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Evaluation of Treatment Strategies by Adsorption for Lead Removal from Aqueous Solution

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ABSTRACT

The contamination due to heavy metals from industrial waste water is most important issues for industrialized area. In this work removal of lead from aqueous solution was investigated using granular activated carbon modified with 1,3,5-Triazine-2,4,6-triamine.The adsorption of lead using GAC filtrasorb 300 (GAC F-300) and filtrasorb 816 (GAC F-816) were carried out at constant temperature 25 + 1^{0}C at about 500 rpm. The adsorption data were well analysed for Freundlich, Langmuir and Temkin adsorption isotherm models.

Keywords: Adsorption, Lead, Granular activated carbon (GAC), Filtrasorb 300 (F-300), Filtrasorb 816 (F-816), 1,3,5-Triazine-2,4,6-triamine

INTRODUCTION

Now days an environment and human being facing a serious problem due to the toxicity, persistence and bioaccumulation affinities of heavy metals in water bodies. Metals and their compounds are extremely important to the industrial and technological development in developed countries due to numerous of applications for commercial uses [1, 2]. Lead is one of the heavy metals found in industrial wastewater and its discharge into water bodies poses an adverse effect on aquatic and terrestrial lives. Lead poisoning causes severe damage to the nervous system, kidney, reproductive system, brain, liver cause illness or death. Severe exposure to lead has been connected with stillbirths, abortion, sterility and neonatal death [3-5].

Lead is naturally occur as an element in insoluble form in the earth crust and biologically inoffensive forms [6]. There are number of methods employed for the treatment of industrial effluents containing Lead. Some of the important methods are chemical precipitation, ion exchange, electrodialysis and carbon adsorption use for water treatment [7-19]. Many advanced techniques are available for removal of heavy metal involves high investments, which are not suitable for small scale industries, which discard comparatively low volumes of wastewater. Adsorption is an effective separation and purification technique used in industry especially in water and waste water treatments [20].Treatable amount of lead wastes are growing need in the industrial sector to try and find solution to remove this metal from waste waters using granular activated carbon [21-33]. Lead is considered as a major threat for various human diseases once it goes beyond the permissible limit recommended by the World Health Organisation (WHO) (3-10 μg/L) in drinking water [34].

MATERIALS AND METHODS

The Granular Activated Carbon filtrasorb 300 (F-300) and filtrasorb 816 (F-816) gifted by M/s Calgon Carbon Corporation Ltd Pittusberg, USA were selected as adsorbent for adsorption study. These adsorbents were first sieved to obtain the carbon particles of desired size. All the particles were collected in clean petridish which used as adsorbent for overall studies. The sieved GAC particles were completely washed with hot double distilled water until the supernatant was free of dirt particles and then kept in an vacuum oven at a temperature of 105°C for 5 hours for dry. It was cooled in a desiccators containing anhydrous $CaCl_2$ to verify complete removal of moisture from the pores on surface of GAC. A synthetic solution of lead ions was prepared by dissolving required quantity of $Pb(NO_3)_2$ (S.D. Fine Chem. Limited) in freshly prepared double distilled water and all working solutions were prepared by dilution with double distilled water.

Each solution was treated with 2 ml aqueous solution of alizarin Red (S) and 1 ml NaOH (2M). The optical densities of all experimental solutions were estimated using Chemito Spectrascan UV 2700 Double beam UV Visible spectrophotometer at λ_{max} 485 nm. A Beer's law standard curve was obtained by plotting optical densities versus concentration of lead. The equation computed was used to estimate residual concentration of Pb^{2+} ions [35]. All the reagents used in this work were of AR grade. A sample of 1,3,5-Triazine-2,4,6-triamine(S.D. Fine Chem. Limited) was purified and recrystallized by standard method. The melting point of 1,3,5-Triazine-2,4,6-triamine was found to be 344.5°C compared with literature value 345°C [36]. The sample was also characterized through determination of molecular weight by the technique of pH titration against standard NaOH. To study the adsorption isotherm of Lead ions, 200 ml of 0.001 M solution of 1,3,5-Triazine-2,4,6-triamine agitated with 0.5 g of GAC in reagent bottles of 300 ml capacity. It was then shaken for about five hours using Teflon bladed stirrer at about 500 rpm. After five hours the solution was decanted and the carbon particles were washed completely with double distilled water which recognized as loaded carbon. This loaded carbon was then transferred to same reagent bottle and then 200 ml of lead solution of pH = 6 were added to it. The contents were agitated for 5 hours in a thermostat at a constant temperature of 25 ± 1°C. The initial and final concentrations of lead ions were estimated by putting the values of absorbance in the equation obtained from Beer's law curve. The experiments were repeated twice to test reproducible results.

RESULTS AND DISCUSSION

The adsorption data of Pb^{2+} on GAC were analyzed in the light of Freundlich, Langmuir and Temkin models. The relationship between the liquid phase concentration and surface concentration of adsorbate at equilibrium was obtained to describe adsorption isotherm.

The quantity of Lead on the modified GAC was estimated using the equation

$$q_e=(C_o-C_e) \times V/W \qquad (1)$$

Where,

q_e=Concentration of Lead ion on the modified GAC (mg/millimoles)

C_o=Initial concentration of Lead ion (mg/L)

C_e=Final concentration of Lead ion (mg/L)

W=Millimoles of the ligand actually present on GAC (0.5 g).

V=Volume of solution in liters,

The adsorption isotherms of modified F-300 and F-816 GAC obtained by plotting q_e versus C_e and shown in **Figure 1.**

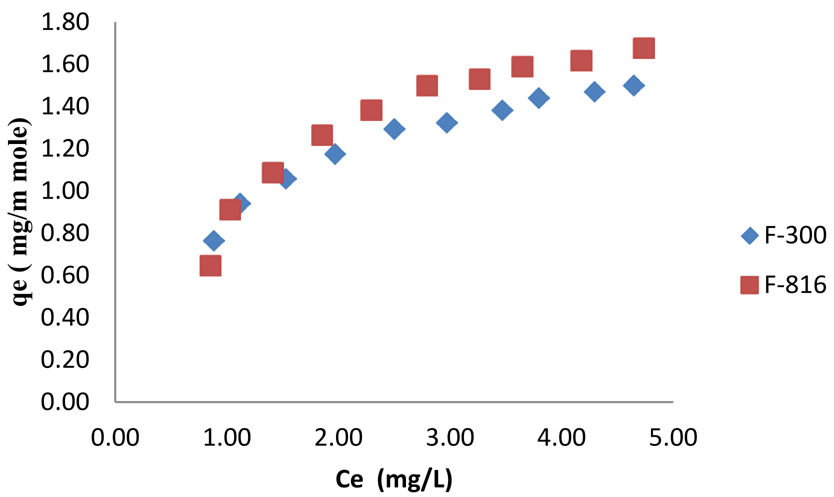

Figure 1: Adsorption Isotherm System: GAC-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}.

The Langmuir equation could be expressed as

$q_e=Q^o b \times C_e/(1+bC_e)$ (2)

Where,

Q^o = Amount adsorbed per unit weight of the GAC to form monolayer.

b = Langmuir constant.

Rearranging equation (2)

$1/q_e=1/Q^o b \times 1/C_e+1/Q^o$ (3)

A plot of $1/q_e$ versus 1/Ce was found to be fairly linear indicate the validity of isotherm.

The Freundlich equation express as

$q_e=K.C_e^{1/n}$ (4)

Where, k and l/n are Freundlich constants determined experimentally. Using equation (4)

$\log q_e=\log K+1/n \log C_e$ (5)

The linearity in the plot of log q_e against log C_e showed validity of Freundlich equation over a range of concentrations. Langmuir and Freundlich isotherms for F-300 and F-816 are illustrates in **Figure 2 and 3.** The plots of $1/q_e$ against $1/C_e$ were found to be linear indicating the validity of Langmuir model. The Langmuir constants relating to the sorption capacity (Q^o) and adsorption energy (b) were determined (**Table 1**).

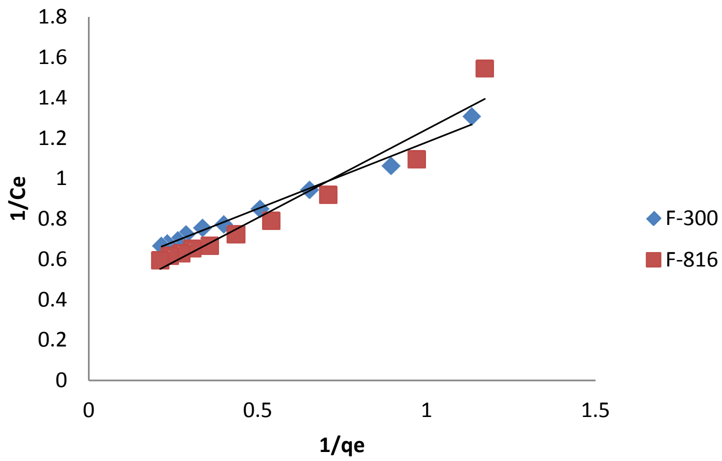

Figure 2: Langmuir Adsorption Isotherm System: GAC-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}.

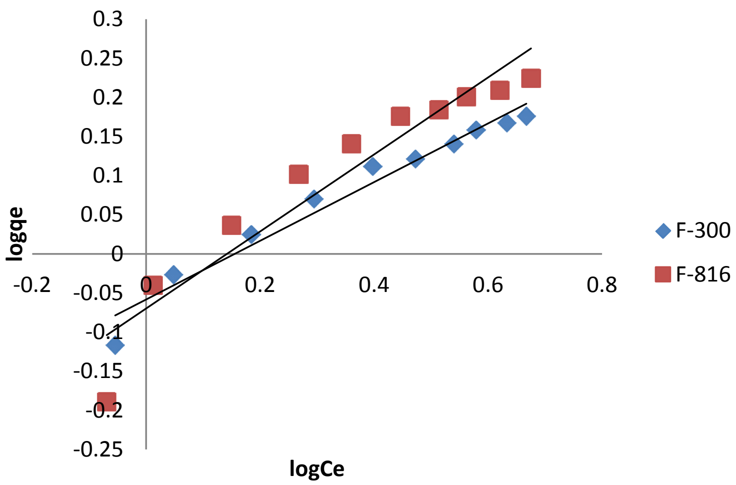

Figure 3: Freundlich Adsorption Isotherm System: GAC-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}.

Sr. No.	Adsorption System	Langmuir Constant			Freundlich Constant		
		Q^o	b	R^2	K	1/n	R^2
1	F-300-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}	1.9173	0.7927	0.9882	0.8744	0.3752	0.9636
2	F-816-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}	2.7236	0.4193	0.9374	0.8515	0.4924	0.9090

Table 1: Equilibrium Isotherm Constants For Langmuir and Freundlich model.

Q^o obtained from graph was used to estimate the surface area occupied by lead ion on GAC. The surface area of the GAC through Lead adsorption can then be represented as

$$S' = Na.Q^o.A \quad (6)$$

Where,

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

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

Na=Avogadro number

Determination of value of S' needed the value of A the surface area occupied by a single Lead ion. The values of A were calculated using the expression given by Brunauer and Emmet.

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

Where,

M=Atomic weight of the lead

Na=The Avogadro number

d=The density of the lead, [37]

The values of S' obtained from Q^o and S obtained from $q_{e\,max}$ are reported in **Table 2**.

Sr. No.	System	A (cm^2)	$q_{e\,max}$ (mg/m. mol.)	S (cm^2/gm)	Q^0	S'(cm^2/gm)
1	F-300-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}	5.4225×10^{-16}	1.5000	1.8381×10^3	1.9173	2.3494×10^3
2	F-816-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}	5.4225×10^{-16}	1.6765	2.0544×10^3	2.7236	3.3376×10^3

Table 2: Values of S, A, Q^O and S' for a system GAC-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}.

Temkin model considers the effect of indirect adsorbate-adsobent interactions on adsorption and suggests that the heat of adsoption of all the layer would decrease linearly with coverage due to adsorbate-adsobent interactions. It assumes that the decrease in the heat of adsorption is linear rather than logarithmic as stated in Freundlich expression. The linearised form of Temkin equation is

$$q_e = RT/b_T \ln K_T + RT/b_T \ln C_e$$

Where,

K_T=equilibrium binding constant (L/mg)

b=Temkin constant related to the heat of adsorption (kJ/mol)

$B = RT/b_T$

Figure 4 illustrates the plot of Temkin isotherms for F-300 and F-816. Temkin constants K_T and b_T are calculated from plot of q_e versus ln C_e given in **Table 3**.

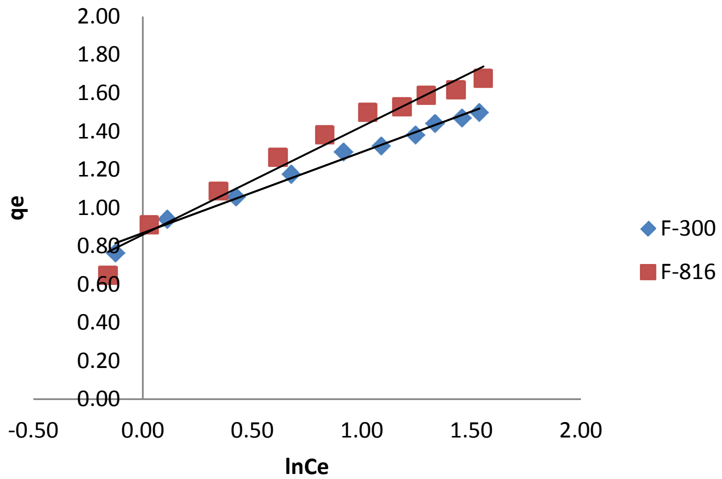

Figure 4: Temkin Adsorption Isotherm System: GAC-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}.

Sr. No.	Adsorption System	K_T	b_T	R^2
1	F-300-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}	7.7673	5849.4436	0.9889
2	F-816-1,3,5-Triazine-2,4,6-triamine-Pb^{2+}	4.576739	4382.762	0.9680

Table 3: Equilibrium Isotherm Constants For Temkin model.

CONCLUSION

This study examined the efficiency of adsorbent GAC in the removal of Pb^{2+} ions from aqueous phase in presence of 1,3,5-Triazine-2,4,6-triamine. The main advantages of the adsorption study include cost effectiveness, simplicity and offers flexibility in design. From the plot of q_e against C_e, it is observed that initially C_e increases with q_e but at the saturation level q_e tends to be constant which indicates monolayer formation of Lead ion on the pores site of surface of adsorbent GAC. The experimental data seen to be of the favourable type and subjected for adherence to Langmuir and Temkin model better than by the Freundlich model. In adsorption study F-816 loaded with 1,3,5-Triazine-2,4,6-triamine-adsorbs lead to a remarkable extent as compared to F-300. This is probably due to presence of large active sites available on GAC surface and its porous nature.

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