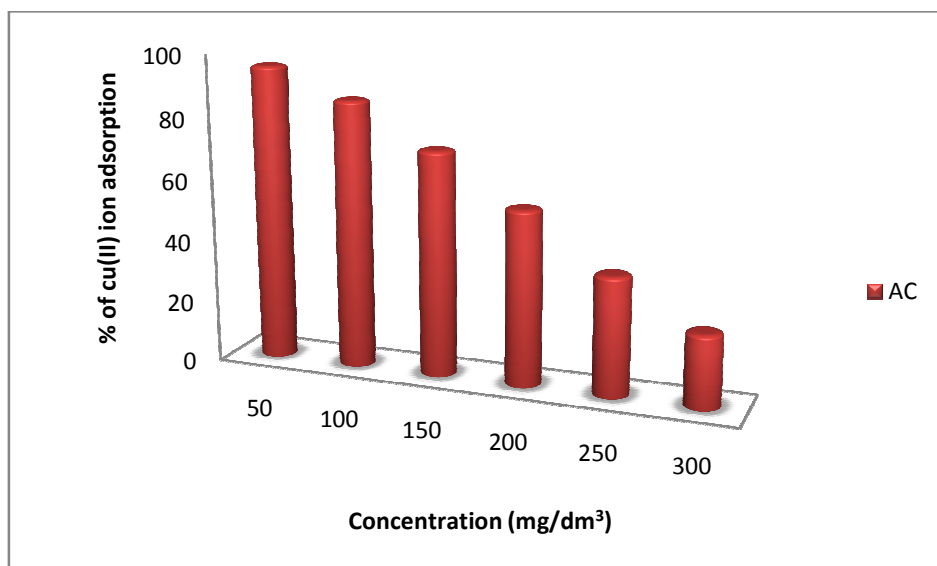


Fig. 3. Effect of initial metal concentration on the adsorption of Cu(II) ions (contact time = 60 min, pH 4.0, temperature = 305 ± 1 K, and adsorbent dosage = 4.0g/L)

It is indicated from the fig (3) that the percent adsorption decreases with the increase of initial metal ion concentration. As a result of the above observations, it is indicated that the adsorption process of Cu(II) ions on AC has to be dependent on concentration of the metal ion solution up to some extent.

3.4 Adsorption Isotherm:

The equilibrium adsorption isotherms are of fundamental importance for the design of adsorption systems since they predict how metal ions will partition between adsorbent and liquid phases at equilibrium as a function of metal concentration.

The simplest adsorption isotherm is based on the assumptions that every adsorption site is equivalent and that the ability of a particle to bind there is independent of whether or not adjacent sites are occupied. Langmuir and Freundlich isotherm are commonly used in batch adsorption studies. Hence these two isotherms have been analyzed for Cu(II) ion adsorption.

3.5 Langmuir Isotherm

This model assumes that the adsorptions occur at specific homogeneous sites on the adsorbent and is used successfully in many monolayer adsorption processes^[3] The data of the equilibrium studies for adsorption of Cu(II) ions onto AC may follow the following form of Langmuir model:

$$C_e/q_e = (1/Q_0) * C_e + 1/b Q_0 \quad \text{-----}(3)$$

Where C_e is the equilibrium concentration (mg/dm³); q_e is the amount of Cu(II) ions adsorbed at equilibrium (mg/g); Q_0 and b are Langmuir constants related to adsorption capacity (mg/g) and energy of adsorption (dm³/mg) which reflects quantitatively the affinity between the adsorbate and adsorbent. The values of Q_0 and b can be obtained from the slope and intercept of a plot of C_e/q_e against C_e respectively. Fig (5) shows Langmuir isotherm model for Cu(II) ions on AC.

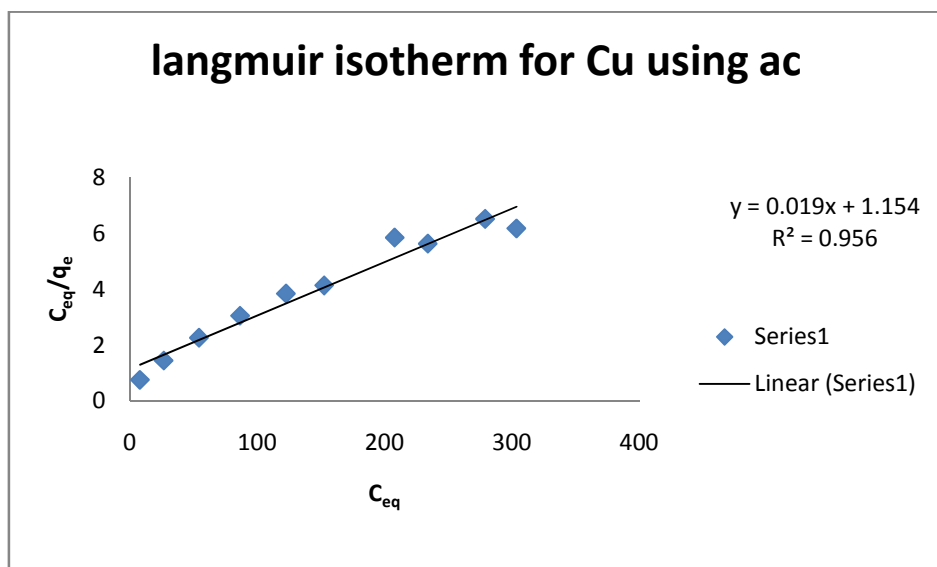


Fig. 4. Langmuir adsorption isotherm plot for the adsorption of Cu(II) ions at 305±1 K

Table 1 Langmuir adsorption isotherm parameters and correlation coefficients for the adsorption of Cu(II) ions on AC at 305±1 K.

Langmuir Parameter	
Q_0	52.63158
b	0.016464
R^2	0.956

The high value of correlation coefficient R^2 from table 1 indicates that the adsorption of Cu(II) ion by AC follows Langmuir isotherm model. The table 1 also gives information about the adsorption capacity (Q_0) and energy of adsorption b of AC.

The essential characteristics of Langmuir isotherm can be expressed in terms of a dimensionless constant separation factor or equilibrium parameter, R_L which is defined by [1],[4]

$$R_L = 1 / (1 + bC_0) \quad \text{-----(4)}$$

Where b is the Langmuir isotherm constant and C_0 is the initial Cu(II) concentrations. R_L value indicate the type of isotherm. The adsorption process as function of R_L may described as [4]

$R_L > 1$ unfavourable

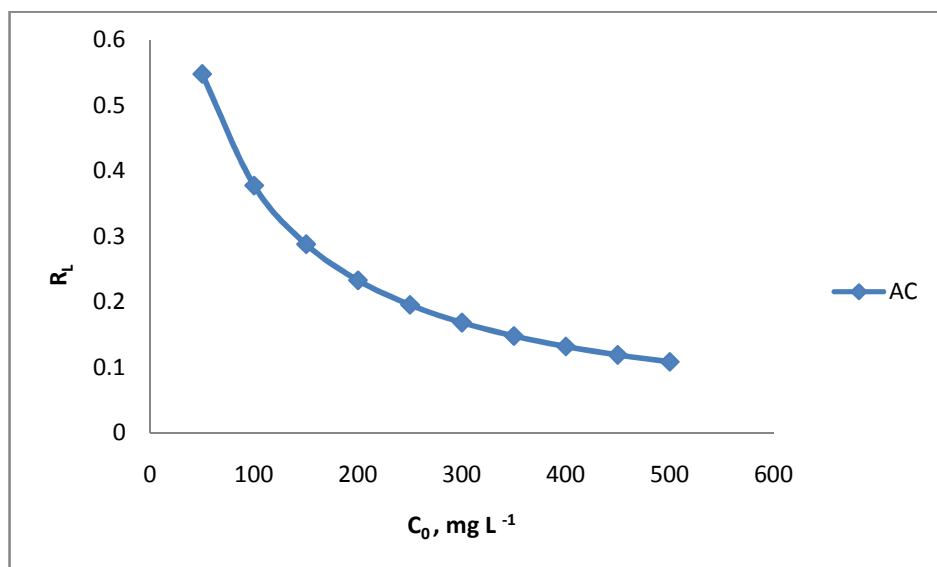
$R_L = 1$ Linear

$0 < R_L < 1$ favourable

$R_L = 0$ irreversible

R_L values were calculated for AC for the adsorption of Cu (II) ion and are shown in fig (6)

In the present study, the calculated R_L value for adsorption of Cu(II) ions on AC obtained at 305 ±1 K based on Langmuir isotherm for the adsorption of Cu(II) ion onto AC was found to be $0 < R_L < 1$ and this indicates a highly favourable adsorption within the concentration range of 50 – 500 mgL⁻¹ [6]

Fig. 5. Plot of R_L Vs. initial Cu(II) concentration

3.7 Freundlich model

The Freundlich model can be applied for non-ideal sorption on heterogenous surfaces and multilayer adsorption. It is expressed by the following equation

$$q_e = K_f C_e^{1/n} \quad \text{-----(5)}$$

The equation may be linerized by taking logarithms

$$\log(q_e) = 1/n \log C_e + \log(K_f) \quad \text{-----(6)}$$

The Freundlich intensity of adsorption ($1/n$) and adsorption capacity K_f were calculated from slope and intercept of the plot of $\log(q_e)$ against $\log(c_e)$ respectively which is shown in Fig (7).

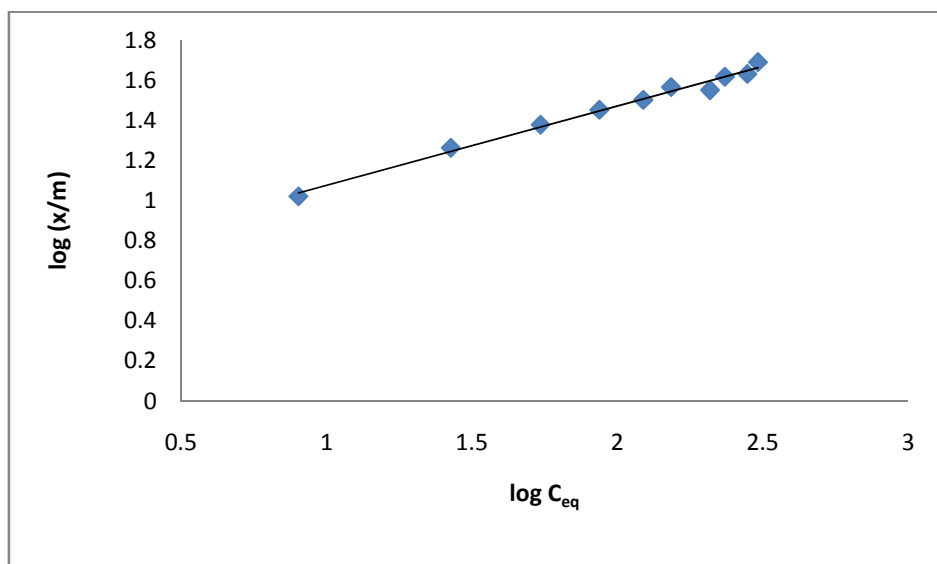


Fig. 6. Freundlich adsorption isotherm plot for the adsorption of Cu(II) ions at 305±1 K

Table 2 Adsorption isotherm model parameters and correlation coefficients for the adsorption of Cu(II) ions on AC at 305±1 K.

Freundlich Parameters	
1/n	0.395
K _F (mg/g)	4.7973
R ²	0.987

From the table (2), the Freundlich constant, 1/n denoting the intensity of adsorption indicates a favourable adsorption since $1/n < 1$ [5],[6] the adsorptions of Cu(II) ions onto AC studied had been more favourable. The adsorption capacity (K_F) obtained for different adsorbents has been comparable, among them AC shows highest value of adsorption capacity.

CONCLUSION

This work clearly indicates the potential of using activated carbon as an excellent adsorbent for the removal of Cu(II) ions from aqueous solutions. The amount of Cu(II) ions adsorbed onto the AC increased with an increase in pH and dosage of adsorbent. The optimum pH was found as pH 5 for the removal of Cu(II) ions by AC. On increasing the adsorbent dosage, the adsorption percentage also increases. The equilibrium data was analyzed for the Langmuir and Freundlich isotherm model. Among these two isotherms, Freundlich isotherm fitted well with the experimental data than Langmuir isotherm. This confirms the multilayer adsorption of Cu(II) ions on AC. Taking into consideration of the above results, it can be concluded that the activated carbon is a suitable adsorbent for the removal of Cu(II) ions from aqueous solution in terms of low cost and natural material.

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