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Studies on Removal Efficiency of Low Cost Adsorbent for Cadmium from Aqueous Phase

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Abstract:
The pollution of heavy metals has gained worldwide attention due to their toxicity, difficult degradation, and accumulation in the living organisms. Therefore, treatment of wastewater contaminated by heavy metals is an important environmental concern. In recent years the adsorption process by colorimetric method has been recognized as an effective method for the removal of heavy metals from wastewater. In the present study Cadmium was removed using Granulated Activated Carbon as a adsorbents from aqueous solution. In batch adsorption experiment the temperature 25 ± 1 °C at pH = 6 were kept constant throughout the study. The experimental data were analyzed for Langmuir and Freundlich adsorption isotherms. The values of Langmuir and Freundlich constants were reported in the paper. The granular activated carbon Filtrasorb 100 (F-100) and Filtrasorb 300 (F-300) gifted by M/s Calgon Corporation Ltd, Pittsburgh USA were used as adsorbents. Granulated Activated Carbon had been the most used adsorbent for removal of heavy metal from contaminated water.

Keywords: Cadmium, Low Cost Adsorbents, Adsorption, Granular Activated Carbon (GAC), Filtrasorb 300 (F -300), Filtrasorb 100 (F -100)

Introduction:

Wastewater and natural water contain a number of trace elements, which are toxic at high levels. If these elements are present in excessive amounts, there presence is a great concern since excessive amounts are determental to health. Of Many metals, which are listed as environmental hazards, are essential dietary trace elements required for normal growth and development of living beings. These include cadmium which come out from industrial discharge, mining waste, metal plating, water pipes etc. As a result of this pollution water bodies become a major environmental problem of the world. According to WHO [1] about 80% of all diseases in human beings are caused by water. [2] Cadmium is found to occur in nature along with zinc ores .When the plants acquire zinc, they also take up cadmium. When animals eat the plants or when human eats the animals which have consumed plants containing cadmium, the cadmium gets accumulated in human bodies. The first case of cadmium poisoning was reported in Japan in the form of 'itai itai' or "ouch ouch" disease. A large number of people suffered from the disease in which there bones became fragile. Other effects of cadmium in the human system are renal dysfunction, anaemia, hypertension, bone marrow disorder, genetic disorder, and cancer. Cadmium ingested in our body is trapped in the kidneys and gets eliminated. However, a small fraction is found by the body proteins, metallothionein, present in the kidney. With age, the accumulation of cadmium in the body increases. When excessive amount of Cd^{2+} are present in the body, it replaces Zn^{2+} at key enzyme site. However, too high concentrations of cadmium may damage human health. Water effluents of metal industry contain very high amounts of cadmium and may cause serious health effects on human being [3]. Even though heavy metal ions can be removed by physicochemical methods such as chemical precipitation, membrane separation [4-5] and ion exchange but adsorption has been shown to be an economical alternative for removing metals from water [6-8]. Adsorption is an important technique in separation and purification processes which is useful in water and waste water industry to removal of colour, odour and organic pollutant [9-10]. Among many types of adsorbent materials, activated carbons which can be produced from almost any carbonaceous materials are most widely used, because of their large adsorptive capacity and low cost [11]. Often a combination of interaction is responsible for the association between a particular chemical (sorbate) and solid (sorbent). In the present work cadmium was removed using granular activated carbon Filtrasorb -100 (F-100) and Filtrasorb -300 (F-300).

MATERIALS AND METHODS

Porous adsorbent such as Filtrasorb 300 (F-300) and Filtrasorb 100 (F-100) gifted by M/s Calgon Carbon Corporation Ltd Pittsburgh, USA were selected as an adsorbent. Desired size of carbon particles were obtained by using sieve shaker (16 x 25 M/s Jayant Test Sieves, Mumbai) and collected in clean petridish for use. The sieved GAC particles were thoroughly washed several times with hot distilled water until clear liquid was obtained and then kept in a vacuum oven at a temperature of 105^{O}C overnight. It was then cooled in a desiccators containing silica gel to ensure complete removal of moisture from the carbon. A stock solution of cadmium ion was prepared by dissolving requisite amount of $CdCl_2.H_20$, (loba chemie) in distilled water. A series of solutions of $CdCl_2.H_20$, were prepared by using stock solution of 0.0001M concentration. In all cases absorbance was measured at 520nm using Chemito Spectrascan UV 2700 Double beam Spectrophotometer. Standard Beer's law curve was constructed spectrophotometrically using series of cadmium solutions by giving treatment of Dithizone, Potassium-sodium tartrate and NaOH [12]. The mathematical equation computed was used to estimate the residual concentration of cadmium ions.

All reagents used in the present work were of analytical grade. To carry out the adsorption of cadmium ion, 200 ml solution at a pH = 6 was stirred for 5hrs in reagent bottle of 300ml capacity at a constant temperature of 25 ± 1^{0}C each time with different weights of Granulated Activated Carbon using a Teflon bladed stirrer. The initial and final concencentration of cadmium ion in mg/lit were estimated using Beer's Law. The experiments were repeated twice to ensure reproducible results.

RESULTS AND DISCUSSION

The experimental data of adsorption of Cd^{2+} ion GAC were analyzed in the light of Langmuir and Freundlich isotherms. The adsorption isotherm describes the relationship between the liquid phase concentration and surface concentration of adsorbate at equilibrium, the amount of cadmium with GAC was estimated using the equation

$$q_e = (C_o - Ce) \times \frac{V}{W} \quad \ldots\ (1)$$

Where,

q_e = Concentration of Cadmium ion in mg/gm,

C_o = Initial concentration of Cadmium ion in solution in mg/L,

C_e = Final concentration of Cadmium ion in solution in mg/L,

V = Volume of solution in liters,

W= Different weight of GAC .

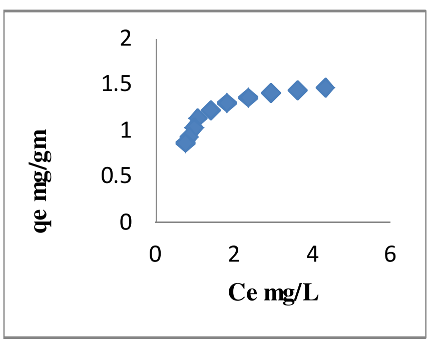

Figure.1. Adsorption isotherm System: F-100_Cd^{2+}

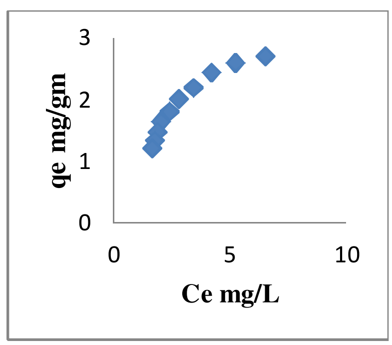

Figure 2.Adsorption isotherm System: F-300_Cd^{2+}

The adsorption isotherms of F-100 and F-300 GAC obtained by plotting q_e versus C_e and shown in Fig.1 and Fig. 2. The Langmuir equation could be expressed as

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

Where,

Q^o = amount adsorbed per unit weight of the adsorbent forming a monolayer on the adsorbent surface.

b = Langmuir constant.

Rearranging equation (3)

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

A plot of $1/q_e$ versus 1/Ce was found to be fairly linear. Similarly, the Freundlich equation could be expressed as

$$q_e = k.C_e^{1/n} \quad \text{..... (4)}$$

Where, k and 1/n are constants determine experimentally. Taking log of both sides

$\text{Log } q_e = \text{Log } K + 1/n \text{ Log } C_e$ ..... (5)

A plot of log q_e versus log C_e fairly showing validity of Freundlich equation over a range of concentrations. Fig.3 to 6 illustrates the plots of Langmuir and Freundlich isotherms for F-100 and F-300. The plots of $1/q_e$ versus $1/C_e$ were found to be linear indicating the applicability of Langmuir model. The parameters Q^o and b are Langmuir constants relating to the sorption capacity and adsorption energy respectively were determined.

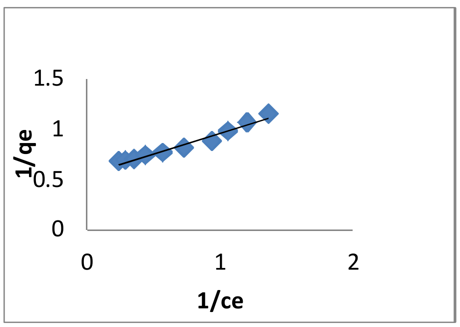

Figure. 3 Langmuir adsorption isotherm
System: F-100_Cd^{2+}

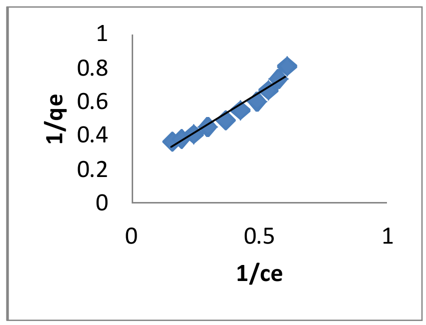

Figure. 4 Langmuir adsorption isotherm
System: F-300_Cd^{2+}

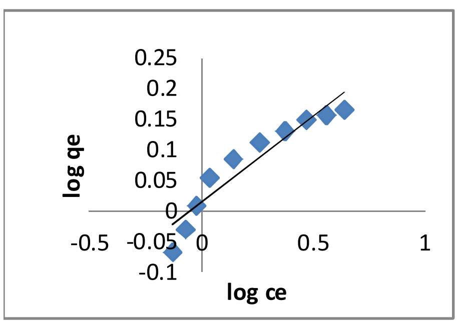

Figure 5 Freundlich adsorption isotherm
System: F-100_Cd^{2+}

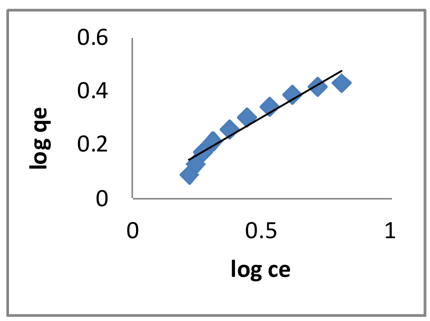

Figure 6 Freundlich adsorption isotherm
System: F-300_Cd^{2+}

The plot of $1/q_e$ versus $1/C_e$ helped in determination of Q^o from which the surface area occupied by Cadmium ion on GAC can be determined. The surface area of the carbon through such Cadmium adsorption can then be represented as

$S' = N_a Q^0 A$ ... (6)

Where,

S' = Surface area of adsorbent, cm^2/g,

Na = Avogadro number and

A = Cross-sectional area of the adsorbent molecule, cm^2.

It is possible to determine the surface area of the adsorbent using the technique of adsorbing Cadmium on GAC at the saturation level when a monolayer of the Cadmium would over the entire surface of the adsorbent. Determination of value of S' needed the determination of A the surface area occupied by a single Cadmium ion. The values of A were calculated using the expression given by Brunauer and Emmet.

$$A = 4 \times 0.866 \left[\frac{M}{4\sqrt{2}.Na.d} \right]^{2/3} \quad \ldots\ldots (7)$$

Where,

M = Atomic weight of the Cadmium

Na = The Avogadro number

d = The density of the Cadmium

The values of S obtained from $q_{e\,max}$ and S' obtained from Q^o are reported in Table 1

Table 1

Values of Q^o, A, S and S' for a system GAC–Cd^{2+}

Sr. No.	System	Q^0	A (cm^2)	S (cm^2/gm)	S' (cm^2/gm)	$q_{e\,max}$ (mg/gm.)
1	F- 100 - Cd^{2+}	1.7921	8.4563 x 10^{-16}	6.6699x 10^3	8.1198x10^3	1.4721
2	F- 300 -Cd^{2+}	5.3763	8.4563 x 10^{-16}	12.3313x 10^3	24.3595x10^3	2.7215

CONCLUSION

Adsorption by granular activated carbon is inexpensive and effective technique for removal of heavy metal from wastewater. In this study, results showed that the adsorption of Cadmium ion performed by GAC was very encouraging. From the adsorption isotherm, it is observed that as C_e increases q_e also increases but at the saturation level q_e tends to be constant with increasing value of C_e which indicates formation of a monolayer of Cadmium ion on the surface of adsorbent. The experimental data seen to be of the favorable type and were then subjected for adherence to both Langmuir and Freundlich adsorption isotherm. All adsorption isotherms of the Cadmium ion on different grades of carbons in presence of dithizone which is an important reagent for quantitative determination of metal clearly show that F-300 adsorbs Cadmium ion to a greater proportion as compared to F-100. This is probably due to availability of large active sites on the surface of GAC.

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