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COCONUT SHELL : A CARRIER FOR THE REMOVAL OF BISMUTH FROM AQUEOUS SOLUTION

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ABSTRACT

The studies on removal of bismuth (III) were conducted using coconut shell. Adsorption efficiency has been evaluated. The effect of pH, contact time, adsorbent dose, concentration of metal, particle size and temperature were studied. The results reveal that Langmuir and Freundlich isotherms are followed during adsorption process. Thermodynamics parameters indicate the feasibility of the process. Kinetic studies have been performed to understand the mechanism of adsorption. Column studies have been carried out to compare these with batch capacities.

Key word: Trivalent bismuth, Adsorption, Langmuir isotherm, Freundlich isotherm, Coconut shell.

INTRODUCTION

The twentieth century started with an extensive damage to the natural resources[1]. Unplanned industrilization, urbanization, pollution explosion, change in life-style, over exploitation of natural resources, commercial establishment and modern agricultural practices have degraded the quality of environment. The main effects being faced are:

- Continental invasion of air and water.
- Marine pollution through waste discharges.
- Release of variety of chemical and biological contaminants into the water bodies, on land and in air.
- Ground water pollution.
- Acid rains and nuclear fallout.

These effects are not only covering the pollution of environment but also are responsible in creating genetic erosion in plants, animals including human beings and microorganisms. Water is a prime natural resource and is a basic human need. The availability of adequate water supply in terms of its quality and quality is essential for the existence of life.

Water is available in nature as surface water and ground water through the self purification mechanisms like physical, chemical and microbiological processes at natural bodies are carried out in nature. However, natural water is rarely suitable for direct consumption to human beings. Rapid industrialization and population growth resulted to generation of large quantities of wastewater and causing problem of their disposal. Industrial waste constitutes the major source of various kinds of metal pollution in natural water. The presence of heavy metals in the environment has been of great concern because of their increased discharge, toxic nature and other adverse effects on the receiving streams. When the concentration of toxic metal ions exceed tolerance limit, they may become real health concern[2]. There is an immediate need to introduce cleaner technologies to minimize the pollution and to protect the degrading environment. It is not possible to achieve zero waste discharge, but it is an essential to treat the waste.

Among the toxic heavy metal ions, which present potential health hazard to aquatic animals and human are Pb, Cd, Cr, V, Bi and Mn. The maximum tolerance limit for bismuth (III) for public water supply is 0.5 mg/L. Toxicity of metal depends on the type of metal, dose and the ionic form. Toxicity of bismuth (III) and its salt include malaise, kidney damage, albuminuria, diarrhea, skin reactions, tremor of the finger and hands and sometimes serious exodermatitis.

Literature survey reveals that there are many methods namely coagulation, precipitation, ion exchange and adsorption, for removal of bismuth (III) metal ions from aqueous medium. However, adsorption is an easy and economical process for removal and retrieval of cation from aqueous medium, efficiency of adsorption process mainly depends on nature of absorbent, absorbate, pH, concentration, temperature, time of agitation etc.

These cheap and efficient absorbents can cater the need of population in the rural areas and the population in the industrial area where safe drinking water is not available. In the present study, bismuth (III) has been removed by using coconut shell[4-9] as adsorbent.

EXPERIMENTAL

Adsorbent

The coconut shell was first dried at a temperature of 160^0C for 6 hours. After grinding, it was sieved to obtain average particle size of 200 mesh. It was then washed several times with distilled water to remove dust and other impurities. Finally, it was dried again in an oven at 50^0C for 6 hours. The adsorbent was then stored in desiccator for final studies.

Batch study

The dried amount of 0.5 g of Coconut shell was taken in 250 mL reagent bottle and synthetic solution (200 mL) containing various concentration of bismuth (III) ion was added and system is equillibrated by shaking the contents of the flasks at room temperature so that adequate time of contact is there between adsorbent and final concentration of metal ion. Bismuth (III) was determined spectrophotometrically[10] using hypophosphorus acid and potassium iodide method and absorbance was measured at 460 nm. The spectrophotometer, Systronic (Model 104) was used to measure the concentration of bismuth (III) ions.

Equillibrium adsorption isotherm for C verses q_e, plotted for coconut shell is shown in Fig. 1. The adsorption capacity in mg/L was calculated then the equation.

$$q_e = \frac{(C_0 - C_e)V}{M} \quad \ldots(1)$$

where, C_0 is the initial concentration of bismuth (III) (mg/L),

C_e is the concentration at equilibrium (mg/L),

V is the volume of solution in litre and

M is the mass of adsorbent in grams.

Adsorption isotherms

An equilibrium isotherm was studied for both Langmuir and Freundlich isotherms. The results are shown in Figs. 2 and 3, which illustrate the plot of Langmuir and Freundlich isotherms of coconut shell for bismuth (III). The saturated monolayer can be represented by:

$$q_e = \frac{Q^0 b C_e}{1 + b\,C_e} \quad \ldots(2)$$

The linearised form of the Langmuir isotherms is –

$$\frac{1}{q_e} = \frac{1}{Q^0 b} \times \frac{1}{C_e} + \frac{1}{Q^0} \quad \text{…(3)}$$

where Q^0 and b are Langmuir constants. The plot of $1/C_e$ v/s $1/q_e$ was found to be linear, indicating the applicability of Langmuir model. The parametrs Q° and b have been calculated and presented in Table 1. The Langmuir constant Q° is a measure of adsorption capacity and b is the measure of energy of adsorption. In order to observe, whether the adsorption is favourable or not, a dimentionless parameter 'R' obtained from Langmuir isotherm is –

$$R = (1 + b \times Cm)^{-1} \quad \text{…(4)}$$

where b is Langmuir constant and Cm is maximum concentration used in the Langmuir isotherm. The adsorption of bismuth (III) on coconut shell is a favourable process as " R" values lie between zero to one. Coefficients of correlation (r) are also shewn in Table 1. The applicability of Freundlich isotherm was also tried using the following general equation –

$$q_e = k.\, C_e^{B} \quad \text{…(5)}$$

The linearised form of this equation is –

$$\log q_e = B.\log C_e + \log K \quad \text{…(6)}$$

where, B and k are Freundlich constants. These constants represent the adsorption capacity and the adsorption intensity, respectively.

Plot of $\log q_e$ vs. $\log C_e$ was also found to be linear. The values of B and k are presented in Table 1. Since the values of B are less than 1; it indicates favourable adsorption.

Table 1. Isothermal constants

Langmuir constants				**Freundlich constants**		
Q^0	**b**	**r**	**R^2**	**k**	**B**	**R^2**
5.4827	0.271	0.402	0.9923	0.5127	0.3741	0.9719

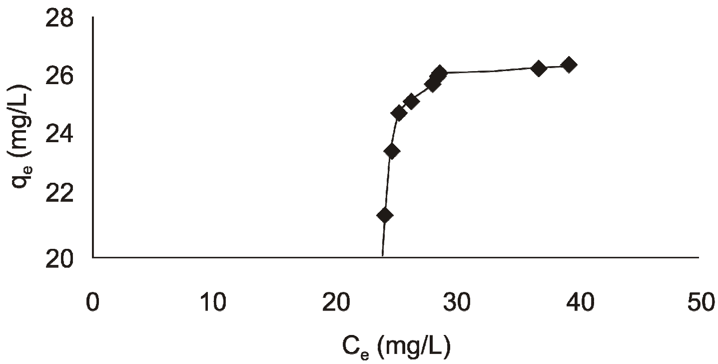

Fig. 1: Equilibrium adsorption isotherm for coconut shell Bi^{3+}

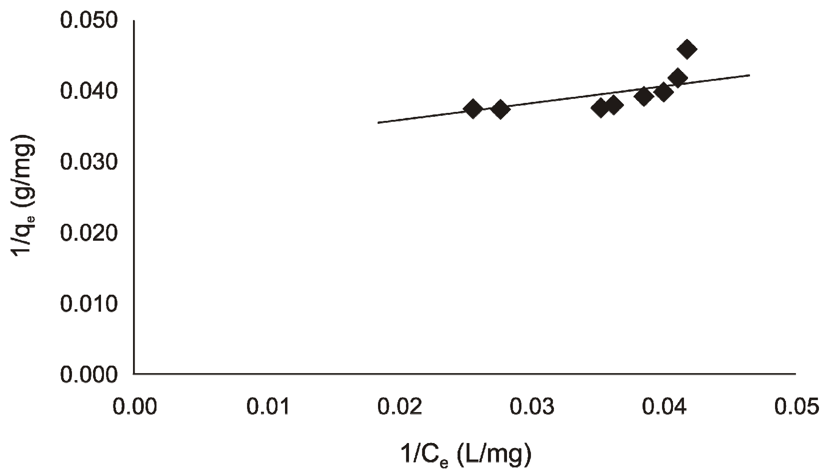

Fig. 2: Langmuir adsorption isotherm

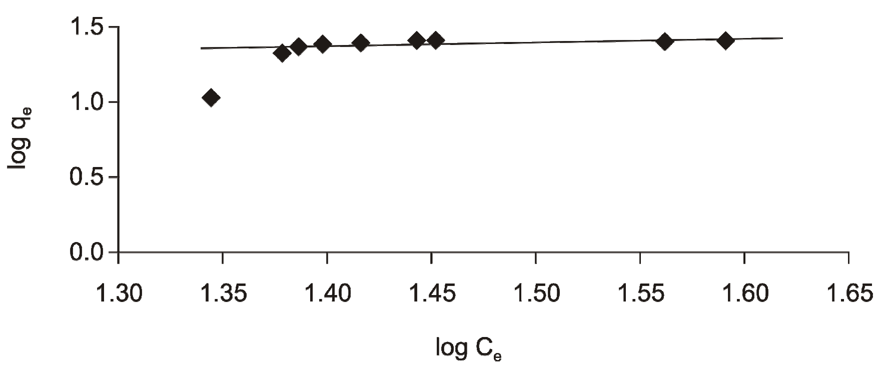

Fig. 3: Freundlich adsorption isotherm

RESULTS AND DISCUSSION

Effect of concentration of metal ion and contact time

The response of adsorbate dose and contact time on the removal of bismuth (III) is presented in Fig. 1. The observations reveal that with an increase in the adsorbate dose, rate of adsorption increases upto a certain level and then, it becomes constant. Also as the time of contact was increased, adsorption increases and then, it becomes constant.

Effect of pH on the removal of bismuth (III)

The effect of pH on the removal of bismuth (III) is shown in Fig. 4. Experiment were conducted at the constant initial bismuth (III) concentration, adsorbent dose (coconut shell) of 0.5 g/100 mL and the contact time of 4 hours. The pH of the aqueous solution is an important controlling parameter in the adsorption process. It was observed that the percentage removal of bismuth (III) is higher at pH = 1 and then, it decreases with increase of pH.

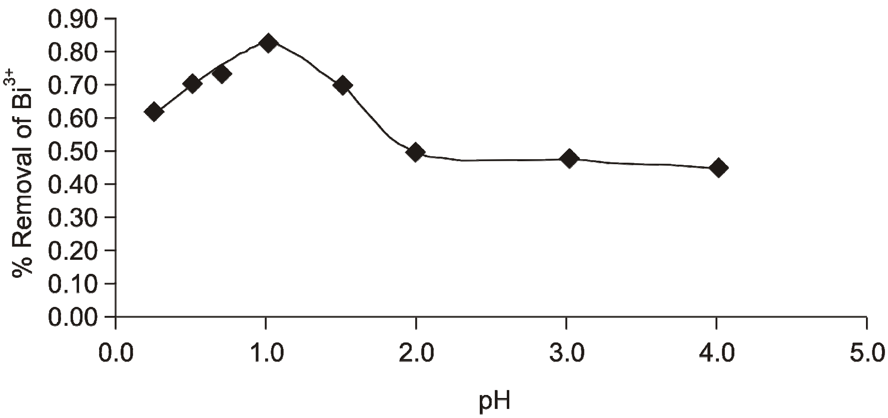

Fig. 4: Effect of pH on % removal of Bi^{3+}

Effect of particle size

The adsorbent particle size has significant influence on the kinetics of adsorption. The influence of particle size furnishes important information for achieving optimum utilization of adsorbent. Four particle sizes 50, 100, 150, 200 micron size (Indian Standard Sieves) under optimum condition were used and it is found that as the particle size was increased, the rate of adsorption decreases.

Kinetics of adsorption

0.5 g of coconut shell and 200 mL Bi^{3+} solution was taken in 1000 mL R.B. and shaken vigorously for about four hours. After every 15 minutes, 5 mL sample of the solution was withdrawn for the first hour and subsequently, the interval between the samples withdrawn was increased to 30 minutes. The concentration of the metal ions in the sample withdrawn were determined spectrophotometrically and were designated as C_t and the value of the concentration of the metal ion on the coconut shell at the same time interval was estimated using the relation

$$\bar{q} = \frac{(C_0 - C_t)\,V}{M} \qquad ...(7)$$

The rate of adsorption of bismuth (III) on coconut shell was studied by using the first order rate equation proposed by Lagergren (II).

$$\log C_t = \log C_0 - \frac{K_{ad}}{2.303}\,t \qquad ...(8)$$

or

$$K_{ad} = \frac{2.303}{t} \log C_0 / C_t \qquad ...(9)$$

Where K_{ad} is the rate constant for adsorption.

The plote of log C_t vs t is shown in Fig. 5.

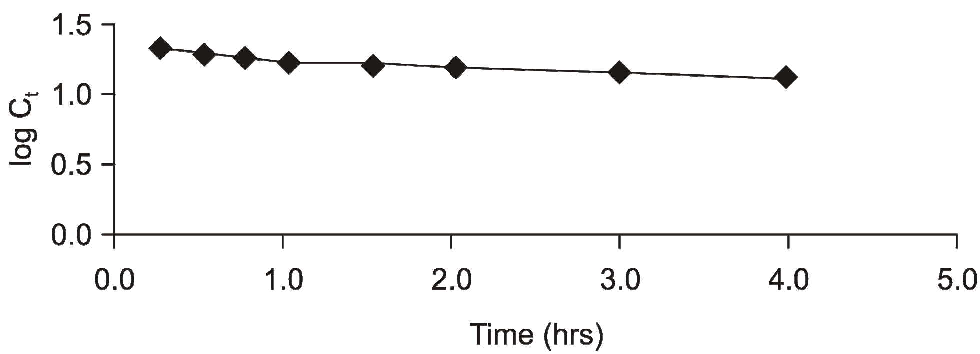

Fig. 5: Lagergren plot system for coconut shell -Bi^{3+} system

CONCLUSIONS

The following conclusions have been drawn from the presents study –

(i) The percentage retrieval of bismuth (III) was found to increase with decrease in the initial concentration of bismuth (III). The removal was found rapid in initial stages followed by slow adsorption upto a saturation limit.

(ii) The developed technique of retrieval of bismuth (III) ions using coconut shell appears to be low cost and practically viable for the use of semiskilled workers in the villages.

(iii) The present work on adsorption process is in good agreement with Langmuir isotherm indicating monolayer adsorption process.

(iv) The result on adsorption process reveals that at pH = 1.0, bismuth (III) uptake capacity is better.

(v) The linear plot of log C_t vs. t for the adsorption show the validity of Lagergren equation and suggest the first order kinetics.

(vi) Regeneration studies are not necessary with the view that the cost of the adsorbent is very low and it can be disposed of safely.

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