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RESEARCH ARTICLE

Adsorption of Chromium Ion by Acid Activated Abutilon Indicum-Kinetic, Mechanistic, Thermodynamic and Equilibrium Studies

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ABSTRACT

The research of the present work was to investigate the removal of Chromium ion from aqueous solution by using Abutilon Indicum (AAAI). Generally, metal ions are used in chemical, textile, paper, printing, leather, plastics and various food industries. The need for the treatment of metal ion contaminated waste water passed out from the industry. In this study, Abutilon Indicum was studied for its potential use as an adsorbent for removal of Chromium ions. The various factors affecting adsorption, such as initial metal ion concentration, contact time, adsorbent dose and effect of temperature, were evaluated. The experimental data were fitted into the pseudo-second order kinetic model. The equilibrium of adsorption was modeled by using the Langmuir and Freundlich isotherm models. The objective of the present work suggests the AAAI may be utilized as a low cost adsorbent for Chromium ions removal from aqueous solution.

INTRODUCTION

Wastewater quality can be defined by physical, chemical or biological characteristics. Wastewater generally contains toxic inorganic and organic pollutants. Inorganic pollutants consist of mineral acids, inorganic salts, finely divided metal compounds, trace elements, cyanides, nutrients and organ metallic compounds. Some of the trace elements play essential roles in biological processes, but at higher concentrations, they may be toxic to the biota; they disturb the biochemical processes and cause hazards. These elements include metals (Cd, Cr, Co, Fe, Cu, Zn, Pd, Hg, Ni, Ag) and metalloids (Se, As, Sb). Most of the trace elements are transition metals with variable oxidation states and coordination numbers. These metals form complexes with organics in the environment thereby increasing their mobility in the biota and manifest toxic effects. Although there are metals that have inherent ability to antagonize the essential functions of other elements, the heavy load of contaminants arising from human activity exceeds the ability of self-purification of aqueous environment.

A number of treatment processes for the removal of heavy metal ions from aqueous solutions have been reported, mainly ion-exchange, electrochemical reduction, evaporation, solvent extraction, reverse osmosis, chemical precipitation, membrane filtration, adsorption, etc. Depending on the nature of the aqueous effluents, flow rates and metal ion concentrations, the industrial application of these processes is restricted by the operating costs or by the inefficiency of the technique [1, 2, 3]. The present study undertaken to evaluate the efficiency of an adsorbent prepared from Acid Activated Abutilon Indicum for removal of chromium ion in aqueous solution. In order to design adsorption treatment systems, knowledge of kinetic and mass transfer processes is essential. In this paper, the applicability of kinetic and mass-transfer models for the adsorption of chromium ion onto Acid Activated Abutilon Indicum was discussed in detailed manner.

Experimental section

Adsorbent Material

The Abutilon Indicum obtained from Agricultural field of Tamilnadu was carbonized, washed and activated around 400°C in a muffle furnace for 5 hrs then it was taken out, ground well to fine powder and stored in a vacuum desiccators.

Abutilon Indicum

Batch equilibration method

The adsorption experiments were carried out in a batch process at 30, 40, 50 and 60° C. A known weight of Acid Activated Abutilon Indicum was added to 50 ml of the metal ion solutions with an initial concentration of 25 mg/L to 125 mg/L, which is prepared from 1000

Corresponding author: arivu3636@yahoo.com mg/L of Metal ion stock solution. The contents were shaken thoroughly using a mechanical shaker with a speed of 120 rpm. The solution was then filtered at present time intervals and the residual metal ion concentration was measured.

Dosage of adsorbents

The various doses consisting of the adsorbents respectively mixed with the metal ions solution and the mixture was agitated in a mechanical shaker. The adsorption capacities for different doses were determined at definite time intervals by keeping all other factors constant.

Initial concentration of metal ion

In order to determine the rate of adsorption, experiments were conducted with different initial concentrations of metal ions ranging from 25 to 125 mg/L. All other factors have kept constant.

Contact time

The effect of period of contact on the removal of the metal ion on adsorbent in a single cycle was determined by keeping particle size, initial concentration, dosage, pH and concentration of other ions constant.

pH

Adsorption experiments were carried out at pH 2, 3,4,5,6,7,8,9 and 10. The acidic and alkaline pH of the media was maintained by adding the required amounts of dilute hydrochloric acid and sodium hydroxide solutions. The parameters like particle size of the adsorbents, metal ion concentration, dosage of the adsorbents and concentration of other ions have kept constant while carrying out the experiments. The pH of the samples was determined using a portable pH meter, Systronics make. The pH meter was calibrated with 4.0 and 9.2 buffers.

Chloride

The experiments were done in the presence of varying chloride environments using various chloride solutions. While doing the experiments, the absence of other anions has ensured.

Temperature

The adsorption experiments were performed at four different temperatures viz., 30, 40, 50 and 60˚C in a thermostat attached with a shaker, Remi make. The constancy of the temperature was maintained with an accuracy of ± 0.5º C.

Zero point charge

The pH at the potential of zero charge of the AAAI was measured using the pH drift method. The pH of the solution was adjusted by using 0.01 M sodium hydroxide or hydrochloric acid. Nitrogen was bubbled through the solution at 25^0C to remove the dissolved carbon dioxide. Acid Activated Abutilon Indicum 50 mg was added to 50 ml of the solution. After stabilization, the final pH was recorded. The graphs of final pH versus initial pH used to determine the zero point charge of the Acid Activated Abutilon Indicum.

Titration studies

According to Boehm only strong acidic carboxylic acid groups are neutralized by sodium bicarbonate, where as those neutralized by sodium carbonate are thought to be lactones, lactol and carboxyl group. The weakly acidic phenolic groups only react with strong alkali, sodium hydroxide. Therefore, by selective neutralization using bases of different strength, the surface acidic functional group in AAAI can be characterized both quantitatively and qualitatively. Neutralization with hydrochloric acid characterizes the amount of surface basic groups that are, for example, pyrones and chromenes. The basic properties have described to surface basic groups and the pi electron system of AAAI basal planes. The results indicate that the activated AAAI used may possesses acidic oxygen functional group on their surface and this is supported well by their respective zero point charge values. The results obtained from the above characterization studies are given in the Table 1.

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the metal ions. The effect of various reagents used for desorption are studied.

RESULTS AND DISCUSSIONS

Characterization of the adsorbent

Acid Activated Abutilon Indicum is a widely used adsorbent due to its high adsorption capacity, high surface area, micro porous structure and high degree of surface respectively. The wide usefulness AAAI is a result of their specific surface area, high chemical and mechanical stability. The chemical nature and pore structure usually determines the sorption activity. The physico chemical properties are listed in Table 1

Table 1. Characteristics of the adsorbent

Properties	AAAI
Particle size (mm)	0.021
Density (g/cc)	0.2852
Moisture content (%)	0.35
Loss on ignition (%)	0.42
Water soluble matter (%)	0.08
pH of aqueous solution	6.50
pH_{zpc}	6.75
Surface groups (m equiv/g)	
i) Carboxylic acid	0.125
ii) Lactone, lactol	0.032
iii) Phenolic	0.022
iv) Basic (pyrones and chromenes)	0.036

Effect of contact time and initial metal ion concentration

The experimental results of adsorptions of at various concentrations (25 to 125 mg/L) with contact time are shown in Figure 1.

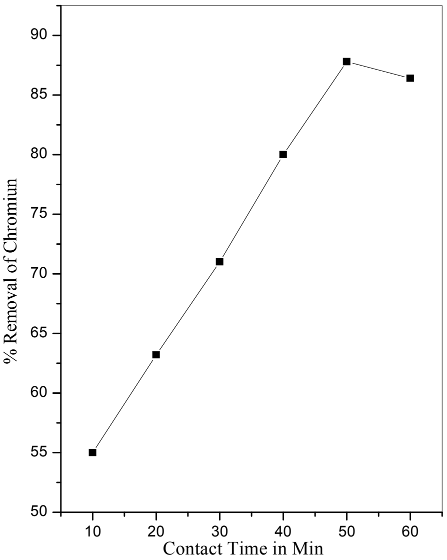


Fig:1-Effect of Contact Time on the Removal of Cr Ion
[Cr]=50 mg/L;Temprature 30^0C: adsorbent dose=25mg/50ml

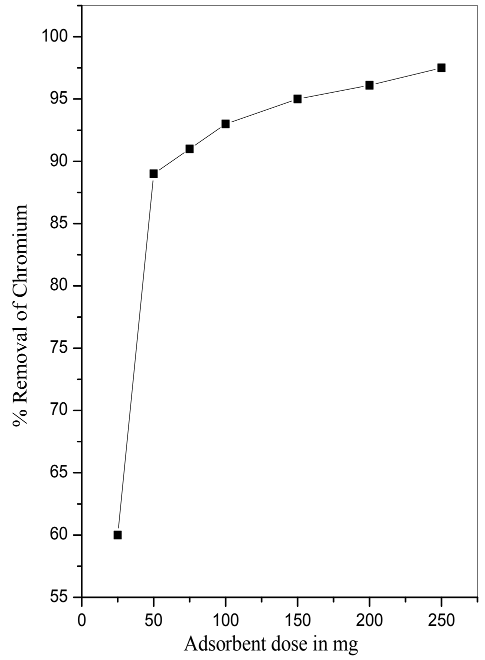
The equilibrium data were collected in Table 2 reveals that, percent adsorption decreased with increase in initial chromium ion concentration, but the actual amount of chromium ion adsorbed per unit mass of adsorbate increased with increase in chromium ion concentration. It means that the adsorption is highly dependent on initial concentration of chromium ion. It is because of that at lower concentration, the ratio of the initial number of chromium ion to the available surface area is low subsequently the fractional adsorption becomes independent of initial concentration. However, at high concentration the available sites of adsorption becomes fewer and hence the percentage removal of chromium ion is dependent upon initial concentration [5, 6]. Equilibrium have established at 45 minutes for all concentrations. Figure 1 reveals that the curves are single, smooth, and continuous, leading to saturation, suggesting the possible monolayer coverage of the chromium ion on the Abutilon Indicum surface.

Table 2. Equilibrium parameters for the adsorption of chromium ion onto abutilon indicum

Cr_0	Ce (Mg / L)				Qe (Mg / g)				Removed (%)			
	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C
25	2.06	1.08	1.68	1.37	45.87	47.82	46.62	47.24	91.75	95.64	93.25	94.49
50	7.34	6.54	5.61	4.55	85.30	86.90	88.77	90.88	85.30	86.90	88.77	90.88
75	15.26	13.63	12.09	10.68	119.47	122.7	125.81	128.63	79.64	81.81	83.87	85.75
100	29.56	27.02	12.09	22.57	140.87	145.94	175.81	154.84	70.43	72.97	87.90	77.42
125	45.62	42.73	24.68	37.88	158.75	164.53	200.62	174.22	63.50	65.81	80.24	69.68

Effect of concentration

The adsorption of the chromium ion on Abutilon Indicum was studied by varying the concentration (10-250 mg/50ml) for 50 mg/L of chromium ion concentration. The percent adsorption increased with increase in the AAAI concentration (Figure 2). This was attributed to increased AAAI surface area and availability of more adsorption sites [5, 6]. Hence remaining part of experiments is carried out with the adsorbent dose of 25 mg/50 ml.



Fig;2- Effect of Adsorbent dose on the removal of Chromium [Cr]=50mg/L;Contact Time 60min;Temprature 30^{0}C

Adsorption isotherm

The experimental data analyzed according to the linear form of the Langmuir and Freundlich isotherms [7, 8]. The Langmuir isotherm represented by the following equation

$$C_e/Q_e = 1/Q_m b + C_e/Q_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where C_e is the equilibrium concentration (mg/L), Q_e is the amount adsorbed at equilibrium (mg /g) and Q_m and b is Langmuir constants related to adsorption efficiency and energy of adsorption, respectively. The linear plots of C_e/Q_e versus C_e suggest the applicability of the Langmuir isotherms. Values of Q_m and b were determined from slope and intercepts of the plots and are presented in Table 3. From the results, it is clear that the value of adsorption efficiency Q_m and adsorption energy b of the AAAI adsorbent increases on increasing the temperature. The observed Q_m values conclude that the maximum adsorption corresponds to a saturated monolayer of adsorbate molecules on adsorbent surface with constant energy and no transmission of adsorbate in the plane of the adsorbent surface. The observed b values shows that the adsorbent prefers to bind acidic ions and that speciation predominates on sorbent characteristics, when ion exchange is the predominant mechanism takes place in the adsorption of chromium ion. Further, it confirms the endothermic nature of the process involved in the system [9, 10, and 11]. To confirm the favourability of the adsorption process, the separation factor (R_L) has calculated and presented in Table 4. The values were found to be between 0 and 1 and confirm that the ongoing adsorption process is favorable [12]. The Freundlich equation was also employed for the adsorption of chromium ion on the adsorbent. The Freundlich isotherm have represented as

$$\log Q_e = \log K_f + 1/n \log C_e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Table 3. Langmuir and freundlich isotherm parameter for the adsorption of chromium ion on to abutilon indicum

TEMP. (C°)	LANGUMUIR PARAMETER		FRUENDLICH PARAMETER	
	Q_m	b	K_f	n
30°	181.73	0.13	4.7	2.47
40°	181.32	0.18	5.31	2.90
50°	278.41	0.09	4.68	1.77
60°	194.94	0.19	5.26	2.54

Table 4. Dimensionless seperation factor (r_l) for the adsorption of chromium ion on to abutilon indicum

(C_i)	TEMPERATURE °C			
	30°C	40°C	50°C	60°C
25	0.23	0.18	0.29	0.16
50	0.13	0.09	0.17	0.09
75	0.09	0.06	0.12	0.06
100	0.06	0.05	0.09	0.04
125	0.05	0.04	0.07	0.03

Where Q_e is the amount of chromium ion adsorbed (mg/g), C_e is the equilibrium concentration of chromium ion in solution (mg/L) and K_f and n are constants incorporating all factors affecting the adsorption capacity and intensity of adsorption, respectively. Linear plots of log Q_e versus log C_e shows that the adsorption of chromium ion follows the Freundlich isotherm. The found values of K_f and n have given in the Table 3 shows that the increase in negative charges on the adsorbent surface, that makes electrostatic force like Vanderwaal's between the AAAI surface and chromium ion. This increases the adsorption of chromium ion. The higher atomic weight, large size and radii of the chromium ion have limits the possibility of the adsorption of chromium ion onto adsorbent in higher concentration. However, the values clearly show the dominance in adsorption capacity. The intensity of adsorption is an indicative of the bond energies between chromium ion and adsorbent and the possibility of slight chemisorptions rather than physisorption of chromium ion. However, the multilayer adsorption of chromium ion through the percolation process may be possible. The values of n are greater than one indicating the adsorption is much more favorable [11, 12].

Effect of temperature

The adsorption capacity of the Acid Activated Abutilon Indicum increased with increase in the temperature of the system from 30°-60°C. Thermodynamic parameters such as change in free energy ($\Delta G°$) (kJ/mol), enthalpy ($\Delta H°$) (kJ/mol) and entropy ($\Delta S°$) (J/K/mol) were determined using the following equations

$K_0 = C_{solid}/C_{liquid}$ ……………………(3)
$\Delta G° = -RT \ln K_O$ …………………..(4)
$\text{I}\log K_0 = \Delta S°/(2.303RT) - \Delta H°/(2.303RT)$ ….(5)

Where Ko is the equilibrium constant, C_{solid} is the solid phase concentration at equilibrium (mg/ L), C_{liquid} is the liquid phase concentration at equilibrium (mg/L), T is the temperature in Kelvin and R is the gas constant. The $\Delta H°$ and $\Delta S°$ values obtained from the slope and intercept of Van't Hoff plots have presented in Table 5. The values of $\Delta H°$ are with in the range of 1 to 93 KJ/mol indicates the physisorption. From the results we could make out that physisorption is much more favorable for the adsorption of chromium ion. The positive values of $\Delta H°$ show the endothermic nature of adsorption and it governs the possibility of physical adsorption. Because in the case of physical adsorption, while increasing the temperature of the system, the extent of chromium ion adsorption increases, this rules out the possibility of chemisorption [12, 13, and 14]. The low $\Delta H°$ value depicts chromium ion are physisorbed onto adsorbent AAAI. The negative values of $\Delta G°$ (Table 5) shows the adsorption is highly favorable and spontaneous. The positive values of $\Delta S°$ (Table 5) show the increased disorder and randomness at the solid solution interface of chromium ion with AAAI, while the adsorption there are some structural changes in the chromium ion and the adsorbent occur. The adsorbed water molecules, which have displaced by the adsorbate species, gain more translational entropy than is lost by the adsorbate molecules, thus allowing the prevalence of randomness in the system. The enhancement of adsorption capacity of the AAAI at higher temperatures was attributed to the enlargement of pore size and activation of the adsorbent surface [14,15].

Table 5. Thermodynamic parameter for the adsorption for the adsorption of chromium ion on to abutilon indicum

C_0	$\Delta G°$				$\Delta H°$	$\Delta S°$
	30° C	40° C	50° C	60° C		
25	-6069.9	-8039.3	-7053.5	-7869.4	7.26	45.66
50	-4430.8	-4925.1	-5553.6	-6367.5	15.02	63.98
75	-3437.4	-3913.2	-4428.4	-4970.2	12.04	51.05
100	-2187.3	-2584.9	-5327.0	-3411.7	17.90	66.93
125	-1395.2	-1704.5	-3764.9	-2304.8	13.61	50.02

Kinetics of adsorption

The study of adsorption dynamics describes the solute up take rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface .The kinetics of Chromium ions adsorption on the AAAI were analyzed using pseudo second-order Elovich [11,12] and intra-particle diffusion kinetic models. The conformity between experimental data and the model predicted values was expressed by the correlation co- efficient (γ) and the values are close or equal to 1. A relatively high correlation coefficient (γ) value indicates that the pseudo second-order model successfully describes the kinetics of Chromium ions adsorption.

The pseudo second- order equation

The pseudo second-order adsorption kinetic rate equation is expressed as

$dq_t/d_t = k_2(q_e-q_t)^2$ …………..(6)

Where: K_2 is the rate constant of pseudo second- order adsorption (g mg/min). For the boundary conditions t = 0 to t= t and $q_t = 0$ to $q_t = q_t$ the integrated form of Eq. (6) becomes:

$1/(q_e - q_t) = 1/q_e + K_2 t$ ………………. (7)

This is the integrated rate law for a pseudo second-order reaction. Equation (7) can be rearranged to obtain Eq.(8),which has a linear form:

$t/q_t=(1/k_2 q_e^2)+ ((1/q_e)t$ ……………….(8)

If the initial adsorption rate (h)(mg $g^{-1}min^{-1}$) is :

$h=k_2 q_e^2$ ……………………………….(9)

Equation (6) and (7) becomes,

$t / q_t = 1 / h + 1 / q_e\, t$ …………….. …(10)

The plot of (t/q_t) and t of Eq.(10) should give a linear relationship from which q_e and k_2 can be determined from the slope and intercept of the plot, respectively. The pseudo-second order rate constants K_2, the calculated h values, and the correlation coefficients (γ) are summarized in Table (6). At all studied initial Chromium concentrations, the straight lines with extremely high correlation co-efficient (>0.99) were obtained. From table 6, the values of the rate constant k decrease with in increasing initial Chromium concentration for AAAI. This is shows that the sorption of Chromium ions on AAAI follows pseudo second order kinetic model.

The Elovich equation

The Elovich model equation is generally expressed as

$dq_t / d_t = \alpha \exp(-\beta q_t)$ ……..(11)

Where; α is the initial adsorption rate (mg g^{-1} min^{-1}) and β is the desorption constant (g/mg) during any one experiment. To simplify the Elovich equation. Chien and Clayton (1980) assumed $\alpha\beta t >> t$ and by applying boundary conditions $q_t = 0$ at t= 0 and $q_t = q_t$ at t = t Eq.(9) becomes:

$q_t = 1/\beta \ln(\alpha\beta) + 1/\beta \ln t$ …………… (12)

If Chromium ions adsorption fits with the Elovich model, a plot of q_t vs. ln(t) should yield a linear relationship with a slope of ($1/\beta$)and an intercept of ($1/\beta$)ln ($\alpha\beta$). The Elovich model parameters α, β, and correlation coefficient (γ) are summarized in Table 6. The experimental data such as the initial adsorption rate (α) adsorption constant (β) and the correlation co-efficient (γ) calculated from this model indicates that the initial adsorption (α) increases with temperature similar to that of initial adsorption rate (h) in pseudo-second–order kinetics models. This may be due to increase the pore or active site on the AAAI adsorbent

The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris[18] based on the following equation for the rate constant:

$q_t = k_{id}\, t^{(1/2)} + C$……………..(13)

Where k_{id} is the intra-particle diffusion rate constant (mg/g/min) and C is the constant. If the rate limiting step is intra-particle diffusion, then the graph drawn between (q_t) (mg/g) verses square root of the contact time ($t^{1/2}$) should yield a straight line passing through the origin. The slope of the will give the value of the intra-particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicate the fitness of this model. The value of C gives an idea about the thickness of the boundary layer. From these data the intercept value indicate that the line were not passing through origin, there are some other process affect the adsorption. But the correlation coefficient (γ) value is very high, so that the intra-particle diffusion takes place along with other process that may affect the adsorption. The values are given in Table 6.

Table 6. The kinetic parameters for adsorption for the adsorption of chromium ion on to abutilon indicum

Metal ion Con.	Temp °C	PSEUDO SECOND ORDER				ELOVICH MODEL			INTRAPARTICLE DIFFUSION		
		q_e	K_2	γ	H	α	β	γ	K_{id}	γ	C
25	30	50.76	22×10^{-3}	0.992	6.66	80.32	0.14	0.990	1.65	0.9921	0.16
	40	52.93	16×10^{-3}	0.991	6.25	51.79	0.12	0.991	1.63	0.9920	0.18
	50	51.47	20×10^{-3}	0.993	7.78	71.62	0.13	0.994	1.65	0.996	0.17
	60	51.17	17×10^{-3}	0.996	7.46	149.76	0.15	0.995	1.69	0.999	0.14
50	30	93.65	25×10^{-3}	0.997	13.54	146.38	0.07	0.996	1.62	0.992	0.17
	40	95.44	25×10^{-3}	0.998	13.60	169.57	0.07	0.997	1.63	0.993	0.16
	50	96.95	23×10^{-3}	0.995	14.42	223.18	0.08	0.998	1.65	0.991	0.15
	60	99.49	22×10^{-3}	0.993	14.60	217.31	0.07	0.999	1.66	0.990	0.15
75	30	130.80	26×10^{-3}	0.992	19.06	309.65	0.05	0.995	1.61	0.993	0.15
	40	136.00	27×10^{-3}	0.992	18.38	188.81	0.05	0.994	1.59	0.996	0.17
	50	139.00	27×10^{-3}	0.990	19.43	199.91	0.05	0.995	1.61	0.997	0.17
	60	140.38	24×10^{-3}	0.992	17.34	351.96	0.05	0.991	1.64	0.991	0.15
100	30	158.97	30×10^{-3}	0.993	17.38	106.05	0.04	0.995	1.47	0.993	0.20
	40	164.66	31×10^{-3}	0.991	17.72	108.16	0.03	0.994	1.48	0.994	0.20
	50	168.15	14×10^{-3}	0.991	20.37	160.43	0.04	0.996	1.53	0.993	0.18
	60	171.58	28×10^{-3}	0.992	23.03	215.38	0.04	0.997	1.56	0.994	0.17
125	30	183.21	32×10^{-3}	0.993	17.04	73.353	0.03	0.998	1.37	0.995	0.23
	40	189.04	32×10^{-3}	0.994	17.82	78.16	0.03	0.992	1.39	0.991	0.23
	50	198.72	21×10^{-3}	0.995	17.67	73.18	0.02	0.993	1.40	0.992	0.23
	60	197.20	31×10^{-3}	0.996	21.02	119.52	0.03	0.992	1.46	0.997	0.20

Effect of pH

The experiments carried out at different initial pH show that the adsorption percentage increases with increase in initial pH of the medium in the range studied i.e. 3 to 10 as depicted in the Figure 3. This behaviour can be explained using pH_{ZPC} of the adsorbent. In the present study the pH_{ZPC} of Abutilon Indicum is 6.1. At any pH below pH_{ZPC}, the surface of adsorbent is positively charged and at pH above pH_{ZPC}, the surface is negative. When the solution pH exceeded pH_{ZPC}, the chromium ions are more easily attracted by the negatively charged surface of adsorbent, favoring accumulation of chromium ion on the surface and thus promoting adsorption. In addition the increase is partially attributed to the formation of different hydroxo species with rise in solution [1, 14]. The decrease in adsorption of metal ions at low pH can be attributed to the competition between H^+ and metal ions. It is thus clear from Figure 3 that at lower pH, the adsorption of chromium ion studied is drastically reduced. This observation was made use of to desorb the chromium ion from the adsorbed material.

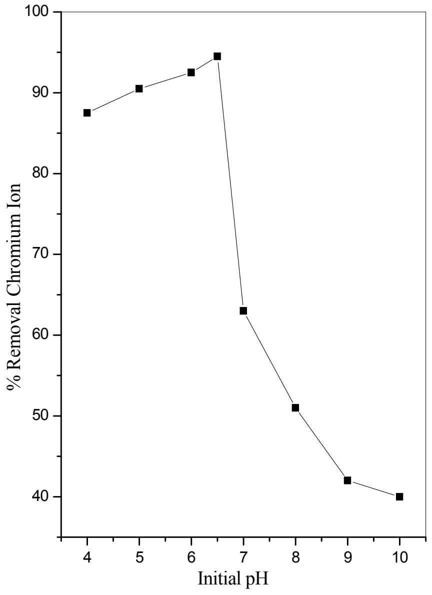


Fig.3-Effect of Initial pH on the removal of Cr Ion
[Cr]=50mg/L: Contact time=60 min: adsorbent dose=25mg/50ml

Effect of the ionic strength on the adsorption of chromium ion on AAAI

The effect of sodium chloride on the adsorption of chromium ion on AAAI is shown in Figure 4. In a low solution concentration NaCl had little influence on the adsorption capacity. At higher ionic strength the adsorption chromium of ion on AAAI will be increased due to the partial neutralization of the positive charge on the AAAI surface and a consequent compression of the electrical double layer by the Cl^- anion. The chloride ion can also enhance adsorption of chromium ion on AAAI by pairing of their charges and hence reducing the repulsion between the chromium ions adsorbed on the surface [1, 19]. This initiates carbon to adsorb more of positive chromium ions

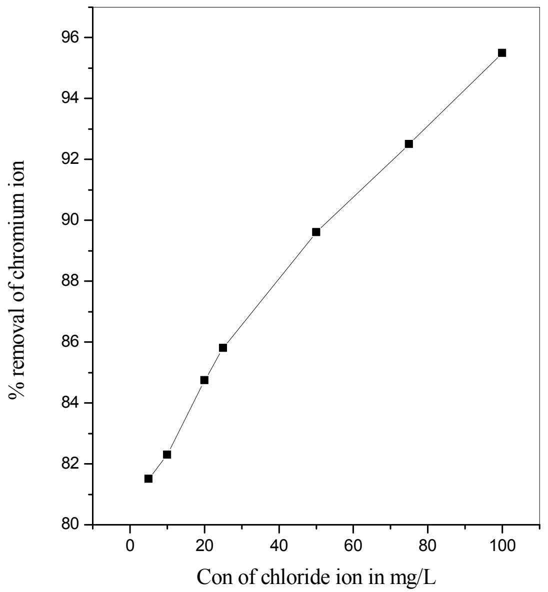


Fig.4-Effect of ionic strength on the adsorption of chromium ion [Cr]=50mg/L;Contact Time 60 min; Adsobent Dose=25mg/50 ml

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the chromium ions. If the adsorbed chromium ions can be desorbed using neutral pH water, then the attachment of the chromium ions of the adsorbent is by weak bonds. If sulphuric acid or alkaline water desorp the chromium ion then the adsorption is by ion exchange. If organic acids, like acetic acid can desorp the chromium ions, then the chromium ions has held by the adsorbent through chemisorption [12,20]. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 82% removal of adsorbed chromium ions. The reversibility of adsorbed chromium ions in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of chromium ions by mineral acids and alkaline medium indicates that the chromium ions were adsorbed onto the AAAI through by physisorption mechanisms.

Conclusion

The experimental data correlated reasonably well by the Langmuir and Freundlich adsorption isotherms and the isotherm parameters were calculated. The low as well high pH values pay the way to the optimum amount of adsorption of chromium ion. The amount of chromium ion adsorbed increased with increasing ionic strength and increased with increase in temperature. The dimensionless separation factor (R_L) showed that the Acid Activated Abutilon Indicum could be used for the removal of chromium ion from aqueous solution. The values of ΔH°, ΔS° and ΔG° results shows that the AAAI employed has a considerable potential as an adsorbent for the removal of chromium ion.

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