Surface Modification of Granular Activated Carbons in Order to Change Its Adsorptive Properties Towards Toxic Metal Lead from Aqueous Solution using 3- Methoxy Catechol

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Abstract:

In the present study the adsorption behaviour of Lead from aqueous solution on to ligand loaded Granular Activated Carbons Filtrasorb 300 (F- 300) and Filtrasorb 820 (F- 820) (GAC) was investigated. The study was carried out to examine the potential and effectiveness of Granular Activated Carbons to remove Lead through adsorption from aqueous solution. Langmuir and Freundlich isotherm models were applied to the equilibrium data. The data was well fitting to both of these isotherms. The results demonstrate that the Filtrasorb 820 (F-820) has a significant capacity to adsorbed of manganese (II) as compared to Filtrasorb 300 (F-300) from wastewater.

Keywords: Adsorption, toxic metal removal, Lead, Granular Activated Carbon (GAC), Filtrasorb 300 (F-300), Filtrasorb 820 (F-820), 3- Methoxy Catechol.

Introduction:

The presence of heavy metal ions in the environment has been a matter of major concern due to their toxicity to human life. Unlike organic pollutants the majority of which are susceptible to biological degradation, heavy metal ions will not degrade into harmless end-product. Even though heavy metal ions can be removed by physical-chemical methods such as chemical precipitation, membrane separation and ion exchange but adsorption has been shown to be economical alternative for removing metals from water. However, adsorption by activated carbon had been reported as a technically and economically viable technology for heavy metal removal.

Lead is one of the heavy substances that are frequently found in industrial effluent, and when it is discharged into waterbodies, it has a detrimental effect on both aquatic and terrestrial life. Lead poisoning causes considerable harm to the nervous system, kidney, reproductive system, brain, and liver, which can lead to illness or death. Strong lead exposure has been associated to new born mortality, abortion, miscarriages, infertility, etc.

Lead is an insoluble metal that naturally exists in forms that are not poisonous to living organisms in the earth's crust. There are several methods for treating industrial effluents that contain lead. One of the most important steps in treating water is chemical precipitation, followed by ion exchange, electrodialysis, and carbon adsorption. Lead's maximum contamination level in drinking water cannot be higher than 3-10 g/L as permitted my WHO (World Health Organization).

There are currently several state-of-the-art techniques for eliminating heavy metals, but they are expensive and not suitable for small businesses that only dispose off minor volumes of wastewater. Adsorption is a practical process for separating and purifying materials used in industry, especially for treating waste water. Granular activated carbon is being used more and more in the industrial sector to try to find a method of removing treatable levels of lead wastes from waste waters.

In this connection work was initiated in laboratory to scavenge Lead metal using coal-based GAC containing adsorbed ligand which are capable of forming a chelate with the Lead and thus help in its recovery. For this purpose, 3- Methoxy Catechol has been chosen in present work.

Experimental:

Commercially available granular activated carbons namely F- 300 and F- 820 obtained from Calgon Corporation, Pittsburg, USA, were used in present work. These GACs were first subjected to sieving using a three-level sieve shaker in order to get uniform sized particles of activated carbon. The sieve shaker only allows the particles having size range of 1400 to 1600 micron to stay in the middle level. Only these particles were taken for current study. These GACs were then thoroughly washed with boiling double distilled water and then dried using an oven at 100-110 0C, then stored in an anhydrous CaCl2 desiccator until they were used for experimentation. A known-weight weighing vial was used to separate and place some of the carbon particles in the same desiccator. The bottle was weighed every day until a stable weight was found, indicating that the carbon particles had completely lost their moisture. The right quantity of analytical grade Pb(NO3)2 (S.D. Fine Chem. Limited) was dissolved in double-distilled water to create a lead ion stock solution. A number of solutions were made with different (known) lead ion concentrations. To estimate the residual Pb2+ ion concentration, the alizarin red (S) technique was used to produce the Beer's law standard curve for Pb2+ [12]. Throughout the experiment, this study used chemicals of the AR grade. To analyse the adsorption isotherm, 200 ml of 0.001 M 3- Methoxy Catechol solution was placed in reagent bottles with 300 ml capacity stoppers and stirred with 0.5 g of GAC. A Teflon-bladed stirrer (Type L-157 M/s Remi Udyog, Mumbai, India) was then used to shake it constantly for five hours at 500 rpm. After five hours, the solution was decanted, and the carbon flakes were meticulously cleaned with double-distilled water. This meant that 3-Methoxy Catechol was abundant to modify the surface of the GAC. The same reagent bottle was then used to hold the loaded carbon. It was then filled with 200 ml of a Pb2+ solution with a pH of 6. 5 hours were spent stirring the materials in a thermostat at a constant temperature of 25°C. The initial and final concentrations of the Pb2+ ion in mg/L were then calculated by measuring absorbance at 470 nm with a UV spectrophotometer (Chemito spectrascan UV 2700 Double beam UV Visible spectrophotometer). To get similar repetitive results, the procedure was applied twice.

Results and Discussion:

The mathematical interpretation of the adsorption isotherms is studied using the two popular models, namely Freundlich and Langmuir. The adsorption isotherms for different grades of granular activated carbon are shown in Fig.1 and 2. The slope of the isotherms indicates the high affinity between sorbent surface and adsorbate molecules. Using the following equation, the quantity of Pb^{2+} on the ligand-loaded GAC was calculated:

$$q_e = (C_0 - C_e)\,\frac{V}{W}$$

Where,

q_e = Concentration of Lead ion on GAC and SAC (mg/gm)

C_0 = Initial concentration Lead ion in solution (mg /L);

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

V = Volume of solution in litres

W = Weight of GAC and SAC in gm. (0.5 gm)

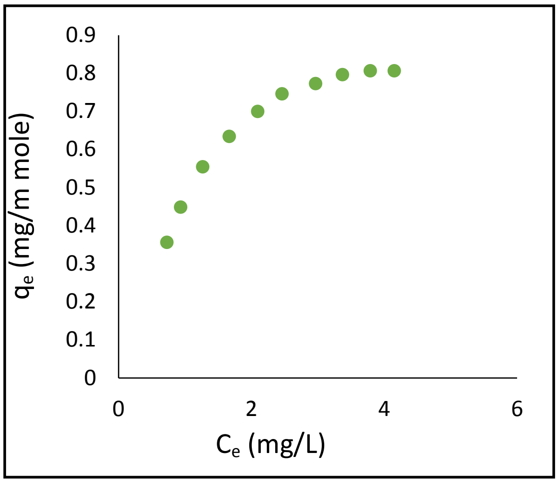

FIG 1 Adsorption isotherm System: F-300- 3- Methoxy Catechol - Pb2+

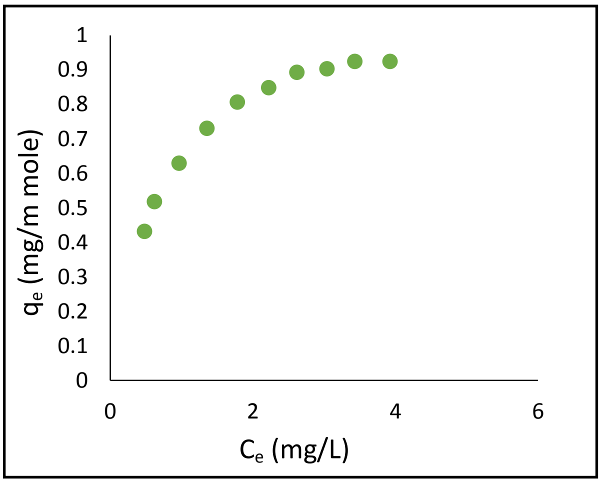

FIG 2 Adsorption isotherm System: F-820- 3- Methoxy Catechol - Pb2+

Figures 1 and 2 demonstrate the adsorption isotherms of ligand-loaded F-300 and F-820 GAC derived by graphing q_e against C_e.

Using values of q_e against Ce, the Langmuir equation can be stated as

$$q_{e} = Q^0 b \times \frac{C_e}{(1+bC_e)}$$

Where,

Q^0 = amount absorbed per unit weight of the adsorbent forming a complex monolayer on the adsorbent surface

b = Langmuir constant

The linear form of above equation can be written as follows:

$$\frac{1}{q_e} = \frac{1}{bQ_e} \times \frac{1}{C_e} + \frac{1}{Q^0}$$

The plot of 1/qe and 1/Ce was found to be substantially linear.

Likewise, the Freundlich equation can be stated as,

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

Where, k and 1/n are constants and can be determined experimentally using above equation in linear form:

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$$\log q_e = \log k + \frac{1}{n}\log C_e$$

Where k and 1/n are Freundlich constants.

The validity of the Freundlich equation was fairly demonstrated by plotting log q_e vs log C_e over a variety of concentrations.

The plot of Langmuir and Freundlich isotherms for F-300 and F-820 is shown in Figures 3 to 6. The graphs of $1/q_e$ vs $1/C_e$ were found to be linear, showing that the Langmuir model is applicable. The comparative adsorption capacities (saturation values of qe) of manganese ion on different grades of granular activated carbon used in the present work can be assessed from Figs. 1 and 2.

The trend in the qe values at the saturation level are in the order F-816 > F-300. The Langmuir constants Q^o and b, which relate to the sorption capacity and adsorption energy, and Freundlich constants K_f and 1/n were obtained and given in Table 1.

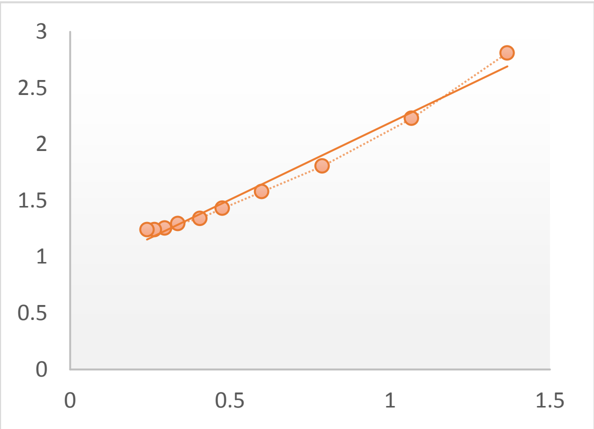

FIG 3: Langmuir Adsorption isotherm System: F-300- 3- Methoxy Catechol - Pb2+

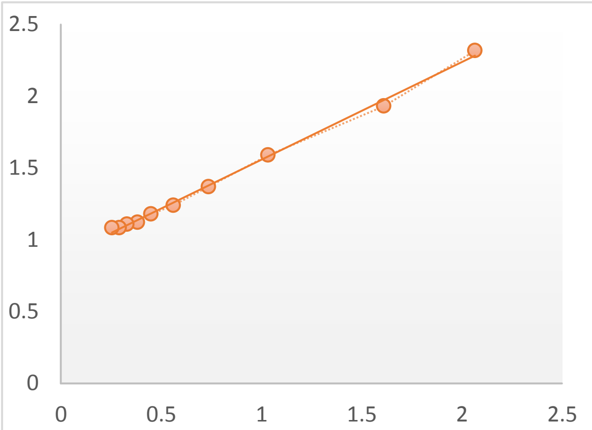

FIG 4: Langmuir Adsorption isotherm System: F-820- 3- Methoxy Catechol - Pb2+

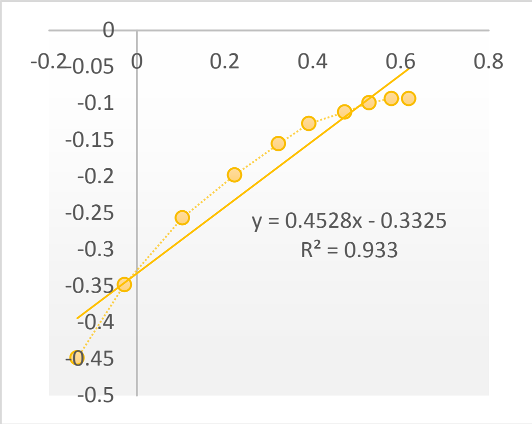

FIG 5: Freundlich Adsorption isotherm System: F-300- 3- Methoxy Catechol - Pb2+

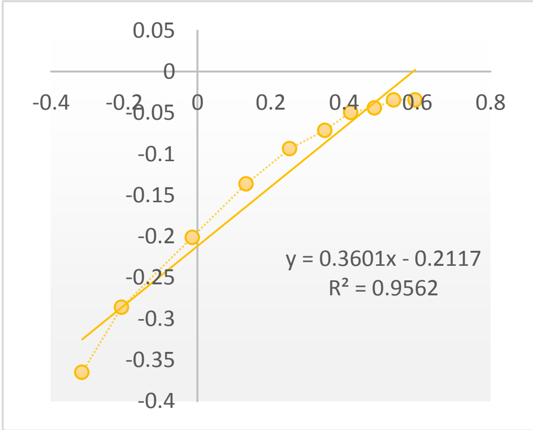

FIG 6: Freundlich Adsorption isotherm System: F-820- 3- Methoxy Catechol - Pb2+

Table 1: Langmuir and Freundlich constant and regression correlation coefficient (R^2)

Sr No	System	Langmuir Constant and Regression Coefficient R2			Freundlich Constant and Regression Coefficient R2		
		Qo	b	R2	K	l/n	R2
1	F-300- 3- Methoxy Catechol -Pb^{2+}	1.2128	0.6033	0.9817	2.1503	0.4528	0.9330
2	F-820- 3- Methoxy Catechol – Pb^{2+}	1.1408	1.2874	0.9970	1.6282	0.3601	0.9562

The trend in the qe values at the saturation level are in the order F-820 > F-300.

Further the essential characteristics of the Langmuir isotherm can be described by separation factor R_L; which is defined as:

$$RL = \frac{1}{1 + bC_i}$$

where, C_i is the initial concentration of Lead (mg/L) and b is the Langmuir constant (gm/L). The value of separation factor R_L, indicates the nature of the adsorption process as given below:

RL Value	Nature of adsorption process
RL >1	Unfavourable
RL=1	Linear
0<RL<1	Favourable
RL = 0	Irreversible

The values of RL in the present study are found to be in between 0 and 1, showing favourability of adsorption process.

Conclusion:

Experimental studies would be very valuable in fostering a fitting innovation for evacuation of heavy metal particles from contaminated industrial effluents. Adsorption of Pb^{2+} from wastewater using granular activated carbon is a cost-effective and efficient method. The findings of this investigation demonstrated that GAC's adsorption of the Pb^{2+} ion was extremely encouraging. The experimental data was found to be of the positive kind, and we were tested for conformity to both the Langmuir and Freundlich adsorption isotherms. In the presence of 3- Methoxy Catechol, the adsorption isotherms of the Pb^{2+} ion on different grades of carbons clearly reveal that F-820 adsorbs Pb^{2+} ion to a larger proportion than F-300. This is most likely owing to the enormous surface area of F-820 that may be used to approach Pb^{2+} ions. Application of the Freundlich and Langmuir isotherm models gave good representations of the experimental data for manganese sorption by GAC .

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