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ADSORPTION CAPACITY OF EGGSHELL POWDER FOR THE REMOVAL OF COPPER FROM SIMULATED WATER AND WASTEWATERS

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ABSTRACT

The efficiency and Characteristics of eggshell powder were investigated as a low-cost adsorbent for the removal of different heavy metal ions from aqueous solution. Potential of eggshell powder indicates that it isan effective adsorbent, due to high concentrations of carbon and calcium and high porosity and availability of functional groups. Adsorption experiments were studied with varying pH, contact time, and adsorbate concentration. Maximum percentages of heavy metal ions removal were recorded at optimum pH, contact time and adsorbent dose. Determination of the isotherms and kinetics confirmed that eggshell powder has high value of adsorption capacity. This experiment demonstrated the ability of eggshell powder as an effective, sustainable, and low-cost adsorbent for removal of the heavy metal ions in different wastewaters.

KEYWORDS: Adsorption capacity, Eggshell Power, Heavy metals,simulated water, pH.

1. INTRODUCTION

Chemical substances such as heavy metals, organic and synthetic compounds generated from industrial activities have resulted in deterioration of the ecosystem due to improper discharge. Unlike other pollutants, heavy metal contamination has gained relatively more significance in view of their persistence, bio-magnification and toxicity. Heavy metal contamination exists in aqueous wastes of many industries, such as metal plating, mining operations, tanneries, radiator manufacturing, smelting, alloy industries and storage batteries manufacture.[1] Among different toxic metals copper is of particular concern in wastewater treatment. Copper as an essential element plays an important role in all living organisms. It is widely used in industries due to its high electrical and thermal conductivity, good corrosion resistance, ready availability, high recyclability and attractive appearance.[2] Copper (II) is one of the heavy metals most toxic to the living organisms and it is one of the widespread heavy metal contaminants of the environment. Intake of Cu contaminated water can causes hemolysis, hepatotoxic and nephrotoxic affects vomiting, cramps, convulsions, or even death.[3] Treatment processes for metal removal from wastewaters include precipitation, membrane filtration, ion exchange, adsorption and co-precipitation/adsorption. Cost-effective alternative technologies or adsorbents for the treatment of metal- containing wastewaters are needed. Natural materials that are available in large quantities, or certain waste plant products, may have potential as inexpensive adsorbents. Due to their low cost, after these materials have been expended, they can be disposed of without regeneration. Generally, adsorbents can be assumed as low cost if they require little processing, are abundant in nature, or are a by-product or waste material from another industry.[4] Reports have appeared on the preparation of activated carbons derived from rice husk[5], rice hull[6], palm kernel shell[7], saffron leaves[8], sorgum vulcaris dust[9], coir pith[10], couroupita guianensis[11], pongamia pinnata leaf[12] and sunflower stem[13] have been used to remove metal ions from water solution.

Pongamia leaf is a low cost adsorbent which is biodegradable and agro- waste which may act as a significant material for copper adsorption. Pongamia leaf waste is discarded all over the world as useless material. It is causing waste management problems though it has some compost, medicinal and adsorbent potentiality. It is an abundant, readily available, low cost and cheap, environment friendly bio-material.

Thus, the purpose of this work was to investigate the adsorption capacity of eggshell powder to remove copper ions from the aqueous solution. The experiments were done to evaluate the effectiveness of adsorbent dosage, pH, contact time, initial metal ion concentration and temperature for the maximum removal of copper from aqueous solutions and the results were presented in a simplified and systematic way.

2. MATERIALS AND METHODS

2.1 Preparation of adsorbate solutions

The copper stock solution (0.5M) was prepared using analytical grades of $CuSO_4 \cdot 5H_2O$. The test solutions were prepared by dilution to the desired concentrations of copper solution. The pH of the solution was adjusted using 0.1M HCl and NaOH solutions. All biosorption experiments in this study were carried out in 250 ml Erlenmeyer flasks with a working volume of 100 ml Cu(II) solution. The flasks were agitated on a rotary shaker set at 140 rpm speed and at $25^{0}C$ temperature. The biomass free supernatant obtained was analyzed for residual Cu(II) concentration was found out volumetrically using EDTA as titrant and muroxide indicator. The amount of metal ion adsorbed per gram of the adsorbent can be calculated. After adsorption, the final effluent solution was analyzed by Perkin Elmer Optima 2100DV model inductively coupled plasma optical emission spectrometry (ICP-OES).

2.2. Batch Adsorption Experimental Studies

Metal investigation was completed in the batch adsorption process. The adsorption studies were completed in the exploratory conditions of various effective process parameters of pH 2 - 6, contact time 1-150 min, metal ion concentration 100 mg/L, the weight of the eggshell power 0.05 - 5 gm. ZHICHENG analytical model thermal shaker was used for the batch experiments. Then it was analyzed using the Perkin Elmer Optima 2100DV model inductively coupled plasma optical emission spectrometry (ICP-OES). The pH measurements were performed with LABQUEST2 analyzer. The surface morphology of eggshell powder was investigated using a Fei Quanta FEG250 model field emission scanning electron microscope (SEM). The chemical composition of the adsorbent sample was determined by X-ray fluorescence machine.[14] The chemical composition of the eggshell powder shows that calcium oxide (CaO) was the most abundant component. Thus, the adsorbent sample can be considered from a chemical viewpoint a pure relatively natural carbonate-based material.[14] The chemical composition of eggshell adsorbent was given below:

Table 1: Chemical composition of Eggshell Powder Adsorbent.

Chemical Constituents	Percentage by weight
CaO	76.992
C	21.128
MgO	0.926
P_2O_5	0.415
SO_3	0.326
Na_2O	0.105
K_2O	0.054
SrO	0.039
Fe_2O_3	0.013

The experiments were carried out by contacting precisely weighted samples of adsorbent with 100 mL of Cu(II) solutions in the sealed 250 ml flask. The suspensions were conducted on a thermal shaker at a shaking speed of 140 rpm at 25°C. After the specified time, suspensions were filtered through filter study 0.45 µm pore size membrane filters. The initial pH of the solution was adjusted to the desired pH by adding HCl or NaOH solutions. After adsorption, the mixtures were filtered and the filtrates were analyzed for Cu(II) content using an ICP-OES (Perkin Elmer Optima 2100DV) at 261.42 nm.

2.3. Copper Adsorption Capacity

The experiments were performed at different process variables for the Eggshell Powder, the amount of Cu(II) deposited onto adsorbent surface utilizing the accompanying mathematical expression:

$$qe = \left[\frac{Co - Ce}{Co}\right].\left[\frac{V}{1000\,w}\right] \quad \text{........(1)}$$

Where, qe is the amount of Cu(II) deposited on adsorbent (mg/g), Co is the initial solute concentration in the solution before adsorption (mg/L), Ce is the final concentration of solute in the solution after adsorption (mg/L), V is the volume of the metal solution (L) and w is the weight of the adsorbent. Adsorption system was quantified by calculating the adsorption percentage as defined,

$$\text{Percentage Adsorption} = \left[\frac{Co - Ce}{Co}\right]100 \quad \text{.........(2)}$$

Adsorption experiments were performed and the mean values of instances were submitted. In addition, blank examples (with deionized water, without Cu(II)) were used to compare the results through all batch adsorption procedures. Data submitted are the mean values from the adsorption tests, standard deviation (≤ 5%) in figures. The experimental data were fitted to the kinetic, isotherm models. The best-fit model indicates the most probable adsorption mechanism.

3. RESULTS AND DISCUSSION

3.1. Determination of Contact Time for adsorbent

The contact time is the key parameter for the selection of adsorbent for the adsorption process. The batch adsorption experiments were conducted for 100 mg/L Cu(II) concentration with the function of contact time and removal efficiency of adsorbent are demonstrated in Figure 1. The removal efficiency of Cu(II) increases gradually with increasing contact times and reaches equilibrium at around 80 min, at this point the maximum amount Cu(II) is removed from the solution. Figure 1 indicates that the adsorption efficiency, increased from 48.88 to 75.99% at a contact time of 80 min with 100 mg/L Cu(II)concentration. At this optimum contact time, the clump of the batch experiments was led to make sure that equilibrium is reached.

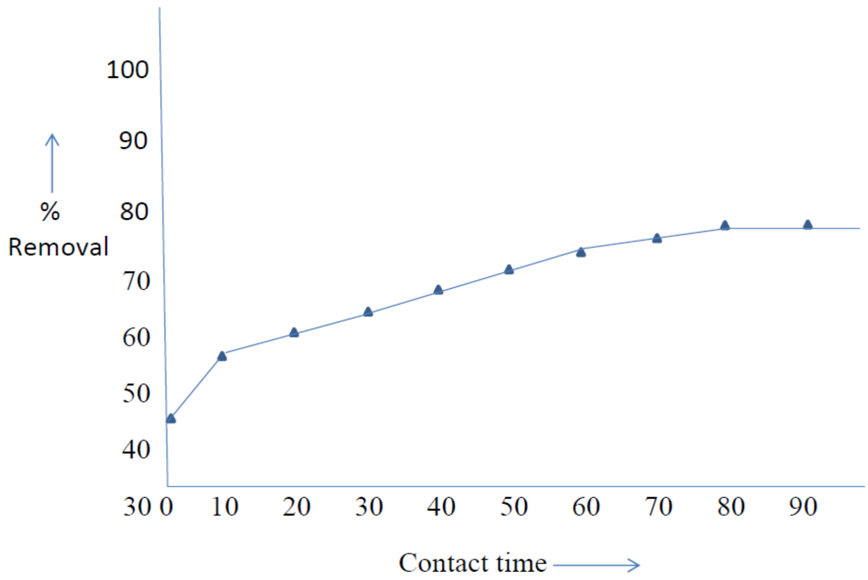

Figure 1: Effect of contact time on percentage removal of Cu(II).

3.2 Effect of Hydrogen Ion Concentration (pH)

The variation of pH is highly effected on the adsorption process for the removal of Cu(II) from wastewater using eggshell powder as an adsorbent. The initial pH of solution is a significant control parameter for the evaluation of adsorption performances.[15] The effect of pH on adsorption of Cu(II) at 25^{0}C for constant concentration and time of adsorption 80 min is shown in Figure 2. It was observed that the pH of the solution varies from 2.0 to 6.0 the adsorption efficiency is very low because repulsion is taking place between solution and adsorbent. The adsorption efficiency is slowly increasing with pH (3.0 to 6.0) of the solution, because the effluent solution is exposed to the negative charges and strongly attracting the Cu(II) ions with the adsorbent surface. The solution pH value is increased 3.0 to 5.0; leads undergo hydrolysis process forming a precipitation of $Cu(OH)_2$ and $Cu(CO_3)_2$,dominate at high pH whereas Cu(II) and aqueous sulfate species dominate at lower pH (< 6). This subsequently leads to change the equilibrium conditions and the kinetics of the adsorption process. These studies were described that the potential of H^+ ions on the adsorbent surfaces is not metal specific. The maximum efficiency 64.04% is obtained at pH 5.0.

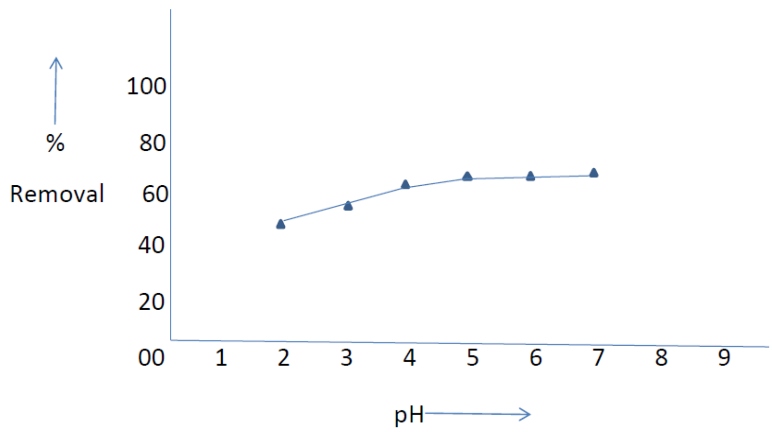

Figure 2: Effect of pH for the removal Cu(II).

3.3 Effect of Amount of Adsorbent

The adsorbent amount in aqueous solution is a momentous parameter in the adsorption works because it makes the capacity of an adsorbent for a given initial concentration of the adsorbate.[16] Effect of adsorbent amounts on the elimination yields of Cu(II) are indicating in Figure 3. It was observed that the Cu(II) removal was a function of adsorbent amounts in the aquatic solution. The amount of Cu(II) adsorbed increase from about 23.82% to 95.93% with an increase in amount of adsorbent from 0.05 to 5 gm. The maximum adsorption efficiency of Cu(II) onto the adsorbent was found to be 95.93% at the dose of 3.5 gm. It can be explained as adsorbent amount increased, more and more surface area available metal ions will be exposed to more active sites for binding.[17]

4. CONCLUSIONS

The present experimental study results indicated that the eggshell powder might be feasible successfully as an adsorbent of Cu(II) from aqueous solution. The adsorption of Cu(II) onto the adsorbent was found to be pH, contact time, and adsorbent amount depended. The optimum pH value for the experimental study was determined as 5.0. The maximum removal efficiencies by the adsorbent were obtained around 65 - 96% for Cu(II) under optimum conditions (pH=5.0, contact time = 80 minute, adsorbent amount = 3.5 gm, shaking speed= 140 rpm and 25^{0}C). It may be concluded that eggshell powder could be used, as a practical, effective and low-cost, high capacity adsorption, and abundant source to remove Cu(II).

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