



Sodium Dodecyl Sulfate Impregnated Granulated Activated Charcoal for the Scavenging of Cr (VI) Metal Ions from Aqueous Solution

U.E. CHAUDHARI, A.K. WANJARI

Department of Chemistry, Mahatma Fule Art's, Commerce and Sitaramji Chaudhari Science College
Warud -444906, Maharashtra, India., Corresponding author: uechaudhari@gmail.com

Abstract

Heavy metals have become eco-toxicological hazards owing to their tendency to not degrade but accumulate in the vital organs of biological bodies. This paper describes the adsorption of Cr(VI) metal ions from aqueous solutions by sodium dodecyl sulfate (SDS) an adsorbed chelating species on impregnated with granular activated charcoal (GAC). The capacity of the granulated activated charcoal to adsorb Cr(VI) increased in proportion to the quantity of sodium dodecyl sulfate with which they were impregnated. The effect of various parameters influencing the Cr(VI) adsorptions such as effect of pH, Contact time have been studied. The kinetics of the adsorption of Cr(VI) onto the sodium dodecyl sulfate -impregnated granulated activated charcoal (SDS-GAC) was best described by a pseudo-second-order model, and was described better by the Freundlich adsorption isotherm and Langmuir isotherm. This method is quite feasible, economic and time saving. The optimum contact time found is equal 400 min. The results indicate that surface modification with sodium dodecyl sulfate (SDS) could be used to significantly enhance the capacity of granulated activated charcoal to adsorb Cr(VI) metal ion.

Keywords: Granular Activated Carbon, Sodium Dodecyl Sulfate, Adsorption, Impregnation, Adsorption kinetics, Chromium.

Introduction

Removal of toxic heavy metals from the environment is an important challenge. Ideally, a removal processes must be simple, effective and inexpensive. Several processes have been suggested to remove heavy metals from wastewaters. These processes include chemical precipitation, ion exchange, cementation^[1], coagulation and flocculation^[2], complexation, biosorption^[3], and membrane processes^[4]. In this study, we focus on the adsorption process because it is inexpensive, widely applicable, efficient, and creates relatively little sludge^[5]. Activated carbon is an effective and inexpensive adsorbent^[6-11] and has been widely used in various industries to purify water. Metals of particular concern in treatment of industrial wastewaters include Cu, Zn, Cd, Pb, Ni, Ag, Hg, Cr and Fe which are toxic to living organisms at fairly low concentrations and tend to either biologically magnify or accumulate in plant and animal systems. In general, to be removed from wastewater, the metals must be precipitated or otherwise attached to an insoluble form through ion-exchange or adsorption.



GAC adsorption can be selective, cheap and relatively inert and the high surface area along with the ability to chemically regenerate and reuse makes it very useful. Huang using 8-hydroxyquinoline as an effective chelating agent improved Cu ion adsorption. Natarajan et al separated Cu ions from aqueous medium either alone or in admixtures with other divalent ions using GAC containing adsorbed 8-hydroxyquinoline-5-sulphonic acid. Similarly, Liu et al used activated carbon loaded with 8-hydroxyquinoline for recovery of vanadium. Activated carbon can, therefore be used to enhance the adsorption capacity for metal ions in aqueous solutions by ligands adsorbed on the surface^[12].

Experimental

Surface Modification Of GAC

The activated carbon was washed several times with deionised water, then dried for several days in an oven at 60 °C. The resulting unmodified dried granular activated carbon (virgin GAC) was modified by impregnating it with the SDS ligand as follows. Ten grams of virgin GAC were mixed with 1 L of 0.035mol L⁻¹ SDS solution. The mixtures were shaken at 100rpm at 20±1 °C for 48 h, then washed and re-dried as described above. The resulting GAC were designated as SDS-GAC.

Batch experiment for Cr(VI) adsorption

The capacities of virgin GAC and SDS-GAC to adsorb Cr(VI) metal ions were examined by measuring the initial and final concentrations of Cr(VI) metal ions in a batch system. Experiments were conducted in 250mL flasks with a working volume of 100 mL. To examine the effect of pH on Cr(VI) metal ions removal by the granulated activated carbons, solutions of SDS-GAC were obtained by adding 0.1 g samples to 100mL of 0.89mmolL⁻¹ Cr(VI) metal ions solution, then adjusting the pH to 2, 3, 4, 5 or 6 by adding 1N NaOH or H₂SO₄ as required. The solutions were shaken at 100rpm at 20±1°C for 48 h.

Effect Of pH On Cr(VI) Metal Ions Adsorption

Because the solution pH has an important effect on the interactions between adsorbent and adsorbate, batch adsorption experiments with virgin GAC and SDS-GAC were conducted at various pH from 2 to 6. The virgin GAC removed Cr(VI) metal ions poorly at all pHs even at pH 6. Thus, the low capacity of virgin GAC to adsorb Cr(VI) metal ions is a result of its low acidity. SDS-GAC, removed Cr(VI) metal ions well even at pH 2 shown in Fig.-I. Impregnating activated carbon with SDS ligand increased the number of active sites capable of binding the Cr(VI) metal ions.

Effect Of Contact Time

The effect of Contact time on the amount of Cr(VI) metal ions adsorbed was investigated by using various initial concentration of Cr(VI) metal ions with 0.5 gram SDS-GAC and GAC at pH 2.0. The effect of Contact time and metal ions concentrations on the percent removal of Cr(VI) metal ions by SDS-GAC and GAC is shown in Fig.-II. The result indicates that removal of Cr(VI) metal ions increases with



increase in Contact time and equilibrium was attained in about 400 min. The extent of removal of Cr(VI) metal ions by SDS-GAC and GAC was found to increase, reach a maximum value with increase in contact time.

Effect of Ligand Loading

To understand the effect of Sodium Dodecyl Sulfate as a ligand on Cr(VI) metal ions removal, virgin GAC was impregnated with eight different amounts of SDS. As the amount of SDS on the surface of activated carbon increased, its specific surface area decreased. The amount of ligand dose varies from 200mg/200ml to 900mg/200ml in SDS-GAC system. The retrieval efficiency is maximum at ligand dose of 900 mg/200ml which is up to 80-85% shown in Fig.-III

Adsorption Isotherms

Equilibrium isotherms were studied for both Langmuir and Freundlich isotherms. The results are shown in Figures IV, and V which, illustrate the plot of Langmuir and Freundlich isotherms of Chromium (VI) SDS-GAC. The saturated monolayer can be represented by:

$$q_e = \frac{Q^0 \cdot b \cdot C_e}{1 + b \cdot C_e}$$

The linearised form of the Langmuir isotherms is

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

where Q^0 and b are Langmuir constants. The plot of $1/C_e$ Vs $1/q_e$ was found to be linear, indicating the applicability of Langmuir model. The parameters Q^0 and b have been calculated and presented in (TABLE-I). The Langmuir constant Q^0 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 dimensionless parameter 'R' obtained from Langmuir isotherm

$$R = (1 + b \times C_m)^{-1}$$

where, b is Langmuir constant and C_m is maximum concentration used in the Langmuir isotherm. The adsorption of Chromium (VI) metal ions on SDS-GAC is a favourable process as "R" values lies between zero to one. Coefficients of correlation (r) are also shown in (TABLE-I). The applicability of Freundlich isotherm was also tried using the following general equation.

Linearised form of this equation is $\log q_e = B \cdot \log C_e + \log k$

where B and k_f are Freundlich constant. 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-I). Since the values of B are less than 1, it indicates favourable adsorption.

Table-I

Adsorbent system	Langmuir Constant				Freundlich Constant		
	Q^0 mg/g	b L/mg	R	r^2	k_f	B	r^2
SDS-GAC	5.225	0.064	0.37	0.963	0.473	7.264	0.968

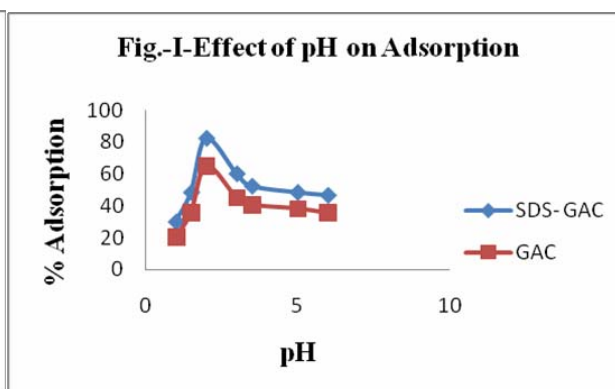
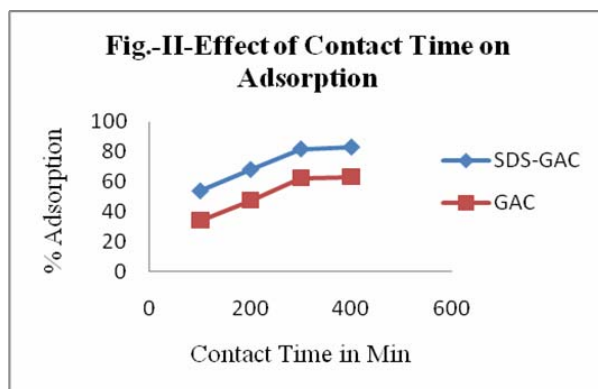
First order kinetics: - The rate of adsorption of Chromium (VI) metal ions on SDS-GAC System was studied by using the first order rate equation proposed by Lagergren. It is found that as initial Chromium (VI) metal ions concentration increases, Lagergren rate constant decrease. This indicates that, adsorption does not follow the 1st order kinetics.

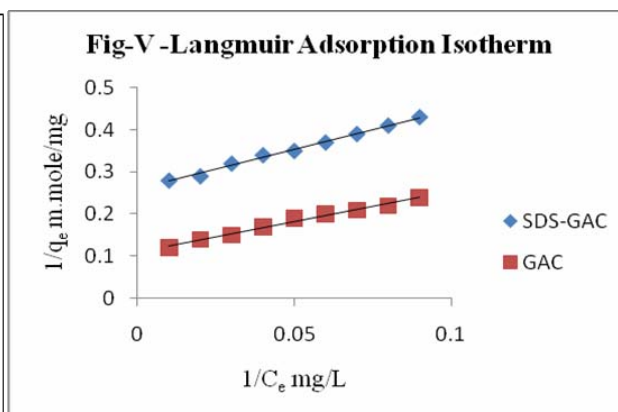
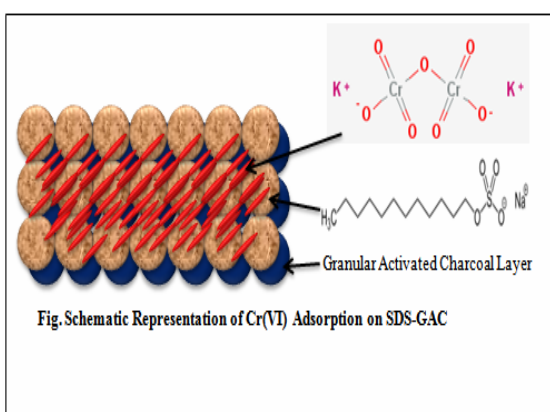
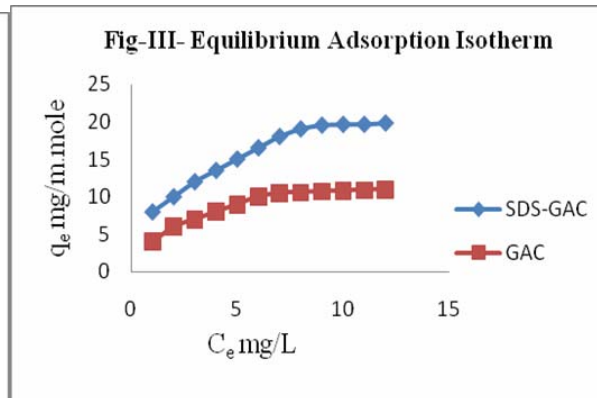
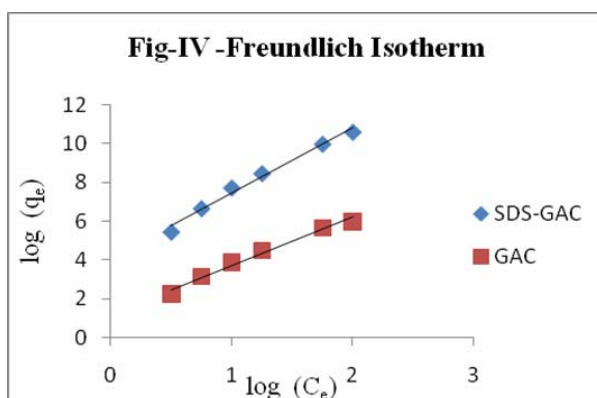
Pseudo Second order Model: Pseudo second order model showed that, Rate constant K_2 is almost constant at different initial concentration which is shown in Table 1. This indicates that adsorption of Chromium (VI) metal ions on SDS-GAC System obey the 2nd order kinetics. Also the concentration of Chromium (VI) metal ions increasing from 15mg/L to 45 mg/L, equilibrium sorption capacity q_e increase.

Elovich Model: - Adsorption of Chromium (VI) metal ions on SDS-GAC System are shown a linear relationship is obtained between the amount of Chromium (VI) metal ions adsorbed qt and $\ln t$. From the Table-II Shows that value and varied as a function of Chromium (VI) metal ions concentration. As the concentration of Chromium (VI) increases from 15mg/L to 45mg/L. value of α increase and β decreases. This favoured the adsorption phenomenon

Table-II- Kinetic Model Value for Adsorption of Cr(VI) on SDS-GAC System

Concentration	1 st Order			Pseudo Order			Elovich		
	K_L	q_e	r^2	q_e	k_2	r^2	α	β	r^2
15mg/L	0.1106	7.23	0.977	8.019	0.0016	0.991	0.4943	0.1472	0.9897
30mg/L	0.0558	13.20	0.996	13.344	0.0014	0.993	1.312	0.0843	0.9860
45mg/L	0.0144	15.73	0.998	18.862	0.0013	0.994	2.272	0.0639	0.9858





Conclusion

To develop a new type of activated carbon capable of removing cationic heavy metal more specifically and effectively. SDS most effectively enhanced the activated carbon's capacity to adsorb Cr(VI) metal ions. The capacity of the GAC to adsorb Cr(VI) metal ions increased in proportion to the quantity of the sodium Dodecyl sulfate with which the activated carbon was impregnated.

The maximum removal efficiency was observed up to 80 to 85% at pH 2.0. The investigations on the surface of GAC revealed that their enhanced adsorptive capacity was due to the negatively charged groups in the hydrophilic head of the ligand SDS. These groups made the surface charge of the activated carbon more negative, resulting in more favourable conditions for Cr(VI) metal ions adsorption. Therefore, we conclude that surface modification method using sodium dodecyl sulfate can be used to enhance the capacity of activated carbon to adsorb cationic heavy metal ions.

References

- [1] J.G. Dean, F.L. Bosqui, K.H. Lanouette, "Heavy metals in from wastewater", Environ. Sci. Technol. 6, 518–522, (1972).



- [2] O.S. Amuda, I.A. Amoo, O.O. Ajayi, “Coagulation flocculation process in the treatment of beverage industrial wastewater”, *J. Hazard. Mater. B* 129, 69–72, (2006).
- [3] D. Park, Y.S. Yun, C.K. Ahn, J.M. Park, “Kinetic of the reduction of hexavalent chromium with the brown seaweed *Ecklonia* biomass”, *Chemosphere* 66, 939–946, (2007).
- [4] C. Aydinler, M. Bayramoglu, S. Kara, B. Keskinler, O. Ince, “Nickel removal from waters using surfactant-enhanced hybrid PAC/MF process. I. The influence of system-component variables”, *Ind. Eng. Chem. Res.* 45, 3926–3933, (2006).
- [5] N. Kannan, G. Rengasamy, “Comparison of cadmium ion adsorption on various activated Carbons”, *Water Air Soil Pollut.* 163, 185–201, (2005).
- [6] D. Mohan, S. Chander, “Single component and multi-component adsorption of metal ions by activated carbons”, *Colloids Surf. A* 177, 183–196, (2001).
- [7] J.R. Rangel-Mendez, M. Streat, “Adsorption of cadmium by activated carbon cloth: influence of surface oxidation and solution pH”, *Water Res.* 36, 1244–1252, (2002).
- [8] C. Moreno-Castilla, M.A. Alvarez-Merino, M.V. Lopez-Ramon, J. Rivera-Utrilla, “Cadmium ion adsorption on different carbon adsorbents form aqueous solutions. Effect of surface chemistry, pore texture, ionic strength, and dissolved natural organic matter”, *Langmuir* 20, 8142– 8148,(2004).
- [9] C.Y. Yin, M.K. Aroua, W.M.A.W. Daud, “Review of modification of activated carbon for enhancing contaminant uptakes from aqueous solutions”, *Sep. Purif. Technol.* 52, 403–415, (2007).
- [10] A. Jusoh, L.S. Shiung, N. Ali, M.J.M.M. Noor, “A simulation study of the removal efficiency of granular activated carbon on cadmium and lead”, *Desalination* 206, 9–16, (2007).
- [11] S. Sato, K. Yoshihara, K. Moriyama, M. Machida, H. Tatsumoto, “Influence of activated carbon surface acidity on adsorption of heavy metal ions and aromatics form aqueous solution”, *Appl. Surf. Sci.* 253, 8554–8559, (2007).
- [12] A. Dabrowski, P. Podkošcielny, Z. Hubicki, M. Barczak, “Adsorption of phenolic compounds by activated carbon—a critical review”, *Chemosphere* 58, 1049–1070, (2005)