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Adsorption mechanism of hexavalent chromium removal using Amberlite IRA 743 resin

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ABSTRACT

A commercially available chelating resin namely, Amberlite IRA 743 (AMB) is a macroporous polystyrene N-methylglucamine with free base form used for the removal of chromium from aqueous solution. AMB resin possesses an enhanced chromium sorption capacity (SC) of 20.41 mg/g in a minimum period of 30 min contact time. The sorption experiments were carried out in batch mode to optimize various influencing parameters viz., contact time, initial chromium concentration, pH, co-ions and temperature. The resin is characterized by FTIR and SEM with EDAX analysis. The mechanism of chromium removal by the resin is by means of electrostatic adsorption coupled reduction and complexation. The adsorption data was fitted with Freundlich and Langmuir isotherms. The calculated values of thermodynamic parameters namely ΔG°, ΔH° and ΔS° indicate the nature of chromium sorption. The dynamic studies demonstrated that the sorption process follows pseudo-second-order and intraparticle diffusion models.

Keywords: Amberlite IRA 743 resin; chromium; removal; adsorption; complexation

INTRODUCTION

Chromium contamination in water is due to the effluents discharged from various industries such as electroplating, leather tanning, mining, steel making and pigments, which has significant impact on human health and other living organisms in the environment.[1,2] The effluents from these industries contain both Cr(III) and Cr(VI). Among them Cr(VI) is highly toxic and Cr(III) is an essential micronutrient in trace amounts necessary for carbohydrate, lipid and protein metabolism.[3] Cr(VI) compounds are carcinogenic that cause lung cancer, as well as kidney, liver and skin damage in human beings. The maximum permissible limit of chromium content in drinking water is 0.05 mg/L.[4] Cr(III) is not a significant ground water contaminant whereas Cr(VI) is approximately 100 times more toxic than Cr(III).[5] It can diffuse as CrO_4^{2-} or $HCrO_4^-$ through cell membranes.[6-9] Cr(VI) in acidic solution demonstrates a very high positive redox potential (+1.33V) which denotes that it is strongly oxidizing and unstable in the presence of electron donors.[10]

Chromium ions are not biodegradable and can be removed through various processes viz., ion exchange, adsorption, reduction, precipitation, membrane filtration and solvent extraction.[11-14] The conventional treatment methods viz., solvent extraction or precipitation, reduction is not completely satisfactory because these processes have several disadvantages like finite aqueous solubility of extractants and dilutions. Precipitation requires Cr(VI) to be reduced to Cr(III) prior to chemical precipitation in order to form the poorly soluble $Cr(OH)_3$ and Cr(VI) directly reduced to Cr(III) using reduction agents like iron sawdust, thiols, sulfites, thiosulphates, ascorbic acid, etc. which is not suitable for drinking water treatment.[15-20]

Ion exchange/adsorption process seems to be the most effective and promising technique for chromium removal. A variety of adsorbents namely clay,[21] zeolites,[22] bone charcoal[23] and polymeric resins,[24] etc., have been reported to reduce the concentration of metal ion from water. Ion exchange resins have been also widely used in recovery and preconcentration of metal ions. The polymeric resin containing functional groups that are capable of complexing or ion exchanging the metal ions in aqueous solution.[25] The resin can be regenerated and reused for continuous process. Further, the main advantages of the polymeric resin are its high porosity in bead forms or cross-linking which can help in improving the kinetics by increasing the accessibility of the polymer -supported ligands to the metal ions.

A number of studies have been performed using ion exchange resins which have received considerable attention in recent years due to their suitability to field condition and reusability. They are also adaptable to continuous process involving columns and chromatographic separations. Their insolubility renders to environmentally compatible state since the cycle of loading /regeneration/reloading allows them to be used for many years. Ion exchange is identified as an efficient heavy metal scavenger due to the presence of its reactive functional groups.[25] Resin, chelates or adsorb metal ions selectively irrespective of other ions present in the water system. Polymeric resins of various types viz., anionic and cationic/chelating resins have been employed for heavy metal removal. Ion exchange resins have been used in water softening, removal of toxic metals from water in the environment, waste water treatment, hydrometallurgy, sensors, chromotography, catalysis and biomolecular separations.[26] However, there is no study regarding the sorption of chromium onto AMB resin. AMB resin is a macroporous polystyrene N-methylglucamime chelating type resin with free base form. It is reported that AMB resin is suitable for removing boron and arsenate from aqueous solution.[27,28] The main aim of this work was to use AMB resin for chromium removal from aqueous solution and establish the probable mechanism of chromium sorption. The various influencing parameters viz., contact time, initial chromium concentration, solution pH and the presence of other ions on SC were optimized. The equilibrium sorption data was fitted with various isotherms and kinetic models to find the best fit model for the sorption system.

EXPERIMENTAL

Materials

Amberlite IRA 743 resin was supplied by Sigma Chemical Co., St Louis, Mo, USA**.** As per the guidelines of the manufacturer, the specification of the resin is given in Table 1. Potassium dichromate, sodium hydroxide, hydrochloric acid, and all other chemicals employed were of analytical reagent grade and used without further purification. All the solutions used for the laboratory studies were prepared using double-distilled water. Cr(VI) solutions at various concentrations were made by dissolving the required quantities of potassium dichromate in double-distilled water.

Table 1 Physical and chemical properties of resin

Constituents	AMB Resin
Matrix	Macroporous polystyrene
Functional groups	N-methylglucamine
Physical form	Beige-coloured beads
Ionic form	Free Base (FB)
Total capacity	0.8 eq/L
Mesh/Bead size	450 µm
Moisture holding capacity	49 to 56 % (FB form)
Maximum operating temperature K	350
Harmonic mean size	0.55-0.70 mm
Uniformity coefficient	1.4
Fine through 300µm	< 1%

Chromium sorption experiments

The batch adsorption experiments in triplicate were carried out by mixing 0.1 g of resin with 50 ml of potassium dichromate solution containing 50 mg/L at pH 4 as initial chromium concentration. The mixture was shaken in a thermostatic shaker at a speed of 200 rpm at room temperature and the filtrate was analysed for chromium. The influence of various parameters viz., contact time, initial chromium concentration, pH and presence of other ions normally present in water on the SC of the sorbent was investigated. For the temperature studies, the effect of different initial chromium concentrations viz., 40, 50 and 60 mg/L at 303, 313 and 323 K on sorption rate was studied by keeping the mass of sorbent as 0.1 g and volume of solution as 50 ml. The solution was then filtered and the residual chromium ion concentration was measured.

Analysis

The concentration of chromium was measured using UV-Visible spectrophotometer (Pharo 300 Merck) at 540 nm, according to the 1,5-diphenyl-carbazide method.[29] The pH measurements were carried out with the expandable ion analyzer EA 940 with pH electrode.[29]

Characterisation

Fourier Transform Infrared Spectroscopy (FTIR) was carried out using JASCO-460 plus model to obtain the structural information of AMB resin. The surface morphology of AMB resin before and after chromium sorption was studied with Scanning Electron Microscope (SEM) with JOEL JSM 6390LV model. Elemental spectra were obtained using an energy dispersive X-ray analyzer (EDAX) during SEM observations which allows a qualitative detection and localization of elements in AMB resin.

Statistical tools

Computations were made using Microcal Origin (Version 6.0) software. The goodness of fit was discussed using error bar plot, regression correlation coefficient (r), chi-square analysis and standard deviation (sd).

RESULTS AND DISCUSSION

Effect of contact time

The removal of Cr(VI) on AMB resin has been investigated as a function of contact time in the range of 5-60 min with 50 mg/L as initial chromium concentration at room temperature. The effect of SC of resin with contact time is shown in Figure 1. It is evident that saturation almost reached after 30 min. Hence 30 min was fixed as the period of contact for further studies. The AMB resin possesses an enhanced chromium SC of 20.4 mg/g at 30 min contact time.

Effect of initial chromium concentration

The influence of sorbate concentration on the Cr(VI) reduction and sorption was examined by varying concentrations from 10 to 70 mg/L were also performed with fixed contact time (30 min) and dosage (0.1g). Figure 2 indicates that the SC of the sorbent increases with an increase in the initial chromium concentration. The results showed that AMB resin possesses high SC at all the initial chromium concentrations studied.

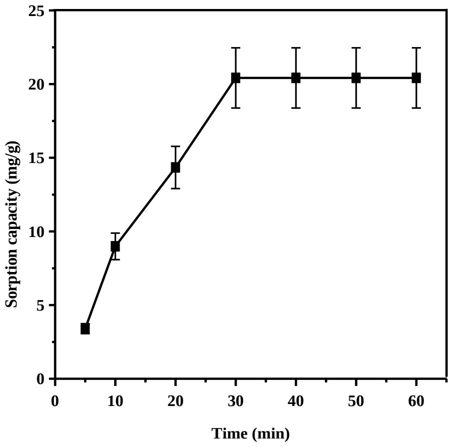


Figure 1 *Effect of contact time on SC of the resin at 303 K*

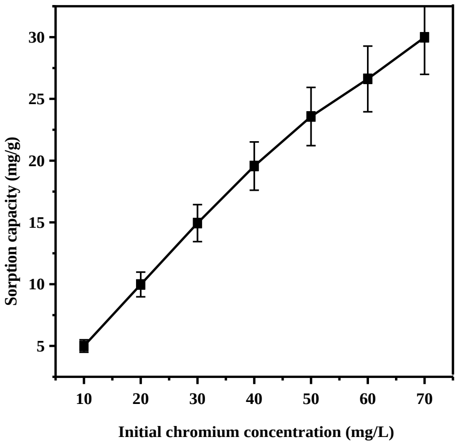


Figure 2 *Effect of initial chromium concentration on SC of the resin at 303 K*

Influence of solution pH

Cr(VI) can exist in several forms such as $Cr_2O_7^{2-}$, $HCrO_4^{\ -}$, $HCrO_7^{\ -}$ and CrO_4^{2-} and the relative abundance of particular complex depends on the concentration of the chromium ion and pH of the solution.[30] Hence the chromium sorption onto the sorbent was studied at five different initial pH levels viz., 3, 5, 7, 9 and 11 by keeping all other parameters like contact time, dose and initial chromium concentration as constant. The pH of the working solution was controlled by adding HCl/NaOH solution.

Figure 3 shows the SC of resin as a function of pH. The effect of pH on the sorption of Cr (VI) onto the sorbent is higher at low pH levels and decreases with increase in solution pH. Similar results were observed by Dantas et al. and Schmuhl et al.[30,31] The reason could be at lower pH levels, AMB resin has acquired positive charge due to the protonation of tertiary amine groups and the predominant species of chromium in the form of $HCrO_4^-$ ion has been adsorbed through electrostatic attraction which may be reduced into Cr(III) and complexed by the sorbent[32] which results in an increased adsorption at low pH ranges.

The sorbital group in AMB resin forms stable complex with Cr(VI) in acid media and reduced to Cr(III) due to electron donor group present in the resin. There is a gradual decrease in SC of the sorbent as the pH of the solution increases, which may be due to the competition of OH^- ion for the sorption sites of the sorbent surface. Irrespective of the initial pH ranges studied, the final pH of the treated water reaches neutral pH.

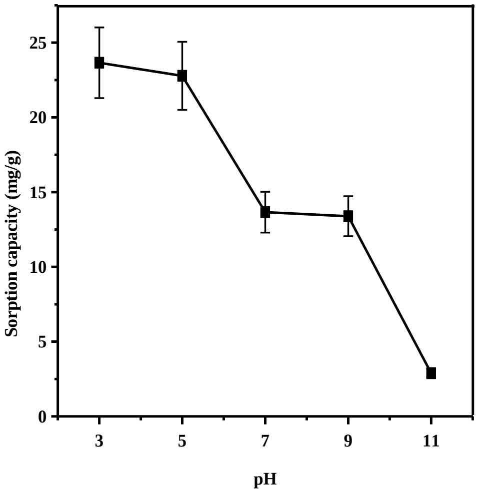


Figure 3 *Influence of pH on the on SC of the resin at 303 K*

Effect of co-ions

Chromium removal studies of AMB resin were carried out in the presence of common ions Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+} and Mg^{2+} that are normally present in water and was experimentally verified. The concentration of other co-ions was fixed at 200 mg/L as initial concentration with 50 mg/L an initial chromium concentration by keeping all other parameters such as contact time, pH, dosage and initial chromium concentration as constants. Ca^{2+} and Mg^{2+} ions alter the sorption capacity due to alkaline pH provided by Ca^{2+} and Mg^{2+} salts. From the graph it is evident that the overall SC of AMB resin was slightly altered by the presence of co-ions. The reduction in SC may be due to co-ion competition for the surface binding sites. Figure 4 explains the effect of SC of AMB resin in presence of co-anions.

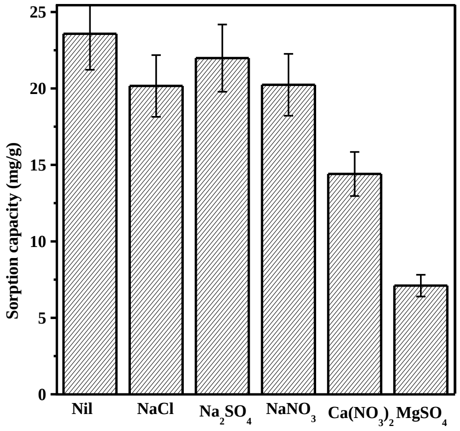


Figure 4 *Effect of co-ions on the SC of AMB resin at 303 K*

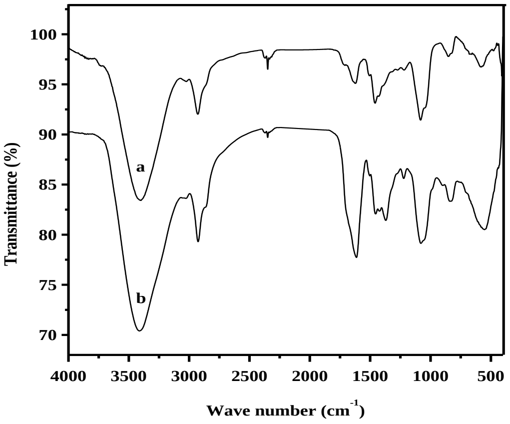
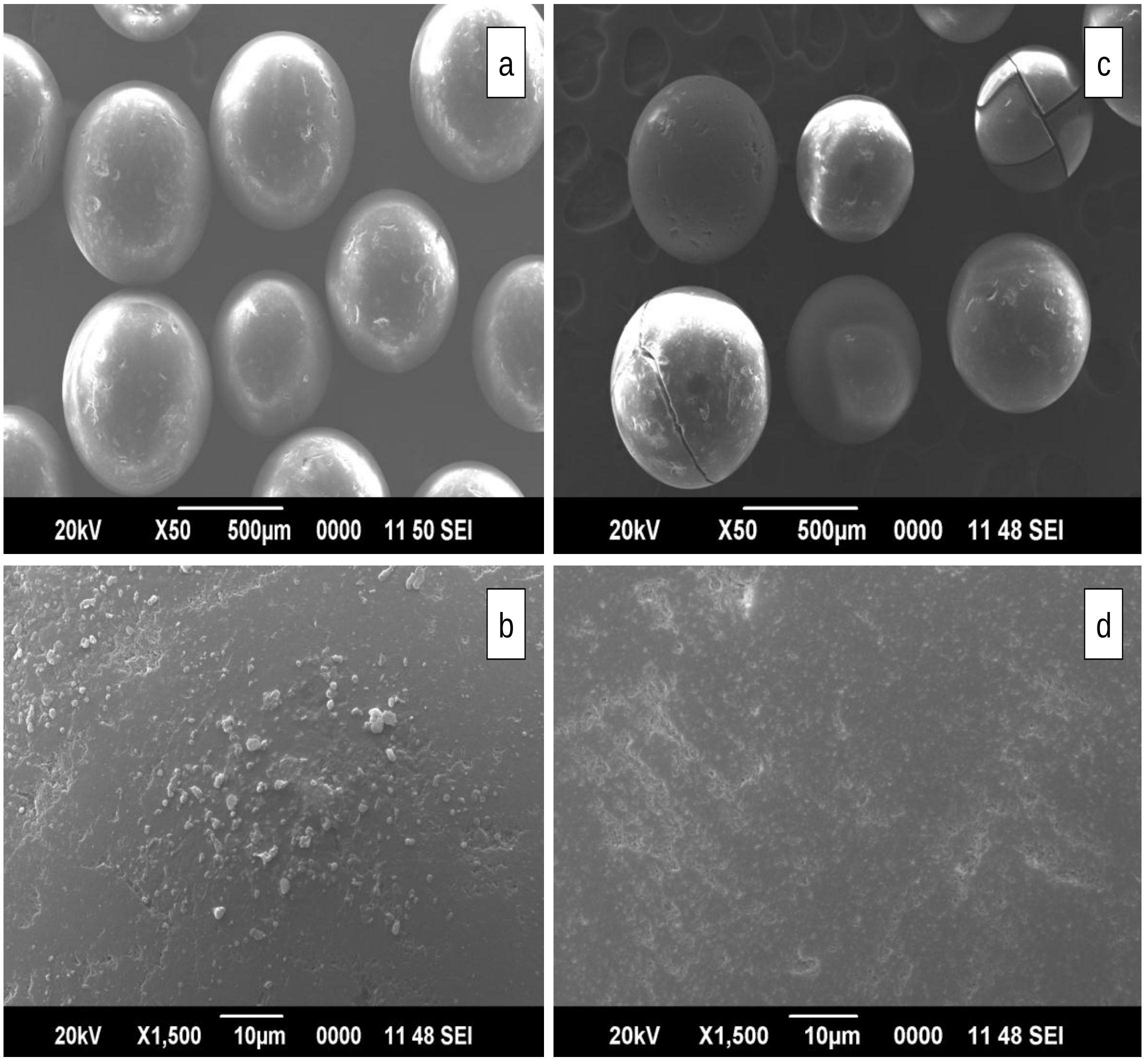


Figure 5 *FTIR spectra of (a) AMB resin and (b) chromium-sorbed AMB resin*

Characterization of AMB resin

Figure 5a and b depict FTIR spectra of fresh AMB resin and chromium treated AMB resin respectively. The broad band at 3440 cm^{-1} indicates the presence of –OH and –NH stretching vibrations.[33] The band at 2924 cm^{-1} indicates the –CH stretching vibration in –CH and $-CH_2$. A band at 1635 cm^{-1} corresponds to –NH bending vibration in $-NH_2$ and 1065 cm^{-1} indicates the presence of –CO stretching vibration in –COH.[34,35] The band at 1079 cm^{-1}($\delta_{C\text{-}O}$), 1052 ($\delta_{C\text{-}N}$), 862 ($\delta_{C\text{-}N}$) cm^{-1} suggesting that N-methyl glucamine present in the AMB resin[35] and in chromium sorbed AMB resin these band become broad and shifted to lower frequencies which confirms that chromium sorption have occurred on the AMB resin. The new band at 906 cm^{-1} indicates the Cr =O bonds of chromate anion confirming the sorption of Cr(VI) onto the AMB resin.[36] The new band at 540 cm^{-1} indicates the presence of $Cr(OH)_3$ in the chromium treated AMB resin.[37,38]

SEM pictures of AMB resin are shown in Fig. 6a-b and the chromium sorbed AMB resin is shown in Fig. 6c-d. The change in the SEM micrographs of the AMB resin before and after chromium treatment indicates the structural changes in the AMB resin. This is further supported by EDAX analysis which provides direct evidence for the sorption of chromium onto AMB resin. The EDAX spectra of AMB resin confirm the presence of elements in the AMB resin. The chromium sorption occurred onto the AMB resin was confirmed by the presence of chromium peaks in the EDAX spectra of chromium treated AMB resin (cf. Figure 6e and f)



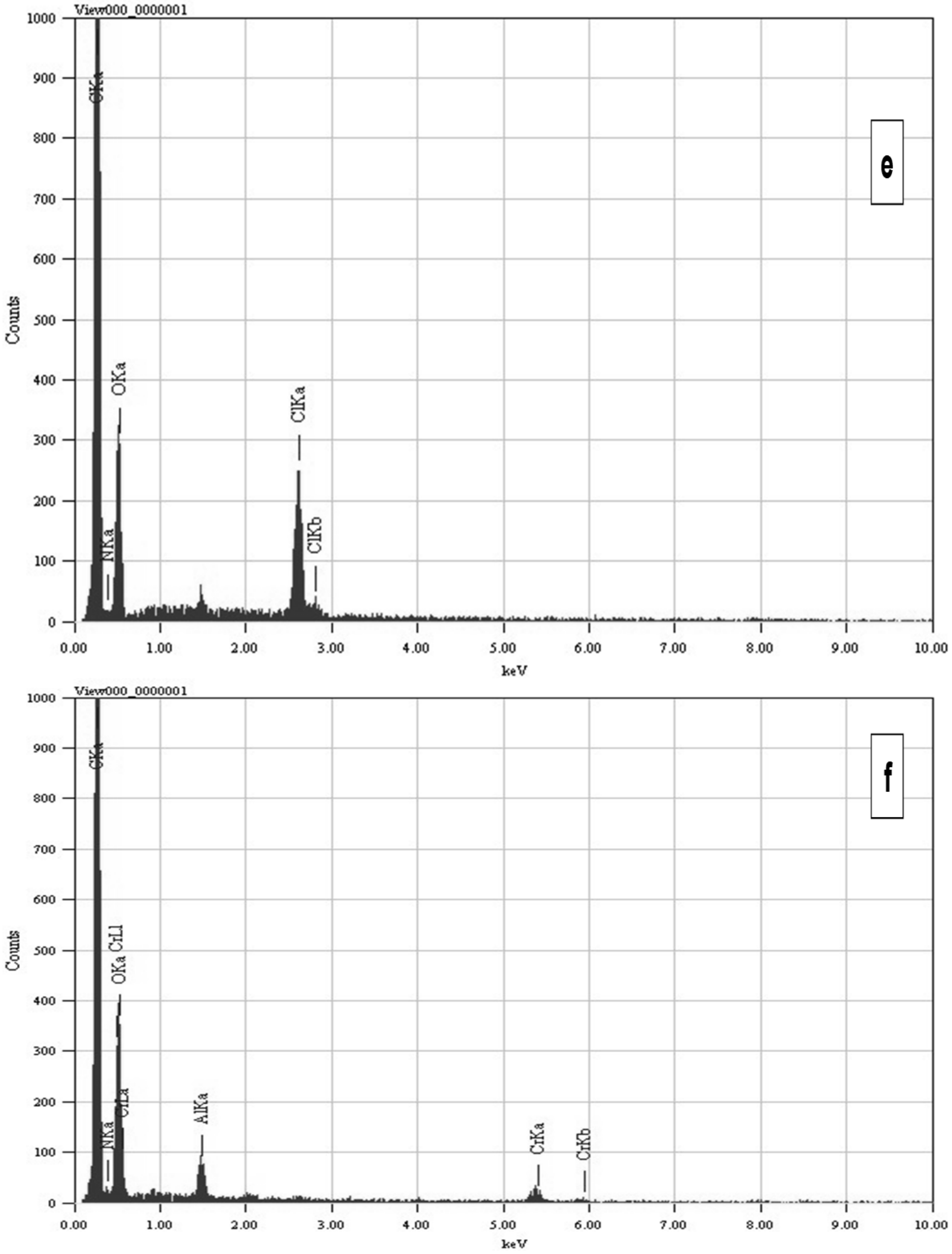


Figure 6 *SEM micrographs of (a-b) AMB resin (c-d) chromium sorbed AMB resin (e) EDAX spectra of AMB resin (f) EDAX spectra of chromium treated AMB resin*

Sorption isotherms

To quantify the sorption capacity of AMB resin for chromium sorption, two-parameter equations namely Freundlich and Langmuir isotherms have been adopted.

Freundlich isotherm

The Freundlich isotherm[39] in its linear form is represented by

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

where q_e is the amount of chromium adsorbed per unit weight of the sorbent (mg/g), C_e is the equilibrium concentration of chromium in solution (mg/L), k_F is a measure of adsorption capacity and 1/n is the adsorption intensity. The Freundlich isotherm constants k_F and n were calculated from the slope and intercept of the plot of log q_e vs log C_e and are presented in Table 2. The values of 1/*n* lying between 0 and l and the *n* values in between 1-10 indicate the conditions favorable for adsorption. The k_F value increased with the rise in temperature. The higher *r* values indicate the applicability of Freundlich isotherm.

Langmuir isotherm

The Langmuir isotherm[40] in its linear form is represented by

$$\frac{C_e}{q_e} = \frac{1}{Q^o b} + \frac{C_e}{Q^o} \tag{2}$$

where q_e is the amount of chromium adsorbed per unit weight of the sorbent (mg/g), C_e is the equilibrium concentration of chromium in solution (mg/L), Q^o is the amount of adsorbate at complete monolayer coverage (mg/g) and gives the maximum sorption capacity of sorbent and *b* (L/mg) is Langmuir isotherm constant that relates to the energy of adsorption. The Langmuir constants Q^o and *b* were calculated from the slope and intercept of the plot C_e/q_e versus C_e respectively and the values are presented in Table 2. There is an increase in Q^o with increase in temperature which indicates sorption capacity increases with the increase in temperature which in turn suggests the mechanism of chromium removal by the sorbent is mainly due to chemisorption. The higher *r* values indicate the applicability of Langmuir isotherm.

The feasibility of the isotherm can be tested by calculating the dimensionless constant separation factor or equilibrium parameter, R_L is expressed as

$$R_L = \frac{1}{1 + bC_0} \tag{3}$$

where *b* is the Langmuir isotherm constant and C_o is the initial concentration of chromium (mg/L). The R_L value at different temperatures studied are calculated and are given in Table 2. The R_L values lying between 0 and 1 indicate the favorable conditions for adsorption.

Chi-square analysis

Chi-square analysis is applied to find the suitable isotherm model for the chromium sorption on to AMB resin. The advantage of using chi-square test is for comparing all isotherms on the same abscissa and ordinate. The equivalent mathematical expression is

$$\chi^2 = \sum \frac{(q_e - q_{e,m})^2}{q_{e,m}} \tag{4}$$

where $q_{e,m}$ is the equilibrium capacity obtained by calculating from the model (mg/g) and q_e is the experimental data of the equilibrium capacity (mg/g). If the data from the model are similar to the experimental data, χ^2 will be a small number, while if they differ, χ^2 will be a bigger number. The results of chi-square analysis are presented in Table 2. The lower χ^2 values of Freundlich isotherms suggest the applicability of the best fitting model for the sorption of chromium on AMB resin than the Langmuir.

Table 2 *Freundlich and Langmuir isotherms of AMB resin on the removal of chromium*

Temp. (K)	Freundlich isotherm					Langmuir isotherm				
	1/n	n	k_F (mg/g) (L/mg)$^{1/n}$	r	χ^2	Q^o (mg/g)	b (L/g)	R_L	r	χ^2
303	0.290	3.439	14.39	0.999	5.5 E-4	29.35	0.54	0.014	0.999	2.7E-03
313	0.220	4.529	18.00	0.930	7.2 E-2	30.30	1.15	0.011	0.980	0.109
323	0.191	5.222	19.42	0.911	9.4 E-2	32.09	1.70	0.009	0.980	0.134

Thermodynamic treatment of the sorption process

The effect of temperature is a major influencing factor in the sorption process. The sorption of AMB resin was monitored at three different temperatures 303, 313 and 323 K under the optimized condition and thermodynamic parameters viz., standard free energy change (ΔG^o), standard enthalpy change (ΔH^o) and standard entropy change (ΔS^o) were calculated as follows,

The change in free energy of sorption is given by

$$\Delta G^0 = -RT\ln K_0 \qquad (5)$$

where K_o is the sorption distribution coefficient, ΔG^o is the free energy of sorption (kJ/mol), T is the temperature in Kelvin and R is the universal gas constant (8.314 J mol^{-1} K^{-1}). The sorption distribution coefficient K_o was determined from the slope of the plot ln (q_e/C_e) against C_e at different temperatures and extrapolating to zero C_e according to Khan and Singh method.[41]

The sorption distribution coefficient can be expressed in terms of enthalpy change (ΔH^o) and entropy change (ΔS^o) as a function of temperature,

$$\ln K_o = \frac{\Delta S^o}{R} - \frac{\Delta H^o}{RT} \qquad (6)$$

where ΔH^o is the standard enthalpy change (kJ/mol) and ΔS^o is standard entropy change (kJ/mol.K). The values of ΔH^o and ΔS^o can be obtained from the slope and intercept of a plot of ln K_o against $1/T$.

The calculated values of thermodynamic parameters are shown in Table 3. The negative values of ΔG^o indicate the spontaneous nature of chromium sorption onto AMB resin. The value of ΔH^o is positive indicating that the sorption process is endothermic. The positive value of ΔS^o shows the increased randomness at the solid/solution interface during chromium sorption.

Table 3 *Thermodynamic parameters of AMB resin on the removal of chromium*

Thermodynamic parameters		AMB resin
	303 K	-6.24
ΔG^o (kJ mol^{-1})	313 K	-3.35
	323 K	-3.34
ΔH^o (kJ mol^{-1})		48.60
S^o (kJ $mol^{-1}K^{-1}$)		0.14

Sorption kinetics

To understand the sorption mechanism such as mass transport and chemical reaction processes, two types of kinetic models viz., reaction-based and diffusion- based models were applied to test the fitness of experimental data.

Reaction-based models

The most commonly used pseudo-first-order and pseudo-second-order models were employed to explain the solid/liquid adsorption.

A simple pseudo-first-order kinetic model[42] is given as

$$\log(q_e - q_t) = \log q_e - \frac{k_{ad}}{2.303}t \qquad (7)$$

where q_t is the amount of chromium on the surface of the AMB resin at time t (mg/g) and k_{ad} is the equilibrium rate constant of pseudo-first-order sorption (min^{-1}). The linear plots of log (q_e-q_t) against t give a straight line that indicates the applicability of pseudo-first-order model. The slope of the straight line plot of log (q_e-q_t) against t sorption at different temperatures viz., 303, 313 and 323 K give the value of the pseudo-first-order rate constant (k_{ad}) and r are listed in Table 4.

In addition, the pseudo-second-order model is also widely used. There are four types of linear pseudo-second-order kinetic models[43] the most popular linear form is

$$\frac{t}{q_t} = \frac{1}{h} + \frac{t}{q_e} \qquad (8)$$

where $q_t = \dfrac{q_e^2\ kt}{1+q_e kt}$, amount of chromium on the surface of the AMB resin at any time, t (mg/g), k is the pseudo-second-order rate constant (g/mg min), q_e is the amount chromium ion sorbed at equilibrium (mg/g) and the initial sorption rate, $h = kq_e^2$ (mg/g min). The value of q_e (1/slope), k ($slope^2$/intercept) and h (1/intercept) of the pseudo-second-order equation can be found out experimentally by plotting t/q_t against t. In addition, the fitness of the data and the values of q_e, k, h and r of the pseudo-second-order model were obtained from the plots of t/q_t vs. t for chromium sorption at different temperatures viz., 303, 313 and 323 K of AMB resin and are presented in Table 4. The values of q_e increase with the increase in temperature indicating the chromium sorption increases with the rise in the temperature. The higher r values obtained for pseudo-second-order model than pseudo-first-order model indicate the applicability of the pseudo-second-order model.

Diffusion-based models

In a solid-liquid sorption process the transfer of solute is characterized by pore diffusion or particle diffusion control. A simple equation for the particle diffusion controlled process[44] is given as follows,

$$\ln\left(1-\frac{C_t}{C_e}\right)=-k_p t \quad (9)$$

where k_p is the particle rate constant (min^{-1}). The value of particle rate constant is obtained by the slope of ln (1- C_t/C_e) against t.

The intraparticle diffusion model used here refers to the theory proposed by Weber and Morris[45] and its equation is

$$q_t = k_i\, t^{1/2} \qquad (10)$$

where k_i is the intraparticle rate constant (mg/g $min^{0.5}$). The slope of the plot of q_t against $t^{½}$ will give the value of intraparticle rate constant.

The respective straight line plots of ln (1-C_t/C_e) vs. t and q_t vs. $t^{0.5}$ indicate the applicability of particle and intraparticle diffusion models. The k_p, k_i and r values at different temperatures viz., 303, 313 and 323 K for both particle and intraparticle diffusion models are illustrated in Table 4. The r values obtained for both particle and intraparticle diffusion models are almost comparable and suggest that the chromium diffusion on AMB resin follows both the models.

The best-fit model

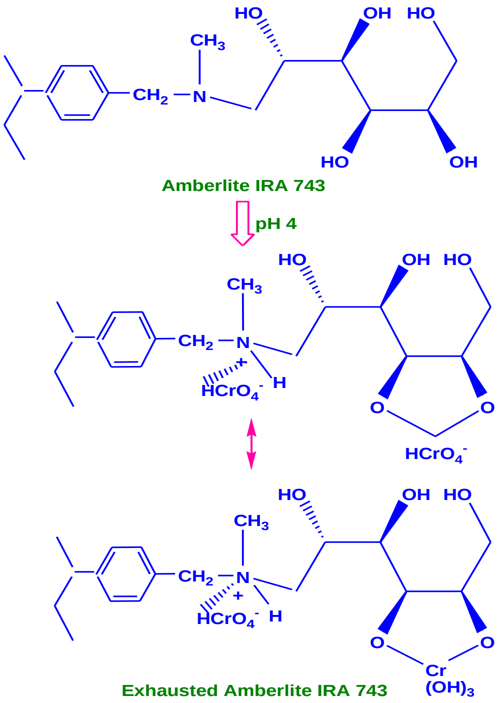
The assessment of the employed kinetic models for fitting the sorption data was made by standard deviation (sd). The sd values of AMB resin for all the kinetic models are shown in Table 4. Smaller sd values were observed for pseudo-second-order and intraparticle diffusion models indicates that these two models are significant in defining the chromium sorption process suggesting that the sorption of chromium is onto the pores of AMB resin.

Table 4 Kinetic *models of AMB resin for chromium sorption*

Kinetic models	Parameters	303 K			313 K			323 K		
		40 mg/L	50 mg/L	60 mg/L	40 mg/L	50 mg/L	60 mg/L	40 mg/L	50 mg/L	60 mg/L
Pseudo-first-order	k_{ad} (min^{-1})	0.105	0.089	0.087	0.096	0.094	0.099	0.138	0.122	0.115
	r	0.879	0.932	0.979	0.938	0.942	0.960	0.888	0.895	0.913
	sd	0.526	0.322	0.165	0.324	0.304	0.260	0.659	0.555	0.467
Pseudo-second-order	q_e (mg/g)	20.83	24.39	27.77	21.73	24.39	28.57	21.73	25.00	29.41
	k (g/mg min)	0.0065	0.0087	0.010	0.006	0.0095	0.0102	0.0066	0.0090	0.0100
	h (mg/g min)	2.840	5.181	8.403	3.115	5.681	8.403	3.154	5.681	8.695
	r	0.996	0.998	0.997	0.997	0.998	0.999	0.997	0.998	0.999
	sd	0.0841	0.0470	0.018	0.0642	0.0409	0.0247	0.0654	0.0479	0.0288
Particle diffusion	k_p (min^{-1})	0.107	0.091	0.088	0.095	0.094	0.097	0.122	0.123	0.108
	r	0.878	0.932	0.979	0.942	0.942	0.962	0.915	0.895	0.921
	sd	1.227	0.743	0.378	0.704	0.701	0.568	1.133	1.279	0.957
Intraparticle diffusion	k_i (mg/g $min^{0.5}$)	1.179	1.045	1.006	1.226	1.012	1.054	1.239	0.990	0.980
	r	0.992	0.992	0.981	0.987	0.991	0.987	0.986	0.987	0.988
	sd	0.268	0.243	0.369	0.372	0.252	0.317	0.396	0.299	0.279

Sorption mechanism

The mechanism of chromium removal by AMB resin was governed by electrostatic adsorption coupled reduction and complexation and the possible mechanism is shown in Scheme 1. At acidic pH, the AMB resin gets positively charged due to the protonation of amino groups which remove hydrogen chromate ion by means of electrostatic attraction/complexation. This results in increased chromium sorption at low pH ranges. The –OH and $–NH_2$ groups present in the AMB resin reduce the toxic Cr(VI) to Cr(III) compounds.[36] The FTIR spectra of Cr(VI) loaded sorbent have a new band at 540 cm^{-1} that confirms the formation of $Cr(OH)_3$ in the chromium sorbed resin.[37,38] Further, Cr(VI) in acidic solution demonstrates a very high positive redox potential (+1.33V) which denotes that it is strongly oxidizing and unstable in the presence of electron donors having lower reduction potential values than that of Cr(VI).[46] This results in increased chromium sorption at low pH ranges. The reactive –OH and –NH_2 electron donor groups present in the AMB resin reduce the toxic Cr(VI) to less toxic Cr(III) compounds confirms the adsorption coupled reduction.[36,46,47] This information was supported by the green colour of chromium sorbed resin which is the typical colour of Cr(III) complexes. The presence of chromium peak in the EDAX spectra of chromium sorbed AMB resin confirms the occurrence of chromium sorption onto the AMB resin (cf. Figure 6d).



Scheme ***1*** *Mechanism of chromium sorption by AMB resin*

CONCLUSIONS

The hexavalent chromium sorption characteristics of AMB resin were studied under various equilibrium and thermodynamic conditions. AMB resin displayed good selectivity towards chromium removal. The SC of AMB resin was influenced by the pH of the medium and in the presence of co-ions. After sorption, irrespective of initial pH ranges, the final pH of the treated water was found to be neutral. The nature of the sorption was spontaneous and endothermic. The sorption of chromium on AMB resin followed Freundlich isotherm. The kinetics of the reaction follows pseudo-second-order and intraparticle diffusion models. The mechanism of chromium sorption by AMB resin was mainly governed by electrostatic adsorption coupled reduction and complexation.

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