Removal of cr (vi) Ions From Aqueous Solution By Using Adsorption Techniques Using Activated Carbon From Amorpophallus Paeoniifolius Isotherm and thermodynamic and kinetic Approach

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Abstract: *The development of a country depends on industrialization and agricultural production. Due to this number of industries and factories like metal industries, dyeing, fertilizers, painting industries are coming continuously which creates severe environmental pollution especially water problem should be created and also cause global warming. To controlling of environmental pollution is very big challenge for scientists especially for chemist. The numbers of physical and chemical process are available to removing water pollution specifically causing by heavy metals like lead, chromium, copper, manganese, etc., Among these one of most low cost method of adsorption of heavy metals by using of activated carbon is prepared from unwanted waste plants.*
The aim of the present study is removing of chromium metal from contaminated aqueous solution by using roots and leaves ofAmorphophallus Paeoniifolius (senai kizhangu). The adsorption process is also affected by various factors like temperature, contact time, adsorbent dosage and pH of the solution is studied. The fitness of present study is also confirmed by verifying of Feundlich isotherm and Langmuir isotherm. The feasibility and nature of the process is also confirmed by thermodynamic parameters like ΔG, ΔH and ΔS. And also calculate kinetic parameters verifying by pseudo-second order kinetics, Elovich model and Intra-particle diffusion model. Finally, the adsorption process is confirmed by FT-IR, XRD of before and after adsorption process of adsorbent.
Key notes: *chromium, aaAP,conc.H_2SO_4 , isotherm, thermodynamic and kinetic parameters, FT-IR and XRD.*

I.   INTRODUCTION

Water pollution is due to the mixing of toxic metals and organic compounds excreted from industries in to the water bodies that cause serious environmental and public problems.

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Hence this has been becoming an alarming concern and priority of the most industrial sectors to avoid such problem. Heavy metal ions are often found in the environment as result of their wide industrial uses. They are common contaminants in waste water and many of them are known to be toxic or carcinogenic[1, 2]. 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 organo 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, and Ag) and metalloids (Se, As, Sb). Most of the trace elements (Se, As, Sb) 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.

In addition, heavy metals are not biodegradable and tend to accumulate in living organisms, causing various diseases and disorders. Therefore, their presence in the environment, in particular in water, should be controlled[3, 4]. The various methods like Biological treatments[5, 6], membrane process[7], advanced oxidation process[8,9], chemical and electrochemical techniques[10,11] and adsorption procuderes[12] are the most widely used for removing metals and organic compounds from industrial effluents. Amongst all the treatments proposed, adsorption using sorbents is one of the most popular methods since proper design of the adsorption process will produce high-quality treated effluents.

In fact, adsorption is now recognized as an effective, efficient and economic method for water decontamination application and for separation analytical purposes. The adsorbents may be of mineral, organic,

biological origin, activated carbons, zeolites, clays, silica beads, low-cost adsorbents (industrial by-products, agricultural wastes and biomass) and polymeric materials are significant examples[13, 14].

The aim of present study is to evaluate the efficiency of an adsorbent prepared from acid activated Amorphophallus Paeoniifolius from Araceae family for removal of Cr(VI) ion in aqueous solution. The metal ion Cr(VI) is very hazards to human as well as environment to cause some diseases and global warming. In order to design adsorption treatment systems, knowledge of kinetic and mass transfer processes is essential which are discussed in detailed manner.

II. MATERIALS AND METHODS

Adsorbent

The Amorphophallus Paeoniifolius (senai kizhangu) roots and leaves are obtained from Agricultural fields with waste water was Carbonized with concentrated sulphuric acid and washed with water and activated around 650°C in a muffle furnace for 7 hours then it was taken out, ground well to fine powder and stored in a vacuum desiccator.

Chemicals

1000 mg/L of stock solution of Cr(VI) ($K_2Cr_2O_7$) was prepared by dissolving accurately weighed 2.828 gram of potassium dichromate in 1000 ml distilled water. All experimental solutions were prepared by diluting the stock solution to the required concentration. The pH of each experimental solution was adjusted to the required initial pH value using dilute HCl (or) NaOH before mixing the adsorbent. The concentration of residual Cr(VI) was determined with photo colorimeter at wavelength of 540nm.

Batch experiments

The effect of various parameters on the removal of Cr(VI) onto acid activated Amorphophallus Paeoniifolius was studied batch

adsorption experiments were conducted at (30-60°C). For all the batch experiments, 50 ml of Cr(VI) solution and 75mg of dosage at 300rpm speed of shaking were taken. The residual solutions were analyzed to determine the Cr (VI) concentration[15].

The adsorption capacity was calculated by using a mass equilibrium equation as follows:

$$q_e = \left(C_0 - C_e \right) V / M \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where C_0 and C_e being the initial chromium ion concentration (mg/L) and equilibrium concentration, respectively V is the experimental volume of Cr(VI) solution expressed in liters [l] and M is the adsorbent mass expressed in grams [g]. The Cr(VI) ion percentage can be calculated as follows:

$$\%R = \left(C_0 - C_t \right) x \, 100 / C_0 \ldots\ldots\ldots\ldots (2)$$

Batch kinetic studies

The batch kinetic[16] experiments were basically identical to these of adsorption equilibrium method. The aqueous samples were taken at present time intervals and the concentration of Cr(VI) ions was similarly measured. The all kinetic experiments are carried out at 30, 40, 50 and 60°C at an initial concentration of 25, 50, 75, 100 and 125 mg/L. The amount of adsorption at time t, q_t (mg/g) was calculated by.

$$q_t = \left(C_0 - C_t \right) V / W \ldots\ldots\ldots\ldots\ldots(3)$$

III. RESULTS AND DISCUSSION

Characteristics of the adsorbent

Acid Activated Amorphophallus Paeoniifolius is an effective adsorbent for the abatement of many pollutant compounds (organic, inorganic, and biological) of concern in water and wastewater treatment. The wide usefulness of aaAP is a result of their specific surface area, high chemical and mechanical stability. The physico-chemical properties of the chosen adsorbent are listed in Table 1.

Table 1-Characteristics of the Adsorbent

Properties	AAAP
Particle size(mm)	0.019
Density (g/cc)	0.2165
Moisture content (%)	0.1534
Loss in ignition (%)	0.011
pH of aqueous solution	6.7

Effect of initial concentration

The experimental results of adsorption of Cr(VI) ions on aaAP at various initial concentration (25, 50, 75, 100 and 125 mg/L) for Cr(VI) ions in terms of equilibrium data are given in Table.2. It reveals that, the actual amount of Cr(VI) ions adsorbed per unit mass of Acid Activated Amorphophallus Paeoniifolius increased with increase in metal ions concentration shown in Fig.1. It means that the adsorption is highly dependent on initial concentration of metal ion. It is because of at lower concentration, the ratio of initial number of metal ions to the available surface area is subsequently the fractional adsorption become independent of initial concentration. However at high concentration the available sites of adsorption becomes fewer and hence the amount of metal ions adsorbed on the adsorbent surface is less.

Effect of contact time

The effect of contact time on the adsorption of Cr(VI) ions on the adsorbentthe possible mono layer coverage of the metal ions on acid activated Amorphophallus Paeoniifolius surface at about 40 minutes and once again there is no big change of amount of metal ion adsorbed with time which gives an indication that of ion exchange[17].

C_0 Cr(VI) (ppm)	C_e				Q_e				% Removal			
	30^{0C}	40^{0C}	50^{0C}	60^{0C}	30^{0C}	40^{0C}	50^{0C}	60^{0C}	30^{0C}	40^{0C}	50^{0C}	60^{0C}
25	1.639	1.428	1.386	1.275	15.574	15.715	15.743	15.817	93.44	94.23	94.46	94.9
50	7.236	6.562	5.874	5.003	28.509	28.899	29.417	29.998	85.53	86.67	88.25	89.99
75	12.175	11.003	10.152	9.941	41.883	42.665	43.232	43.373	83.77	85.33	86.46	86.75
100	24.317	22.993	22.007	21.714	50.455	51.338	51.995	52.191	75.68	77.01	77.99	78.29
125	48.193	47.105	46.628	46.003	51.205	51.930	52.248	52.665	61.44	62.32	62.70	63.20

Effect of adsorbent dosage

The adsorbent dosage is an important parameter, which influence the extent of metal uptake from the solution. The effect of varying doses of 25 to 125 mg of aaAP was investigated using 50 mg/L of initial chromium concentration at initial pH 6.7 shows an increase in percentage removal of chromium with increase in dose of adsorbent up to a certain limit shown in Fig.2. Increase in the adsorption with increasing dose of adsorbent is expected due to the increase in adsorbent surface area and availability of more adsorption site[18].

Table: 2. Equilibrium Parameters for the Adsorption of Cr (VI) ion onto aaAP

Fig: 2 Effect of Adsorbent Dose on the Removal of Cr(VI) Ion
[cr]=100mg/L; Contact Time:60 min; Temperature=60℃
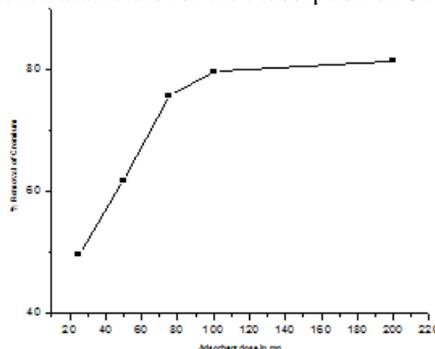
Effect of pH

The experiment were carried out at different pH shows that there is a change in the quantity of adsorbed Cr(VI) ions on the solid phase of activated aaAP over the entire pH range of 2 to 10 for chromium as shown in Fig.3. The initial metal ion concentrations were kept constant. Adsorption of Cr(VI) ions increased appreciably (1-2 times) with increase of pH from 2 to 10 and consistent with results obtained by others. The increase is partly attributed to the formation of different hydroxo species with rise in solution pH. Based on the hydrolysis constants of metal ions as defined in

$$M^{6+} + nH_2O \longrightarrow M(OH)_n^{6-n} + nH^+$$

and taking only primary metal species expected to be formed in the working pH range into consideration, the species distribution diagrams for Cr(VI) ion is constructed and given in Fig. 3, It is evident that Cr^{6+} ions and its monohydroxo species are the predominating species up to pH ~ 9, while dihydroxo species are also formed to a significant extent above pH ~ 7.0 for Cr(VI) ion. Since maximum adsorption of Cr(VI) ion was achieved at pH ~ 6.5, it may safely be stated that the removal of Cr(VI) ion was mostly due to adsorption and not precipitation. However, precipitation of small fractions of Cr^{6+} even at pH ~ 6.5 on the surface by nucleation cannot be neglected. At still higher pH (>7), however, part of Cr^{6+} may be precipitated as dihydroxo species, which also depend upon the initial metal ion concentration. The other important factor, which might contribute to the higher adsorption of metal ion with increased pH, is the pH_{zpc} (zero point charge) of aaAP. At any pH below pH_{zpc} the surface of metal oxides/ oxyhydroxides is positively charged and at pH above pH_{zpc} the surface is negative.

When the solution pH exceeded pH_{zpc}, the metal species are more easily attracted by the negatively charged surface of adsorbent, favoring accumulation of metal species on the surface and thus promoting adsorption[19].
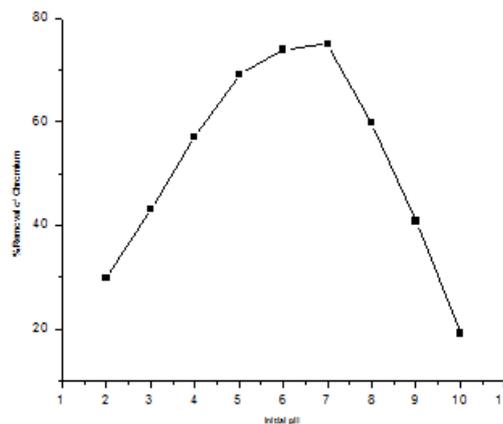

Fig:3=Effect of Initial pH on The Removal Cr(VI) ion
[Cr]=100mg/L; Temperature=30°C; Adsorbent=75mg/50ml

Adsorption isotherm

Freundlich isotherm
The linear form of Freundlich isotherm[43]is represented by the equation

$$log\ q_e = log\ K_f + (1/n)log\ C_e \dots\dots\dots\dots (4)$$

Where q_e is the amount of Cr(VI) ions adsorbed per unit weight of the sorbent (mg/L), K_f is a measure of adsorption capacity and 1/n is the adsorption intensity. The value of K_f and n are calculated from the intercept and slope of the plot of log q_e vs log C_e respectively. The constant K_f and n values are given in (Table-3). The value of n>1 represents favorable adsorption condition[20] (or) the value of 1/n are lying in the range of 1 to 10 confirms the favorable condition for adsorption. The adsorption co-efficient K_f of chromium on activated aaAP was found to be around 6.5 L/g. The K_f values indicates that the saturation time for adsorption of metal ion is attained quickly due to high affinity of activated aaAP towards adsorbate, while low K_f values indicates low adsorption rate of metal ion [21, 22.] The values of 1/n were around 4.0 (mg/L) for Cr(VI) ions. The high values of 1/n signifies that the forces which are exerted on the surface of aaAP during metal ion adsorption are strong rate from the values K_f and 1/n it is reveals that activated aaAP is more efficient for removal of Cr(VI) ions.

Table: 3. Langmuir and Freundlich Isotherm Parameter for the Adsorption of Cr (VI) ions

TEMP (^{0}C)	LANGUMUIR PARAMETER		FRUENDLICH PARAMETER	
	Q_m	B	K_f	N
30°	181.22	0.12	4.66	2.39
40°	186.67	0.13	4.79	2.42
50°	271.82	0.09	4.62	1.75
60°	196.94	0.16	5.00	2.36

Langmuir isotherm

The Langmuir isotherm model[23] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. The linear form of the Langmuir isotherm equation can be described by

$$C_e / q_e = \left(1/Q_m b\right) + \left(C_e / Q_m\right) \dots\dots\dots (5)$$

Where C_e (mg/L) is the equilibrium concentration of the adsorbate, q_e (mg/g) is the amount of adsorbate per unit mass of adsorbent, Q_m and b are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the mount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption capacity of the adsorbent and b (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption).

The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e), the Langmuir constant Q_m and b were determined from the slope and intercept of the plot and are presented in Table -3. In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless constant separation factor R_L[24, 25] by the equation

$$R_L = \left(1/\left(1+bC_o\right)\right) \dots\dots\dots (6)$$

Where C_o (mg/L) is the highest initial concentration of adsorbent and b (L/mg) is Langmuir isotherm constant. The parameter R_L indicates the nature of shape of the isotherm accordingly.

$R_L > 1$ Unfavorable adsorption
$0 < R_L < 1$ Favorable adsorption
$R_L = 0$ Irreversible adsorption
$R_L = 1$ Linear adsorption

The R_L values between 0 to 1 indicate favorable adsorption for all initial concentration (C_o) and temperatures studied. The calculated R_L values are given in Table - 4. The values of b were increased with increasing the dose of adsorbent for aaAP.High b values indicate high adsorption affinity. The monolayer saturation capacity Q_m were around   145 mg/L for aaAP.

Table: 4. Langmuir and Freundlich Isotherm Parameter for the Adsorption of Cr (VI) ions

(C_i)	TEMPERATURE °C			
	30°C	40°C	50°C	60°C
25	0.25	0.24	0.31	0.20
50	0.14	0.13	0.18	0.11
75	0.1	0.09	0.13	0.08
100	0.08	0.07	0.1	0.06
125	0.06	0.05	0.08	0.04

Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0), and standard entropy change (ΔS^0) were calculated as follows. The free energy of adsorption process considering the adsorption equilibrium constant K_0 is given by the equation.

$$\Delta G° = -RT \ln K_0 \dots\dots\dots (7)$$

Where $\Delta G°$ is the free energy of adsorption (kJ/mol), T is the temperature in Kelvin and R is the universal gas constant (8.314 J mol/K).The adsorption distribution coefficient K_O for the sorption reaction was determined from the slope of the plot of $\ln(q_e/C_e)$ against C_e at different temperature and extrapolating to zero C_e according to the method suggested by Khan and Singh[26]. The adsorption distribution coefficient may be expressed in terms of enthalpy change ($\Delta H°$) and entropy change ($\Delta S°$) as a function of temperature, i.e

$$ln\ K_o = \left(\Delta H^o / RT\right) + \left(\Delta S^o / R\right) \dots\dots\dots(8)$$

Where $\Delta H°$ is the standard heat change of sorption (kJ/mol) and $\Delta S°$ is standard entropy change (kJ/mol). The value of $\Delta H°$ and $\Delta S°$ can be obtained from the slope and intercept of plot of ln K_0 against $1/T$. The value of thermodynamic parameter calculated from equation 7 and 8 are shown in Table -5. The thermodynamic treatment of the sorption data indicates that $\Delta G°$ values were negative at all temperature. The results point out that physisorption is much more favorable for the adsorption of Cr(VI) ions. The positive values of $\Delta H°$ show the endothermic nature of adsorption and it governs the possibility of physical adsorption[21].Because in the case of physical adsorption, while increasing the temperature of the system, the extent of metal ion adsorption increases, this rules out the possibility of chemisorptions [21, 22]. The low $\Delta H°$ value depicts metal ion is physisorbed onto adsorbent aaAP.The negative $\Delta G°$ values from Table- 5 conform the spontaneous nature of adsorption of Cr(VI) ions onto aaAP**.** The lesser values of $\Delta G°$ suggest that adsorption is physical adsorption process. The positive value of $\Delta H°$ further confirms the endothermic nature of adsorption process. The positive values of $\Delta S°$ in Table- 5, showed increased randomness of the solid solution interface during the adsorption of Cr(VI) ion onto acid activated Amorphphallus Paeoniifolius.

Adsorption kinetics

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 Cr(VI) ions adsorption on the aaAP were analyzed using pseudo second-order[27] Elovich[28,29] 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 Cr(VI) ions adsorption.

The pseudo second- order equation

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

$$dq_t / d_t = k_2 \left(q_e - q_t\right)^2 \dots\dots\dots\dots(9)$$

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. (9) becomes:

$$1/\left(q_e - q_t\right) = 1/q_e + K_2 t \dots\dots\dots\dots (10)$$

This is the integrated rate law for a pseudo second-order reaction. Equation (10) can be rearranged to obtain Eq.(11),which has a linear form:

$$t / q_t = \left(1/k_2 q_e^2\right) + \left((1/q_e)t\dots\dots\dots\dots(11)\right.$$

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

$$h = k_2 q_e^2 \dots\dots\dots\dots\dots\dots\dots\dots(12)$$

Equation (9) and (10) becomes,

$$t / q_t = 1/h + 1/q_e t \dots\dots\dots\dots(13)$$

The plot of (t/q_t) and t of Eq. (13) 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 thecorrelation 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 ironconcentration for aaAP carbon. This shows that the sorption of Cr(VI) ions on aaAPfollows pseudo second order kinetic model[30].

Table: 5. Thermodynamic Parameter for the adsorption of Cr (VI) ion onto aaAP

C_0	30^0C		40^0C		50^0C		60^0C		ΔH^0 KJ/ Mol	ΔS^0 J/K	r^2
	K_{ads}	ΔG^0 KJ/mol	K_{ads}	ΔG^0 KJ/mol	K_{ads}	ΔG^0 KJ/mol	K_{ads}	ΔG^0 KJ/mol			
25	14.253	-5629.3	16.507	-6378.2	17.037	-6715.8	18.607	-7005.4	873.4	6.873	0.9873
50	5.893	-5296.2	6.619	-5839.5	7.512	-6195.4	8.994	-6835.8	737.7	5.392	0.9745
75	5.160	-4839.6	5.816	-5164.7	6.388	-5671.5	6.544	-6003.7	642.9	4.004	0.9997
100	3.112	-4198.5	3.349	-4629.3	3.544	-5190.8	3.605	-5629.8	541.8	3.519	0.9952
125	1.594	-3428.2	1.653	-3962.9	1.681	-4726.9	1.717	-4985.2	369.1	2.671	0.9946

The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / d_t = \alpha \ exp \ (-\beta q_t)........(14)$$

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 assumed αβt>>t and by applying boundary conditions q_t = 0 at t= 0 and q_t = q_t at t = t Eq.(12) become\

$$q_t = 1/\beta \ln \ (a\beta) + 1/\beta \ln \ t \ .... (15)$$

If Cr(VI) ions adsorption fits with the Elovich model, a plot of q_t vs. lnt should yield a linear relationship with a slope of (1/β) and an intercept of (1/β)ln (αβ). 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 kinetic models. This may be due to increase in the pore or active site on the aaAP adsorbent.

The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris[30]based on the following equation for the rate constant

$$q_t = k_{id} t^{(1/2)} + C ....(16)$$

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[30], the slope 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.

Evidences for adsorption:

Fourier transform infrared spectroscopy (FTIR) is a technique which is used to obtain an infrared spectrum of absorption, emission, photoconductivity or Raman scattering of a solid, liquid or gas. An FTIR spectrometer simultaneously collects spectral data in a wide spectral range. This confers a significant advantage over a dispersive spectrometer which measures intensity over a narrow range of wavelengths at a time. FTIR has made dispersive infrared spectrometers all but obsolete (except sometimes in the near infrared). The FT-IR spectra of the aaAP before and after adsorption of Cr(VI) ion are shown in Fig. 4(a) and Fig. 4(b). It could be seen that the slight reduction of stretching vibration adsorption bands. This clearly indicates the adsorption of Cr(VI) ion on the adsorbent by physical forces not by chemical combination.

The scattered X-rays can be recorded at different angles. In SAXS, you analyze the scattering pattern at small angles, typically below <10° 2Θ, to probe nano-sized particles and domains in a size range from 1 nm to 200 nm, which scatter towards these small angles. To investigate smaller structures, such as crystal lattices at the atomic level, you interpret the scattered X-rays at wider angles. This approach is called Wide-Angle X-ray Scattering (WAXS) or X-ray Diffraction (XRD). The obtained WAXS pattern enables you to analyze structures below nanometer size – as atoms and interatomic distances scatter towards wider angles. The XRD diagrams of aaAP and Cr(VI) ion adsorbed aaAP are shown in Fig. 5a and Fig 5b. The intense main peak shows the presence of highly organized adsorbed aaAP, after the adsorption of metal ion, the intensity of the highly organized peaks is slightly diminished.This was attributed to the adsorption of Cr(VI) ion on the upper layer of the crystalline structure of the aaAP surface by means of physisorption[10, 20].

Table: 6. The Kinetic Parameters for the Adsorption of Cr (VI) ion onto aaAP.

| C_0 Cr (VI)	Temp °C	PSEUDO SECOND ORDER				ELOVICH MODEL			INTRAPARTICLE DIFFUSION		
		q_e	K_2	γ	h	α	β	γ	K_{id}	γ	C
25	30	25.32	14×10^{-3}	0.9998	8.97	0.8825	0.1731	0.9928	2.2456	0.9935	0.13
	40	27.55	12×10^{-3}	0.9978	9.11	1.6221	0.1911	0.9932	1.9748	0.9956	0.17
	50	33.72	11×10^{-3}	0.9993	12.51	3.9379	0.2651	0.9979	1.4594	0.9924	0.15
	60	37.39	10×10^{-3}	0.9990	13.98	7.7996	0.3732	0.9965	1.0285	0.9922	0.16
50	30	52..32	20×10^{-3}	0.9976	54.74	2.8058	0.1042	0.9935	3.7260	0.9949	0.118
	40	56.76	18×10^{-3}	0.9985	57.99	3.8420	0.1212	0.9921	3.2175	0.9942	0.117
	50	65.46	17×10^{-3}	0.9963	72.84	5.2830	0.1386	0.9924	2.9418	0.9934	0.14
	60	68.89	15×10^{-3}	0.9981	71.19	7.2661	0.1629	0.9966	2.3401	0.9921	0.15
75	30	77.17	22×10^{-3}	0.9957	131.01	2.6658	0.1267	0.9998	3.1173	0.9929	0.18
	40	86.95	25×10^{-3}	0.9982	189.01	10.1031	0.1397	0.9935	2.8157	0.9922	0.14
	50	95.87	23×10^{-3}	0.9987	211.39	14.6461	0.1810	0.9942	2.1601	0.9919	0.16
	60	98.66	21×10^{-3}	0.9955	204.41	21.5081	0.2416	0.9990	1.5965	0.9916	0.17
100	30	99.89	24×10^{-3}	0.9943	450.89	7.5552	0.0919	0.9943	4.3202	0.9918	0.21
	40	107.48	28×10^{-3}	0.9952	323.45	8.6281	0.0985	0.9988	4.0101	0.9914	0.20
	50	115.14	24×10^{-3}	0.9987	318.17	10.4499	0.1134	0.9941	3.4727	0.9911	0.22
	60	122.86	27×10^{-3}	0.9977	407.55	15.8692	0.1548	0.9965	2.5344	0.9919	0.16
125	30	134.93	32×10^{-3}	0.9991	582.59	5.3205	0.0717	0.9987	5.5301	0.9917	0.24
	40	132.93	28×10^{-3}	0.9953	494.77	5.7511	0.0716	0.9998	5.5153	0.9927	0.21
	50	133.89	31×10^{-3}	0.9989	555.72	6.6886	0.0796	0.9946	4.9858	0.9998	0.24
	60	135.98	29×10^{-3}	0.9977	536.23	8.1422	0.0898	0.9913	4.3643	0.9943	0.24
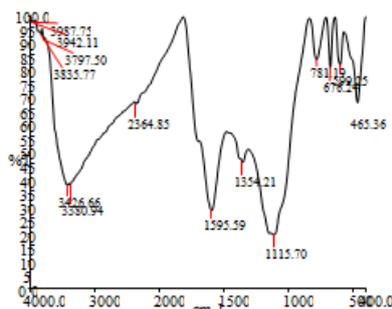
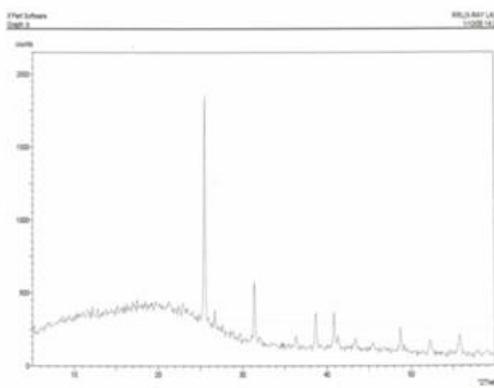**Fig.4a-**FT-IR Spectrum of aaAP before adsorption

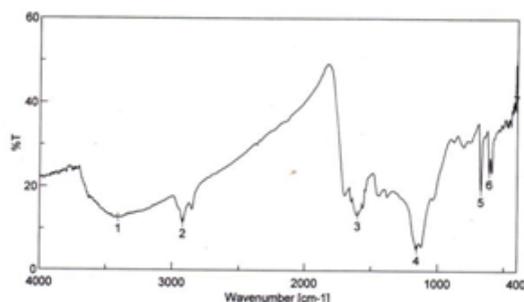**Fig.5a-** XRD pattern of aaAP before adsorption

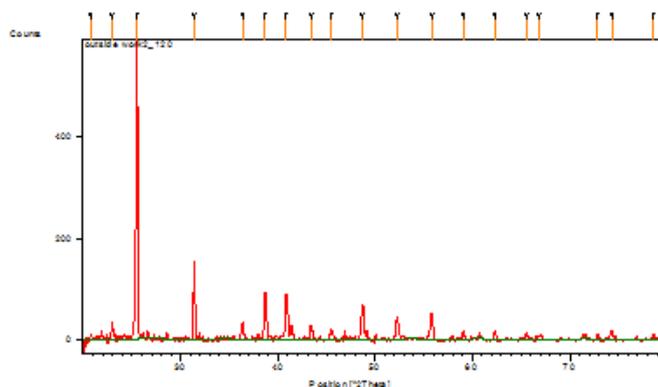**Fig. 4b-** FT-IR Spectrum of aaAP after the adsorption of Cr (VI) ion

Fig.5 b- XRD pattern of aaAP after the adsorption of Cr (VI) ion

IV. CONCLUSION

From the experimental data of adsorption of Cr(VI) ions onto aaAP carbon surface
The following points can be concluded.
aaAP could be used as a potential adsorbent for the removal of Cr(VI) ions from polluted water.

1. The initial pH's of aqueous solutions affect the Cr(VI) ion removal. On the other hand percent removal of Cr(VI) ion decreased with increasing initial concentration but increased with increasing adsorbent concentration.
2. From the experimental data's obtained shows that the adsorption of Cr(VI) ions
   on to aaAP well fit with Freundlich isotherm and Langmuir isotherm.
3. The adsorption of Cr(VI) ions on to activated aaAP shows negative $\Delta G°$ values; this indicates sorption process is physisorption.
4. The sorption of Cr(VI) ions on aaAPfollows pseudo second order kinetic model and it is controlled by intra-particle diffusion.
5. The removal percentage of Cr(VI) ions by the new adsorbent is fairly high. The mechanism of adsorption of Cr(VI) ion onto aaAP is confirmed by FT-IR and XRD studies.

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