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Biological Removal of Chromium (VI) from synthetic waste water by using "Acid Treated Banana Peel".

Mandeep Kumar*, and CB Majumder.

[1]Department of Chemical Engineering, IIT Roorkee, Roorkee, Uttrakhand, 247667,

ABSTRACT

The batch removal of hexavalent chromium Cr (VI) from synthetic waste water by using "Acid Treated Banana Peel" under different experimental conditions was investigated in this study. The '"Acid Treated Banana Peel"'was characterized by EDX and Fe-SEM. Batch adsorption techniques using "Acid Treated Banana Peel" was applied for removal of Cr (VI) from aqueous solution. Parameters like initial concentration, contact time, adsorbent dose and pH were studied to find the best operating conditions for maximum removal of Cr (VI). The optimum pH, initial concentration, adsorbent dose and contact time were found to be 2, 100ppm, 2g/l and 1 h, respectively. A maximum removal of 99.9 % was achieved at an initial concentration of 100 mg/l. The Kinetics of sorption of Cr (VI) ions were described by a pseudo-First-order kinetic, pseudo-second-order kinetic and intra particle diffusion model in which Pseudo second order model isotherm was found to be fitted best. The equilibrium isotherm data were comparing by using the Langmuir, Freundlich and Temkin isotherm models in which Freundlich isotherm was found to be fitted best.

Keywords: banana peel, potassium dichromate, 1, 5-diphinylecarbazide, hydrochloric acid, acetone, sulphuric acid, and Ultra-pure de-ionized water.

Corresponding author

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INTRODUCTION

Water is the most important life-sustaining thing of nature. The presence of toxic heavy metal in water bodies cannot be overstated. The heavy metals in water stream represent an important pollutant. These heavy metals get into water bodies through two major sources - gynogenic and anthropogenic sources. Among the toxic heavy metals which present potential danger to human health are Cu, Pb, Cd, Cr and Hg [1] because these are not biodegradable, react irreversibly with enzymes and proteins and their effective characteristic such as toxicity, accumulation in living organism, strong oxidant capable of being adsorbed by the skin hence causing various disorder and diseases. In all the heavy metals, Cr (VI) is one of the most hazardous inorganic water pollutants due to its carcinogenic nature and toxic effect. Cr (VI)present in aqueous waste stream which comes from many industries, such as leather tanning , metal plating industry, mining industry, fertilizer, paint and pigment industry, cement , glass, industry, electroplating, paper, ink, steel fabrication and wood preservation treatment. Exposed in the environment it causes severe environmental and public health problems [2].

Chromium is commonly present in the environment as many valence states like Cr(0), Cr(II), Cr(III) and Cr(VI) but according to pollutant, Cr(III) and Cr(VI) are important in which Cr(VI) is 500 times more toxic than Cr(III)[3], Because Chromium (VI) reported to cause lung perforation and carcinoma in human beings[4]. Other disorders caused from short or long term exposure to this heavy metal are lungs skin, asthma, and irritation of the nasal mucosa, pneumonitis, ulcer, dermatitis, and gastrointestinal track, kidney and liver failure [5,6].If this metals are continuously introduced into our environment without been avoided or treated then the living things on earth are comes in danger According to the world health organization guidelines, the maximum level of Cr (VI) in drinking water is 0.05 mg/l. [7], so chromium containing water must be treated to attain the Cr (VI) to permissible limit. There are number of conventional methods used for removing heavy metals from industrial waste water like Chemical precipitation, ion-exchange, ultra filtration, membrane separation, coagulation, solvent extraction, electrochemical deposition and bio-sorption[8][9][10] however, these methods have their attendant disadvantages which include incomplete metal removal, generation of sludge or secondary waste, high running cost, etc. Among all these processes activated carbon adsorption is one of the most common wastewater treatment methods due to its high efficiency, simplicity of design, and ease of operation, reuse potential of adsorbents during long-term applications and being least expensive treatment option. Among all the processes Adsorption has been pointed out as one of the efficient methods for the removal of heavy metals from wastewater [11].because of its low cost, large surface area, variable characteristics surface chemistry. Investigations have been conducted and reported on the use of inexpensive, easily available and environmentally friendly biomaterials for the removal of Cr (VI) from aqueous solution. High adsorption capacity of these biomaterials has been attributed to the presence of certain functional groups like amino, phosphate, carboxylic, hydroxyl and sulphate groups [12]. Several reports have been made on the adsorption of Cr(VI) on different biomaterials include lichen [13], moss [14], rice straw [15], raw and modified seaweed [16], chemically modified seaweed[17], tea factory waste [18], maize corn cob, jatropha oil cake, sugarcane bagasse [19], tamarind hull [20], live and pretreated biomass of Aspergillums flavus

[21], sawdust [22], saltbush [23], wool, olive cake, sawdust, pine needles, almond shells, cactus leaves, and charcoal [24].Most of these biomaterials reported for the removal of chromium (VI) are of plant origin.

Therefore, objectives of this work was aimed at investigating the use of "Acid Treated Banana Peel" for the removal of Cr (VI) from aqueous solution since little or no report is available still this time and to optimize the important parameters that affect adsorption with a purpose to achieve complete removal and to provide optimum consumption of "Acid Treated Banana Peel". A comparative study of various adsorption kinetic models and isotherms has been also made. This will also serve as a way of cleaning up the environment and putting banana peel into significant use.

EXPERIMENTAL DESCRIPTIONS

Materials

All chemicals used in the current study were of analytical grade. Chemicals used for the experiments were potassium dichromate ($K_2Cr_2O_7$), 1, 5-diphinylecarbazide (DPC), hydrochloric acid, acetone, sulphuric acid, and Ultra-pure de-ionized water [25]. Adsorbent material used in this work was "Acid Treated Banana Peel"

Preparation of banana peel

Banana peel obtains from local Market. Banana peels were cut into small pieces, washed with tap, then three times with distilled water to remove the external dirt particles and unwanted materials. Wetted banana peels were kept in air for removing the free water from the surface and dried in oven for 24 h at 70^{o}C. The dried banana peel were grounded into powder and sieved using 520 µm and it was impregnated with HCl (1 N) and placed in it for 24 h. Powder banana peel was filtered and again washed with distilled water until the pH reaches to 7. Filtered banana peel kept into oven at 50^{0}C again until it was dried. At last dried "Acid Treated Banana Peel" was used as adsorbent.

Moisture test

The moisture present in "Acid Treated Banana Peel" was calculated by taking 2 g of banana peel. Keep in oven at a temperature of 105^{0}C for 1 h. After heating it was cooled and weighted. Result was obtained in the form of difference in weigh of acid treated banana peel, following formula show the moisture contents present in "Acid Treated Banana Peel"

$$X = \frac{w_i - w_f}{w_i}$$

w_i = weight of acid treated banana peelinitially

w_f=weight of acid treated banana peel after heating

X =moisture contents

Experimental procedure

Stock solution of 500 ppm of Cr (VI) was prepared by dissolving the necessary amount of $K_2Cr_2O_7$ in 1 l deionized water. The stock solution was diluted as required to obtained standard solution of concentration ranging from 50 to 400 ppm. Adsorption of Cr (VI) on "Acid Treated Banana Peel" was processed out with different adsorbent doses (0.04 to 0.26g/100ml) at pH 1 to 6, and the initial concentration 50 ppm. The solutions were stirred for periods of 120 mints in an incubator shaker at 150 rpm. Samples were collected, filtered and add the reagent solution 2ml which was prepared by dissolving 250 mg 1, 5-diphenylcarbohydrazide in 50 mL acetone and stored in a brown bottle. While adding the reagent, filtered solution change into a pinkish red colored at last absorbance was measured by using UV spectrophotometer at 540 nm wavelength. While using the batch process there is no need for volume correction. These batch experiments were conducted at 50ppm Cr (VI) solution, pH 2 and 0.04 – 0.26 g/100ml "Acid Treated Banana Peel". All the adsorption studies were repeated thrice. The reported value was the average of the measurements.

The amount of metal ions adsorbed at equilibrium per unit mass of bio sorbent was determined according to the following equation [26]

$$q_e = \frac{(C_o - C_e)V}{m} \quad \text{..... (1)}$$

Where, m is the mass of adsorbent (g), V is the volume of the solution (L), C_0 is the initial concentration of metal (mgL^{-1}), C_e is the equilibrium concentration of the adsorbate in the liquid phase (mgL^{-1}) and q_e is the amount of metal adsorbed at equilibrium (mgg^{-1}).

The percentage adsorption (%R), for chromium was calculated using the following expression:

$$\%R = \frac{(C_o - C_e)\ X\ 100}{C_0}$$

RESULTS AND DISCUSSION

Characterization of adsorbent

Removal of Cr (VI) from wastewater over Acid treated banana peel using adsorption depends on the factors such as pH, initial concentration, contact time, and adsorbent amount [27]. Therefore, the effect of these parameters was studied by varying process parameters, holding the other parameters constant.

In order to understand the adsorption of Cr(VI) onto "Acid Treated Banana Peel" (ATBP), physicochemical characterization of the adsorbent was carried out. EDX spectra of "Acid Treated Banana Peel" before and after adsorption shown in figure 1 (a) and (b),The presence of C, O, Si, P, S, Cl, Ca and a particularly intense peak of potassium in comparison, chromium-treated banana peel had additional peaks confirming the sorption of chromium onto the

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surface. It was clear from the EDX spectrum that Cr was adsorbed on the surface of ATBP shown in table1. SEM of Banana peel before acid treated and after treated indicates the porous structure of adsorbent. Scanning Electronic Microscope (SEM), operating in variable pressure mode used for studying the surface morphology of the ATBP, **figure 2**shows the acid treated banana peel which exposed the combination of small and large particles size, heterogeneous rough and porous surfaces with crater-like pores before the adsorption. These characteristics increase the adsorption capacity of the adsorbent and act as reactive adsorption centers for adsorption of Cr (VI).

Element	Weight%	%	Net Int.	Error%
C k	39.23	51.2	58.97	10.91
O K	43.17	42.29	113.22	10.73
P K	0.38	0.19	5.45	30.75
S K	0.37	0.18	5.78	34.06
Cl K	7.35	3.25	102.89	4.37
Ca K	0.22	0.09	2.27	66.23
CrK	9.28	2.8	56.36	6.22

Table 1: EDX weigh % of various constituents present on adsorbent

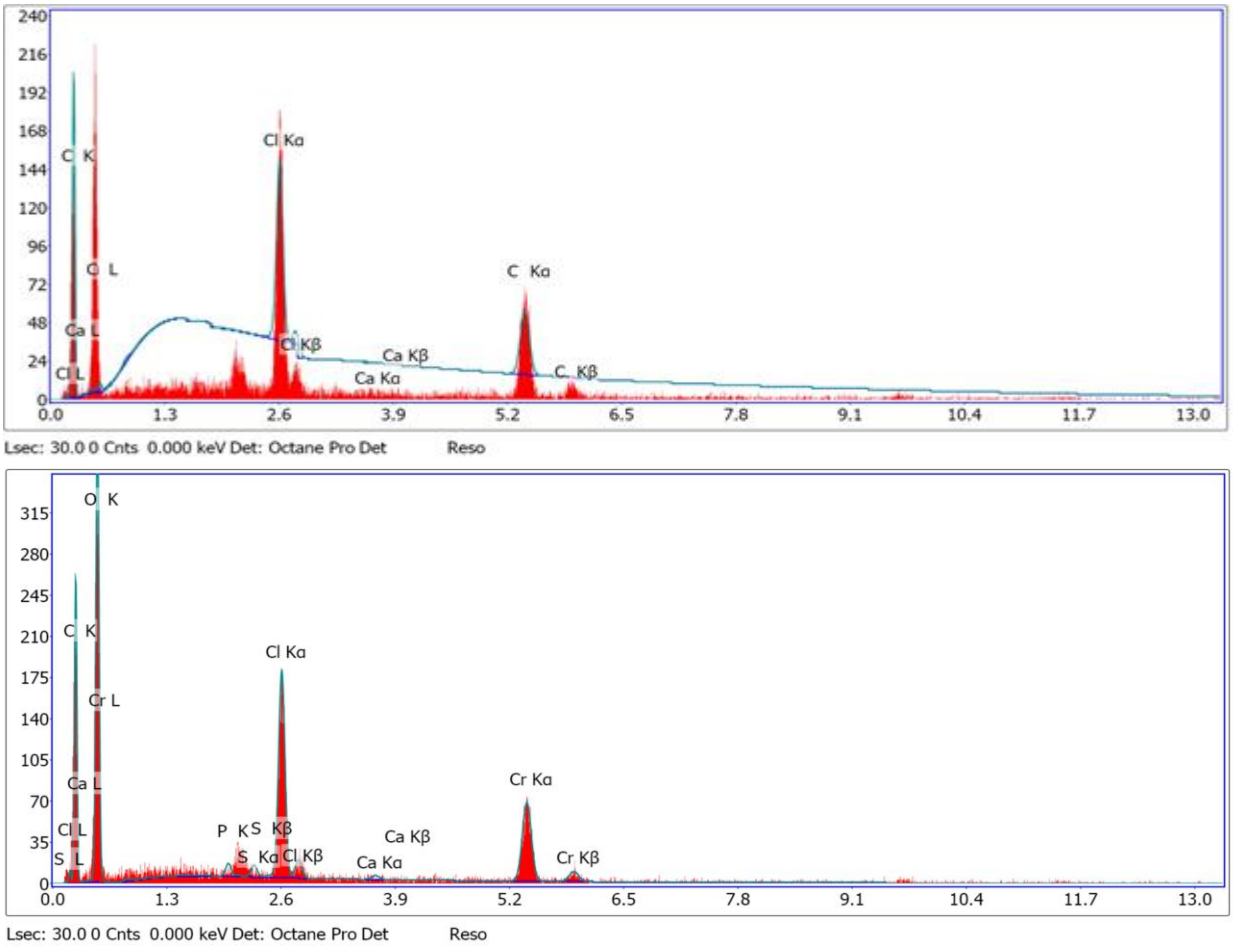

Figure 1: (a) EDX spectrum of "Acid Treated Banana Peel" before adsorption (b) after adsorption

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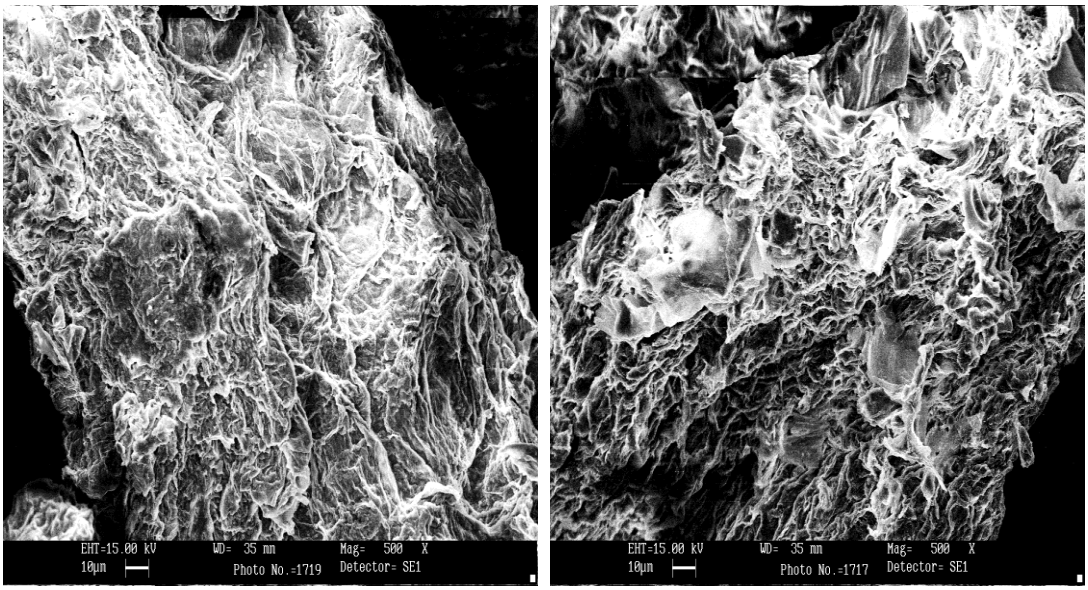

Figure2: SEM image of "Banana peel" before acid treated and after treated.

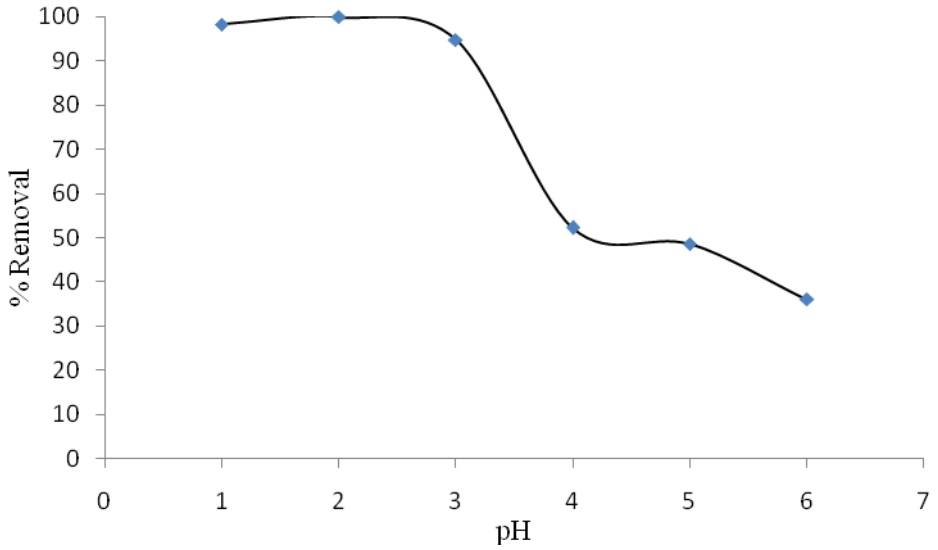

Figure 3: Percentage removal of Cr (VI) versus pH values

Effect of pH

For Cr (VI) stability pH is one of the most important parameter which controls the surface properties of adsorbents, functional groups and ionic state of metal's species. The adsorption capacities of Cr (VI) from aqueous solution onto ATBP were strongly affected by the pH. Adsorption experiments were carried out over the pH range of 1–6, While other parameters were keep constant. The experimental results show that the adsorption was favorable at acidic condition, which is maintained by 0.1 N HCl and 0.1 N NaOH. Maximum Cr(VI) uptake was observed at pH 2. The percentage of Cr (VI) adsorbed by "Acid Treated Banana Peel" decreased from 99.99 to 36.02% when the pH was increased from 2 to 6, and at

pH 1 removal of Cr (VI) is98.23 shown in Figure 3. So pH 2 was the optimum pH for maximum removal of Cr (VI). Between pH 1.0 and 6.0, chromium species co-exist in various forms, such as $Cr_2O_7^{2-}$, $HCrO_4^-$, $Cr_3O_{10}^{2-}$, and $Cr_4O_{13}^{2-}$, of which $HCrO_4^-$predominates [28]. As the solution pH increases, $CrO_4^{2-}$and $Cr_2O_7^{2-}$ became prominent. Since the binding of hexavalent Chromium was occurs via a complex mechanism, it is likely that Cr(VI) might be adsorbed at acid treated banana peel surface. Therefore, the concentration of Cr (VI) was measured. There are some steps which were involved during the sorption and reduction processes: At its optimum pH 2,$HCrO_4^-$is the main chromium species in the solution. Cr(VI) is adsorbed in parallel with the increase in H^+ ion concentration at the adsorbent surface; consequently protein amino groups become protonated. As a result, electrostatic forces of attraction become important between the positively charged adsorbent surfaces and negatively charged chromate ions and the following reaction takes place:

$$HCrO_4^- + NH_3^+ \rightarrow HCrO_4^- + NH_3^+$$

Therefore, sorption was more efficient at pH 2 and became less significant at higher pH values due to the competition between negatively charged Cr(VI) and OH^-ions.Thus,a proportion of bio reduced Cr (VI) is released from ATBP surface and the reaction mechanism may be represented by:

$$HCrO_4^- + H^+ + ATBP \rightarrow HCrO_4^- \; -H^+ \; -ATBP \rightarrow Cr_3^+ + H_2O + ATBP$$

Maximum adsorption at pH 2.0 indicates that it is the $HCrO_4^-$form of Cr (VI) which is adsorbed partially on the “Acid Treated Banana Peel”.

Effect of Acid Treated Banana Peel dosage

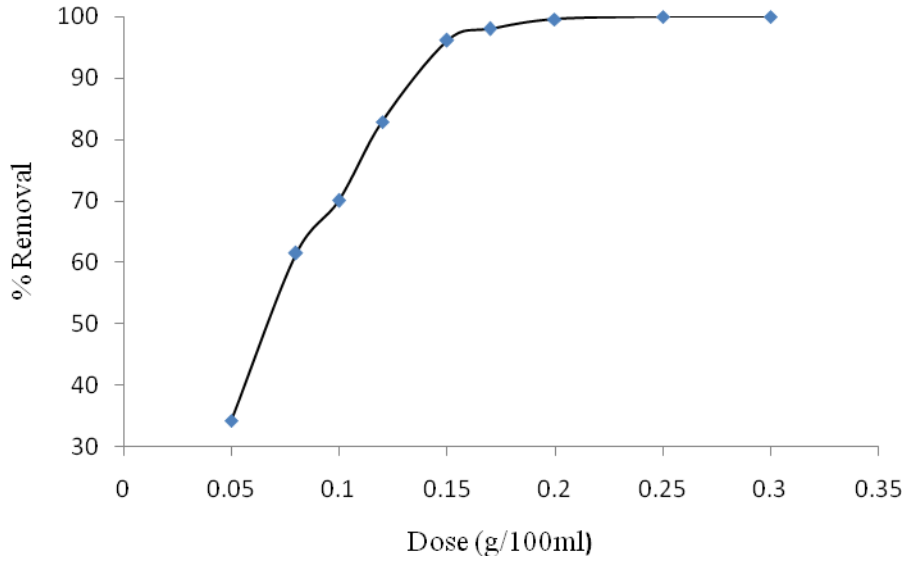

Figure 4:Percentage removal of Cr (VI) versus ATBP Dose

The effect of sorbent mass on the adsorption study is shown in Figure 4. The figure shows that percentage chromium (VI) removal (%R) is highly a function of the mass of the biosorbent used. It means adsorbent dosage is an important parameter because it determines the ability of an adsorbent for removal of Cr(VI). In this paper, the percentage of metal Cr (VI) adsorbed increased with increase in the mass of the adsorbent. Removal of Cr (VI) increased rapidly from 34.17% to 99.99% when "Acid Treated Banana Peel" dosage was increased from 0.05g to0.3g/100ml at concentration of 100 ppm. This was expected because the greater the amount of the adsorbent in solution, the greater the number of binding sites available for metal uptake. At adsorbent dose 0.2g/100ml, maximum removal of 99.53 % was occurring. So it was the optimum adsorbent dose. After increasing the optimum dose from .2 g/100ml, the removal was unaffected because on increasing the dose further, equilibrium is approached between solution of Cr(VI) and surface.

Effect of Initial metal ion Concentration

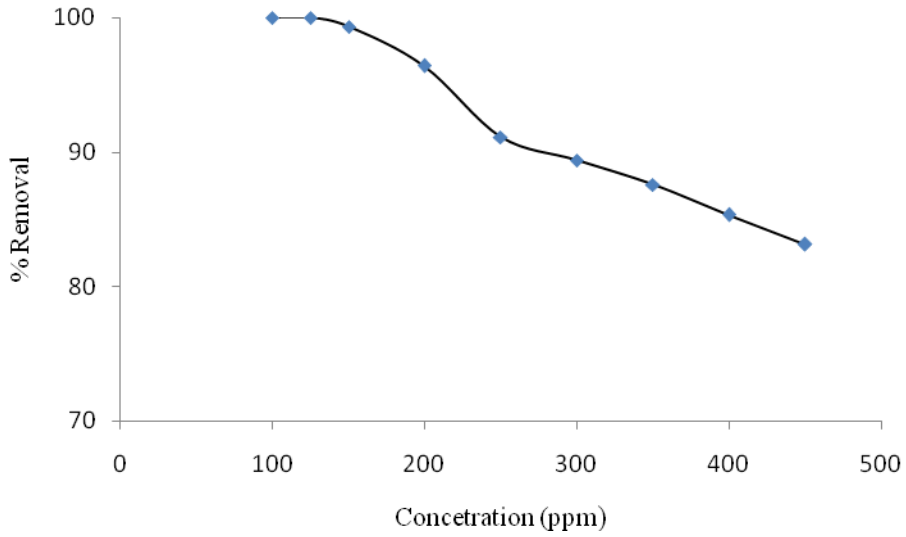

Figure 5: Percentage removal of Cr (VI) versus concentration

The effect of initial metal concentration Cr (VI) on ATBP was investigated at different chromium concentrated solutions shown in figure 5which tells that maximum removal takes place at lower ion concentration at optimum pH and adsorbent dose. Increasing Cr (VI) concentration decreased the percent removal at optimum pH 2.0.The increase ininitial concentration of chromium results in the increased uptake capacity and decreased percent removal since at high initial concentrations, number of moles of chromium available to surface area is high [29], number of collisions between chromium molecules and adsorbent get increased, and a driving force to overcome all mass transfer resistances between the aqueous and solid phases is developed. Figure 5 describes the effect of initial Cr (VI) concentration on adsorption for ATBP adsorbent. When the initial Cr (VI) concentration was varied from 100 mg $L^{-1}$to 450 mg L^{-1}, adsorption capacity of ATBP increased from 49.86 mg g^{-1} to 149.62 mg g^{-1}.

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Effect of contact time

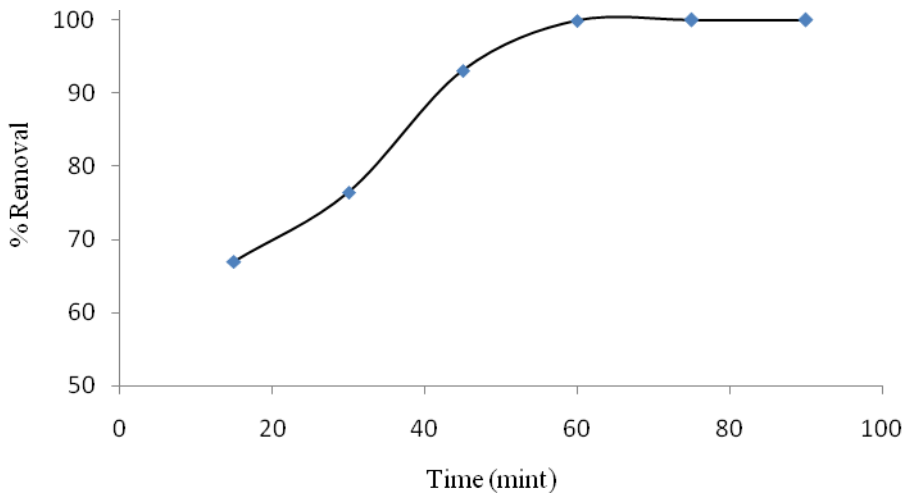

Figure 6: Percentage removal of Cr (VI) versus contact time (mint)

Figure 6 shows the result of the effect of contact time on the extent of adsorption of Cr (VI) on the ATBP at 100mg/L initial chromium concentration at pH 2.0 and temperature 303 K. It has been observed that the metal adsorption rate is high at the beginning and then decreases slowly till saturation levels were completely reached at the equilibration point (60 min). Initially, there were large number of vacant active binding sites available during the initial period of time and large amount of Cr (VI) were bound rapidly on ATBP at a faster adsorption rate. The binding site was shortly become limited and the remaining vacant surface sites were difficult to be occupied by chromium ions due to the formation of repulsive forces between the chromium on the solid surface and the liquid phase [30].Equilibrium time is attain nearly at 60 minute, therefore contact time of approximate 1hwas used to perform the entire batch Experiments.

KINETIC MODELS

Kinetic models are very important due to its mechanism of reactions. Kinetic studies for adsorption of Cr (VI) on “Acid Treated Banana Peel” were analyzed using three kinetic model lager gren pseudo first order, pseudo second order and intra particle diffusion. The time-dependent behavior of Cr (VI) was also studied by varying the contact time and adsorbent at concentrations 100 mg/L and the results are shown in Figure 7. The data showed that the adsorption of Cr (VI) ions onto ATBP was rapid in the beginning and then slowly attained equilibrium at about 60 mints. Hence this was fixed as the optimum contact time.

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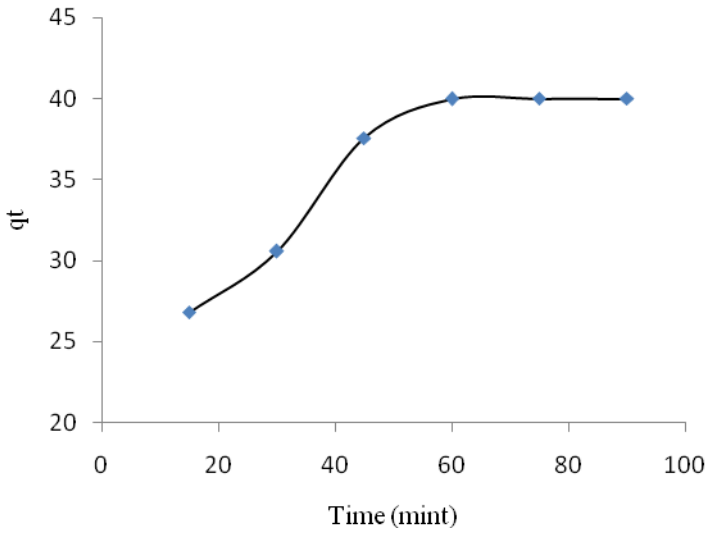

Figure 7: Adsorption kinetics of Cr (VI) onto ATBP at initial concentrations 100 mg/L

The association between the experimental data and the model-predicted values was examined by R^2in kinematic models. The linear fitting line of the pseudo-first-order, pseudo-second-order and Intra particle diffusion equations for adsorption of chromium (VI) onto ATBP and parameters are summarized in **Table 2**.

Pseudo first order model	$k_{ad}(min^{-1})$ = 0.1305 $q_{e(cal)}(mgg^{-1})$ = 39.99 $q_{e(expl)}(mgg^{-1})$ = 232 R^2 = 0.8165
Pseudo second order model	$k_2(min^{-1})$ = 0.0015 $q_{e(cal)}(mgg^{-1})$ = 39.99 $q_{e(expl)}(mgg^{-1})$ = 47.8 R^2 = 0.9911
Intra particle diffusion model	$K_{dif}(min^{-1})$ = 3.064 R^2 = 0.9338

Table 2: Values of pseudo-first order, pseudo-second order and intra-particle diffusion constants for the adsorption of Cr (VI) on "Acid Treated Banana Peel"

The pseudo first order kinetic model can be represented by the following equation [31]

$$\frac{dq}{dt} = k_{ad}(q_e - q_t)$$

By integrating this equation it becomes:

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

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Where q_t is amount of chromium (VI) adsorbed (mg/g) at time t(mint), q_e is the amount of chromium adsorbed at equilibrium (mg/g), k_{ad}(1/min) is pseudo- first order kinetic rate constant, a graph was plotted in between the two parameters $\log (q_e - q_t)$ and t which gives the straight line shown in figure 8.This model was successfully applied to know the values of k_{ad} and q_e which is obtained from the slope and intercept in figure 8 and value of k_{ad}, q_e and R^2 is given in table2.

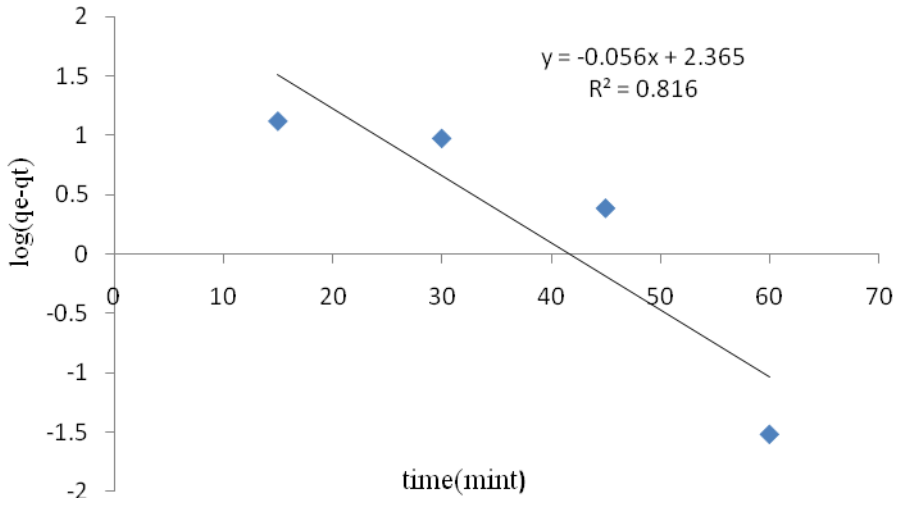

Figure 8:Pseudo-first order kinetic plots for the adsorption of Cr (VI) on "Acid Treated Banana Peel"

The adsorption kinetics may also be described by pseudo-second order kinetic model.

Equation of pseudo second order model can be expressed as follow: [32]

$$\frac{dq}{dt} = k_2 (q_e - q_t)^2$$

The linearized integral form of the pseudo second-order model

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_t} t$$

Where k_2 (g mg^{-1} min^{-1}) is the pseudo-second order rate constant of adsorption. A graph was plotted in between $\frac{t}{q_t}$and t which give a linear relationship shown in figure 9. The values of rate constant (k_2) and q_e were calculated from the plot which is shown in table 2.

The adsorption kinetic may also be analyzed by the intraparticle diffusion model.

Equation of intra particle diffusion model rate constant as follow: [33]

$$q_t = k_{dif} \sqrt{t} + C$$

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Where k_{dif} is the intra-particular diffusion rate constant (mg g^{-1} $min^{-1/2}$)
k_{dif} was easily calculated by using this equation.

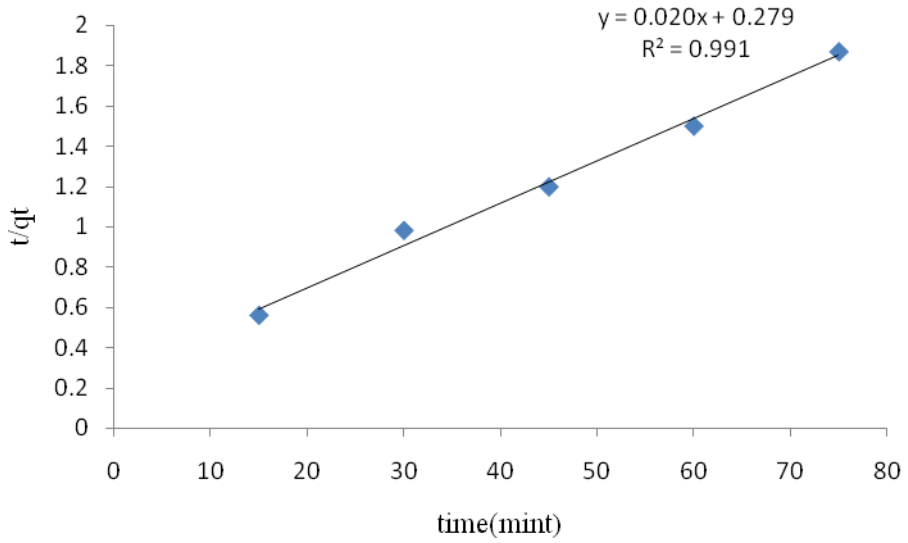

Figure 9:Pseudo-second order kinetic plots for the adsorption of Cr (VI) on Acid treated banana peel

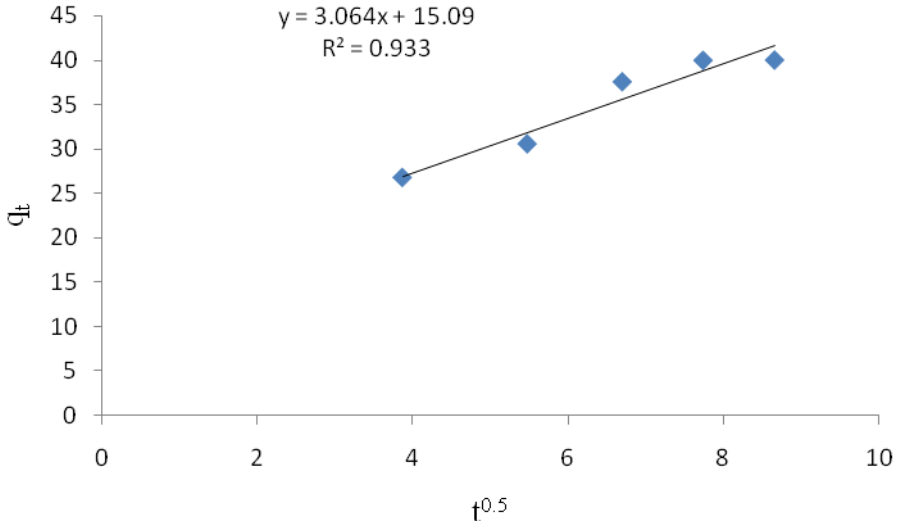

Figure 10: Intra-particle diffusion kinetics for adsorption of Cr (VI) on "Acid Treated Banana Peel"

A graph was plotted in between the q_t versus $t^{.5}$ for the adsorption of Cr(VI) which gives the result in a linear relationship shown in figure 10. The Value of k_{dif} and C was calculated from the graph given in table 2.

The applicability of the above three models can be examined by each linear plots shown in figure 8, 9 and 10. To calculate the applicability of each model, the correlation coefficient, R^2, was calculated from these plots. The linearity of these plots indicates the applicability of the

three models. However, the correlation coefficients, R^2, showed that the pseudo-second-order model, an indication of a chemisorption mechanism, fits better the experimental data (R^2= 0.9911) than the pseudo-first-order model (R^2= 0.8165) and intra particles diffusion model (R^2= 0.9338). The pseudo-first (k_{ad}), pseudo-second order (k_2) and intra-particle diffusion (k_{dif}) rate constant and correlation coefficients are shown in the Table 2.

Adsorption Isotherms

Analysis of the isotherm data is important in order to develop an equation which accurately represents the results of batch. Adsorption isotherms are describing the equilibrium relationships between the adsorbent and adsorb at combination. Several models have been used in the literature to describe the experimental data of adsorption isotherms. The Langmuir, Freundlich and Temkin isotherm models are the most frequently employed models. In the present work these models were used. These models help in calculating the adsorption capacity of materials.

The study of Langmuir isotherm model is the widely used two parameter equation to estimate the adsorption capacity of "Acid Treated Banana Peel". Langmuir equation can be used to calculate the maximum adsorption q_m (mgg^{-1}) and the energy parameter of adsorption k_L (dm^3mg^{-1}). [34]

$$q_e = \frac{q_m k_L C_e}{1 + k_L C_e}$$

By solving this equation it becomes

$$\frac{1}{q_e} = \frac{1}{q_m k_L C_e} + \frac{1}{q_m}$$

Where C_e (mg/L) is the equilibrium concentration of Cr(VI) remaining in the solution, $_{qe}$ (mg/g) is the amount of adsorbate adsorbed per mass unit of adsorbent at equilibrium, q_m(mg/g) is the maximum adsorption capacity of metal ions, and k_L (L/mg) is the Langmuir isotherm coefficient.

A further analysis of the Langmuir equation can be made on the basis of a dimensionless factor R_L also known as the separation factor and calculated from the following equation. [35]

$$R_L = \frac{1}{1 + k_L C_o}$$

Where C_0 is the initial solute concentration (mgL^{-1}) and k_L is the Langmuir adsorption equilibrium constant (L mg^{-1})

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The dimensionless separation factor, R_L used to describe the affinity between adsorbent and adsorbate as unfavorable (R_L>1), linear (R_L=1), favorable (0<R_L<1) or irreversible (R_L=0).

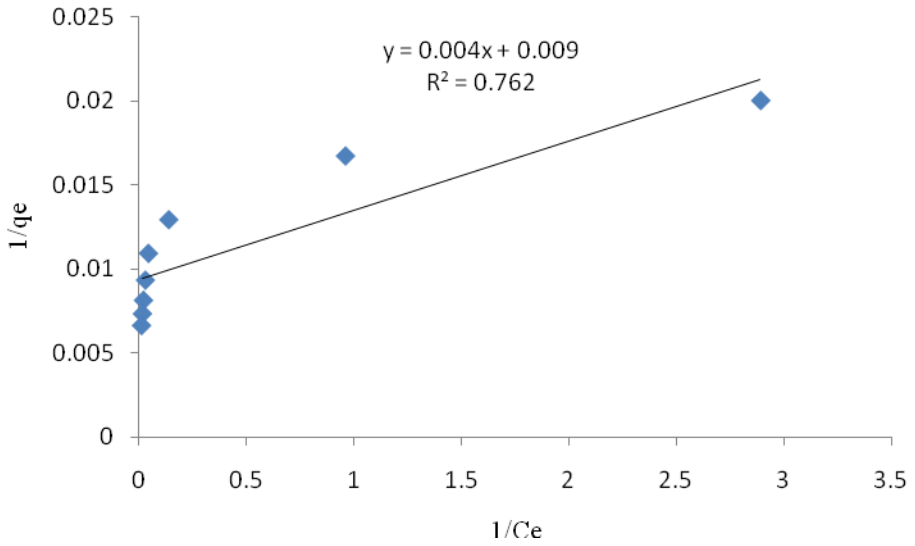

Figure 11: Langmuir isotherm plot for adsorption of Cr (VI) on "Acid Treated Banana Peel"

A linear graph is plotted in between$1/q_e$ versus $1/C_e$ for Cr (VI) which is show in figure 11. The values of q_m and k_L were obtained from the slope and intercept of a plot of $1/C_e$ versus $1/q_e$ and all the values are reported in Table 3.

Langmuir Isotherm model	q_m(mg/g)	106.38
	k_L(L/mg)	2.29
	R_L	0.0043
	R^2	0.7621
Freundlich Isotherm model	1/n	0.1934
	n	5.1706
	k_F(mg/g)	57.78
	R^2	0.95
Temkin Isotherm model	A_T(L/mg)	30.36
	b_T	146.732
	B	16.885
	R_2	0.8692

Table 3: Comparing all these model Langmuir, Freundlich, and Temkin Isotherm constants for the adsorption of Cr (VI) ion unto "Acid Treated Banana Peel"

Freundlich isotherm model is based on adsorption on heterogeneous surfaces and also on a multilayer adsorption. It assumes that the uptake of adsorbate ions occurs on a heterogeneous adsorbent surface. Freundlich equation indicates the adsorptive capacity or loading factor on the adsorbent surface. Freundlich model is expressed as follows [36]

$$q_e = k_F C_e^{\frac{1}{n}}$$

Logarithmic form of equation is expressed as follows

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

Where k_F and n are Freundlich constants which are related to the adsorption capacity and adsorption intensity

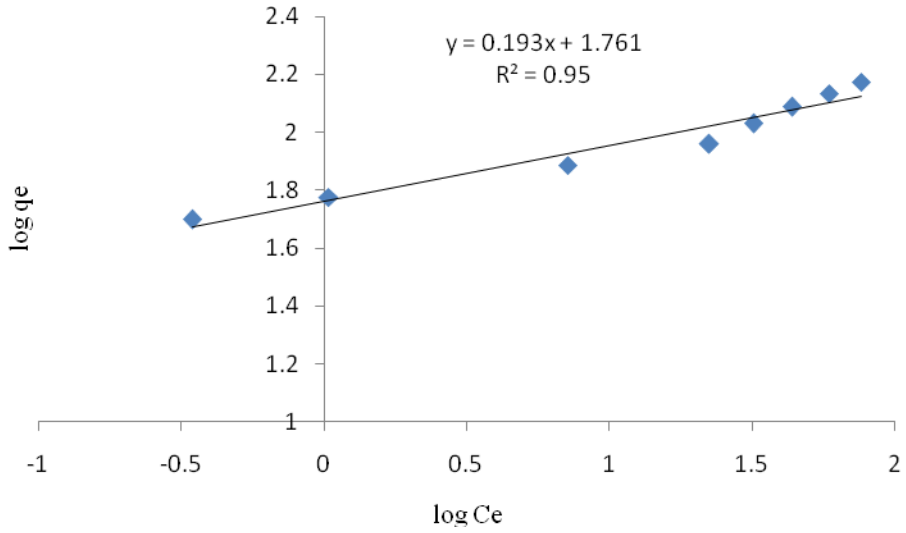

Figure 12: Freundlich isotherm plot for adsorption of Cr (VI) on "Acid Treated Banana Peel"

The linear graph is plotted in between log q_e and log C_e from which the values k_F and 1/n can be obtained from the graph shown in figure 12. All the calculated values are summarized in table 3.

Temkin isotherm model contains a factor that explicitly taking into the account of adsorbent–adsorbate interactions. This model have some assumption like heat of adsorption of all the molecules in the layer decrease linearly with coverage due to adsorbate adsorbate interaction and adsorption is characterized by a uniform distribution of binding energies, up to some maximum binding energy [37]:

$$q_e = \frac{RT}{b}\ln(A_T C_e)$$

The linear form of equation (10)

$$.q_e = B\ln K_T + B\ln C_e$$

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Where $B = \frac{RT}{B_T}$

Where K_T is equilibrium binding constant (L/g) corresponding to maximum binding energy, b_T is Temkin isotherm constant, R is universal gas constant (8.314J/mol/K), T is Temperature at 298K, B is Constant related to heat of adsorption(J/mol).

A plot of q_e versusln $C_e$allows us to determine the isotherm constant from the slope and intercept shown in figure 13. The following values are estimated which are shown in table 3.

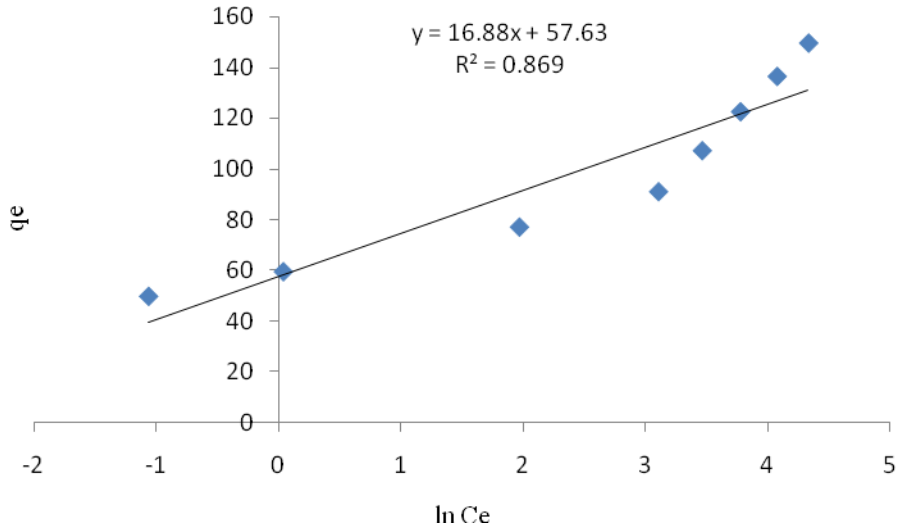

Figure 13:Temkin Isotherm plot for adsorption of Cr (VI) on "Acid Treated Banana Peel" at room Temperature

From the Table 3; Freundlich isotherm was successfully fitted to the adsorption data with a high degree of correlation coefficient as compare to the Langmuir isotherm and Temkin.

CONCLUSIONS

The present work shows that "Acid Treated Banana Peel"isa sufficient adsorbent for the removal of Cr(VI) from aqueous solution and it will be best alternative to more costly adsorbents. The adsorption was found to be strongly dependent on pH, ACBP dose, initial concentration and contact time. Maximum uptake of Cr (VI) was obtained at pH 2, contact time 60 mints, initial concentration 100 ppm and adsorbent dose 2g/l. The adsorption data were well described by the pseudo second-order kinetic model as compare to pseudo first order and intra particles diffusion model. The Adsorption patterns of acid treated banana peel was well fitted by Freundlich adsorption isotherm model as compared to Langmuir and Temkin model. The value of the adsorption capacity of 2 g/l for acid treated banana peel for removal Cr (VI) is found to be significant, which indicates that it can be successfully used for the removal of Cr (VI).

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