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RESEARCH ARTICLE

ADSORPTION KINETICS ON REMOVAL OF CHROMIUM FROM WASTEWATER USING ACACIA NILOTICA WOOD BASED ACTIVATED CARBON

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Abstract

Adsorption Capacity for the elimination of Chromium from the waste water has been studied from wood of *Acacia Nilotica* based activated carbon through various batch adsorption experiments .The adsorption kinetics of chromium using wood of *Acacia Nilotica* was done by differing factors such as amount of carbon added , pH and concentration levels of Chromium in wastewater. It was observed that the optimum dosage of wood of *Acacia Nilotica* based activated carbon to remove 80 mg/L of chromium from aqueous solution was 0.4gms/150 mL ,and the optimum contact time was 20 minutes. The isotherm data was found to be fit with both Langmuir and Freundlich isotherms.

INTRODUCTION

Chromium compounds are used in electro plating , metal finishing , leather tanning , paints and pigments etc. The use of chromium in industrial applications accidentally causes a severe threat to the environment as it is not bio degradable and will be present on the earth for a long time{1} . The concentrations of the chromium must be reduced to the permissible limit before they are let out in the environment or else it will cause a danger to all living things if they consume polluted water containing chromium{2}. All chromium compounds may cause Dermatitis and chrome ulcers which forms a little hole in the skin .Short term exposure causes irritation and inflammation of nose and upper respiratory tract{3} .Long term exposure may damage the nose and also lead to ulcerations in eye lids{4}. Many treatment methods are available for the removal of chromium from industrial waste water such as chemical precipitation, ion exchange, filtration, membrane separation, adsorption, oxidation and reduction{5}{6}{7}{8}{9}{10} . Comparing with other methods, adsorption is found to be technologically simple and lesser in cost{11}{12}{13}{14}{15}. Commercial activated carbon is used all over the world for the removal of chromium from the wastewater{16}. The price of the commercial activated carbon and its removal capacity in eliminating chromium makes the industry people to keep a distance from utilizing the same{17}{18}{19}{20}. Mainly Developing countries such as India suffers due to Chromium and hence there is a need for making a activated carbon which is of low cost and easily available. Several researchers proposed various cost economical adsorbents still there is a requirement to obtain a suitable adsorbent for the removal of chromium from waste water.

Activated carbon prepared using sawdust (Nadhem K. Hamadi et. al 2001), rice husk carbon (Narsi Ram Bishnoi et.al 2004), eucalyptus bark (Vikrant Sarin and Pant 2004), tea factory waste (Emine Malkoc,Yasar Nuhoglu 2005), *Hevea Brasilinesis* sawdust (Karthikeyan et. al 2005) . walnut hull (Xue Song Wang et. al 2007), ceiba pentandra hulls (Madhava Rao et al 2006), Terminalia arjuna nuts (Mohanty et al 2005), plant leaves (Salim et.al 2008), neem bask (Tarun kumar et al 2009), sugar cane Bangasse (Vinod et .al 2003) coconut coir pith(Namasivayam and Sureshkumar 2007).

Acacia Nilotica is the plant available in all parts of India , especially in Tamilnadu .Normally it is of no medicinal use and it is considered as agricultural waste material.Hence all the experiments were tried using wood of *Acacia Nilotica* based activated carbon to examine the removal efficiency of chromium from the wastewater.

The main aim of this research is to brief the removal capability of using wood of *Acacia Nilotica* based activated carbon for the removal of chromium from wastewater.

2.0 Materials and Methods

2.1 Preparation of activated carbon

Acacia Nilotica is the agricultural waste plant available in plenty at all areas in India especially Tamilnadu. These waste plants are accumulated and their size was reduced by breaking into small pieces. It was then dehydrated in a hot air oven at a constant temperature of 170° C for 24 hours. It was then placed in an air tight iron container with top portion fully sealed with iron cover to prevent the entry of air during charring process. The sealed iron container was warmed in a muffle furnace by slowly increasing the temperature upto 600°C and retained the same for 1 hour. During this process, wood of *Acacia Nilotica* was transformed into its carbon. The activated carbon thus prepared was subsequently washed in distilled water, oven dried and crushed into tiny particles and sieved with of 710 – 500 micron sieve. The particle of size between that was collected , packed in a air tight container for further experiments.

2.2 Preparation of Synthetic Solution

Synthetic Solution of 80 mg/L of chromium concentration was made by dissolving 409.95 mg of $CrCl_3 .6 H_2O$ in 1 L of distilled water. The Synthetic chromium solution thus made was used for all experiments.

2.3 Experimental Procedure

To calculate the optimum dosage and optimum time for the removal of chromium using wood of *Acacia Nilotica* , 8 conical flasks were packed with 150mL of 80 mg/L Chromium solution . 0.1g, 0.2g, 0.3g, 0.4g, 0.5g, 0.6g, 0.7g & 0.8g of *Acacia Nilotica* wood based activated carbon was added in each flask. These 8 conical flasks was kept in magnetic stirrer for continuous stir. Samples was taken at the intervals of 5min, 10min, 15min, 20min, 25min and 30min. Samples taken out were kept in the test tubes after filtering them using whatman filter paper No.41. The un adsorbed metal ions were estimated by uv spectrophotometer.

Optimum p^H for the removal of Chromium reduction is second set of experiments done by varying the pH with NaOH and HCl . Optimum concentration of chromium removal is another set of experiments done to find out the maximum concentration of chromium that can be removed at optimum dosage. All the batch mode experiments were carried out at a temperature of 20±2 ^oC.All the experiments except optimum pH was carried out with a pH of 3.37(Original pH). The remaining Chromium ion concentration is calculated by

$$\% \text{ of Chromium Removal} = (C_0-C_e)*100/C_e \quad \text{------------------------(1)}$$

Where C_0 = Initial Chromium concentration in mg/L

C_e = Residual Chromium concentration in mg/L

2.4 Instrumentation:

To calculate the concentration of Chromium, double beam pc based spectrophotometer was used. The least detection value was within EPA requirement. Standard solution with various chromium concentrations was used to calibrate the instrument. All analysis were repeated 2 times and the readings which have standard deviations more than 0.1 mg/L were omitted.

The pH meter was adjusted by using buffer solutions of values 4 and 7. Magnetic stirrer (KMS 450) was used for mixing all samples.

2.5 Chemicals:

Chemicals such as concentrated hydrochloric acid and Sodium Hydroxide (Madras Scientific Company) were used in changing the pH of the sample. Distilled water is used in all tests.

2.6 Adsorption Isotherms:

Equation which are used to explain the experimental isotherm data[29] was

a) Freundlich sotherm
b) Langmuir Isotherm

The general form of Freundlich isotherm is

Log (X/m) = log K_F + 1/n (Log C_e) ---------------- (1) where

X/m = amount adsorbed per unit weight of adsorbent(g/kg)
C_e = equilibrium concentration of adsorbate in solution after adsorption (mg/L).
K_F, n = empirical constants.

The general form of Langmuir equation is

1/(X/m) = 1/q_m + 1/K_a*q_m (1/c_e)------------------------(2)

Where X/m = amount adsorbed per unit weight of adsorbent (g/kg)
K_A , q_m = constants
c_e = equilibrium concentration of adsorbate in solution after adsorption (mg/L).

3.0 Result and discussion:

3.1 Effect of dosage:

The removal of chromium was illustrated in Figure-1 . From the graph, it is clear that the increase in quantity of carbon added increases the chromium removal from the aqueous solution. Later Chromium removal reaches equilibrium and there was least variation from each other. It is also observed that effective dosage for the removal of chromium of concentration 80 mg/L was 0.4g at an optimum time of 20 minutes. After that there is no significant change in chromium removal

Table – 1 Effect of dosage on chromium removal

Sl.No.	Contact Time(Minutes)	% of Cr removal for 150mL							
		0.1g	**0.2g**	**0.3g**	**0.4g**	**0.5g**	**0.6g**	**0.7g**	**0.8g**
1	5	16.13	34.38	70.75	85.38	85.88	86.13	86.75	87.25
2	10	25.25	39.13	73.88	87.13	87.50	87.75	88.25	88.63
3	15	27.00	43.63	75.88	87.38	88.00	88.38	88.63	89.00
4	20	27.86	44.00	76.25	87.75	88.50	89.00	89.25	89.88
5	25	28.50	44.75	77.00	88.25	89.13	89.50	89.75	90.00
6	30	29.00	45.13	77.38	88.63	89.38	89.88	90.50	90.75

Table: 2 Effect of dosage on Chromium removal at equilibrium(20 minutes)

Weight of adsorbent added in g/150 mL	**0.1g**	**0.2g**	**0.3g**	**0.4g**	**0.5g**	**0.6g**	**0.7g**	**0.8g**
% of Chromium removal	27.86	44.00	76.25	87.75	88.50	89.00	89.25	89.88

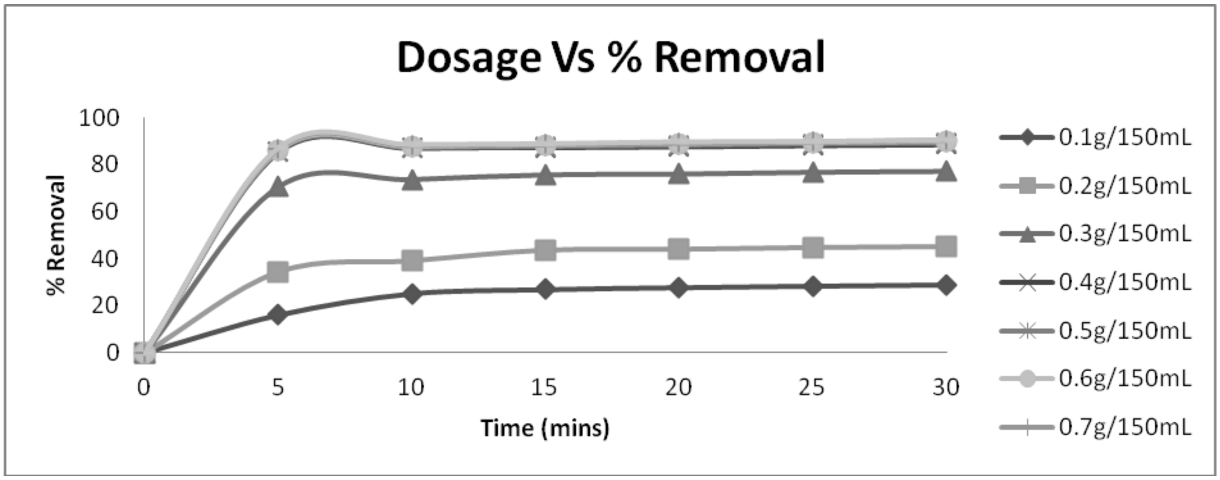

Fig-1 Dosage against percentage removal of Chromium

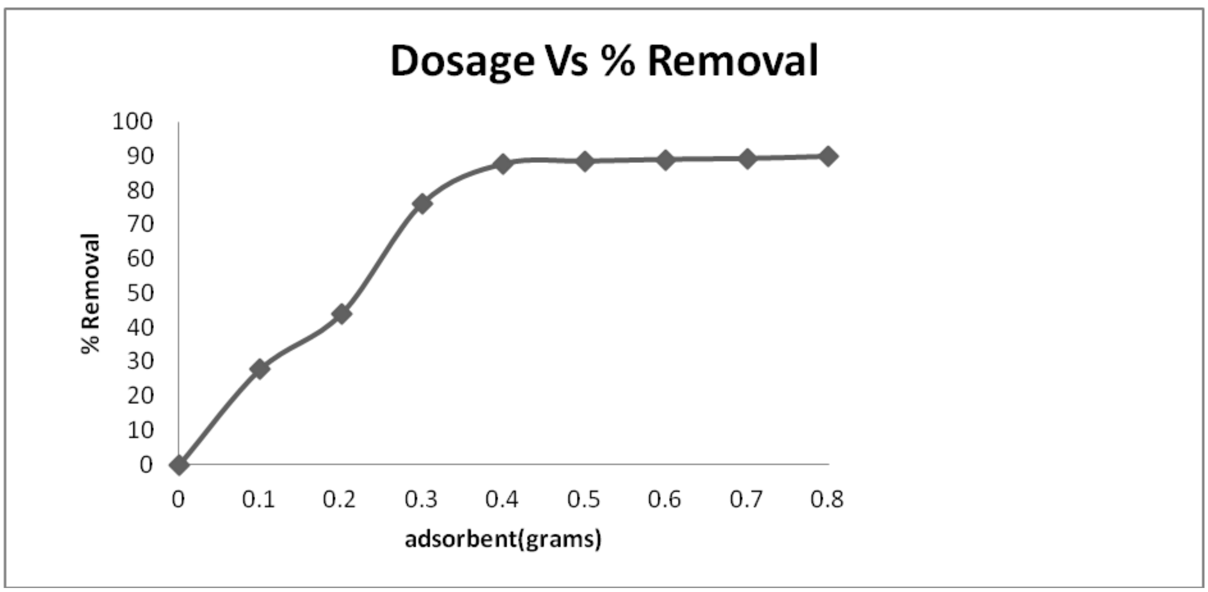

Figure-2 Dosage against percentage removal of Chromium at optimum time – 20 minutes

3.2 Effect of pH:

The major factor that controls the removal of chromium from the wastewater is pH . Figure– 3 indicates the impact of pH on chromium removal abilities of Wood of Acacia Nilotica**.** The experimental study was done at 80 mg/L of chromium concentration, adsorbent dose of 0.4 g with differing pH from 1 to 8.From the graph it is clearly understood that the chromium removal percentage increase with rise of pH and at definite point removal percentage comes to equilibrium.At pH 3.37(Original pH) to 8 adsorption of chromium by the wood of acacia nilotica takes place. It was noted that 80mg/L of chromium concentration can be reduced to 89 % from original pH to pH 8 at a contact time of 20 minutes. So all the experiments were conducted in original pH itself.

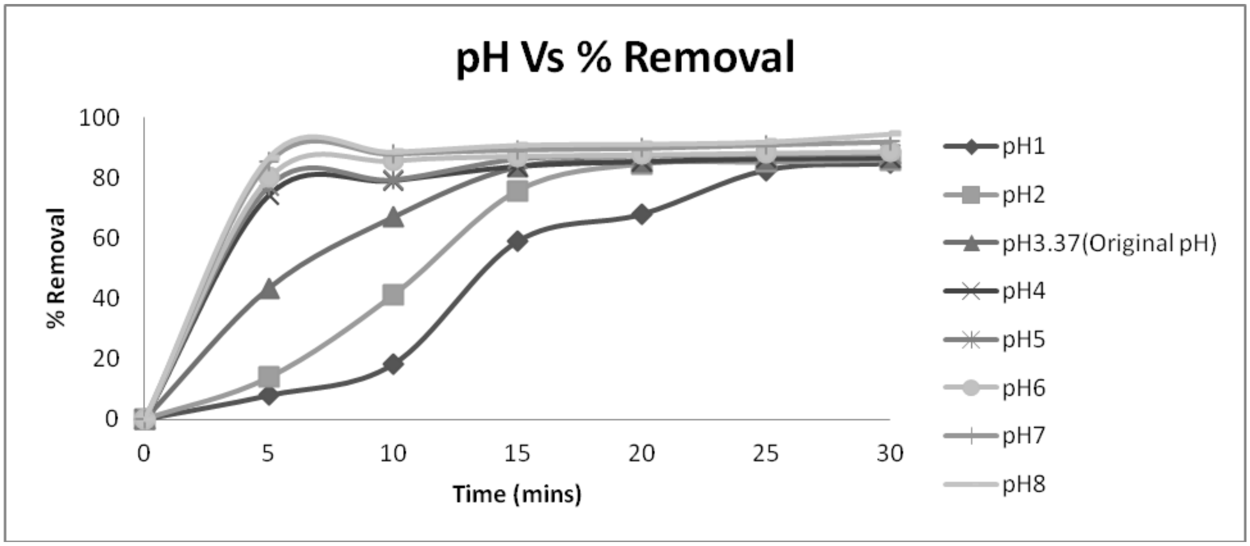

Figure 3– pH against percentage removal of chromium

3.3 Effect of Initial Concentration:

To illustrate the chromium adsorption at different concentrations solutions of of 10 mg/L , 20 mg/L , 30 mg/L , 40 mg/L, 50 mg/L, 60 mg/L, 70 mg/L & 80 mg/L were taken in 8 conical flasks. The samples were checked for remaining chromium concentration at an interval of 5 minutes up to the contact time of 30 minutes. The data attained was given in figure -4. To express the chromium adsorption at several concentrations a graph was plotted between contact time against percentage removal of chromium .From the graph it is observed that initial concentration has marked a greater influence on adsorption potential. The percentage of chromium removal increases up to initial concentration of 70 mg/L and reaches equilibrium.

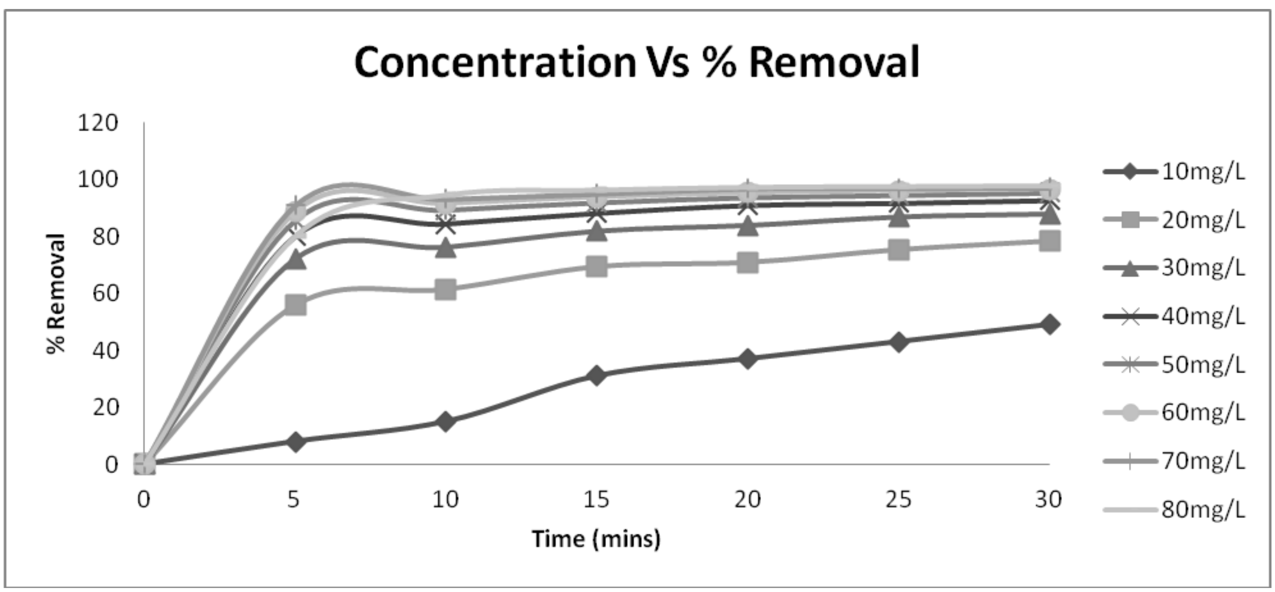

Figure 4 – Optimum Concentration against percentage removal of chromium

3.4 Isotherm study :

A known volume (150mL) of synthetic Chromium solution was treated with various dosages of Wood of *Acacia Nilotica* based activated carbon (0.1g,0.2g,0.3g,0.4g,0.5g,0.6 g,0.7g,0.8g)for 30 minutes .The steady state chromium concentrations were observed out from each of 8 reactors .The data which are necessary for isotherm plot for *Acacia Nilotica* wood based activated carbon was given in Table 3(Langmuir isotherm) and Table 4 (Freundlich isotherm). The isotherm test data was found to be fit with

Langmuir and Freundlich isotherms .While the corresponding readings were plotted in Langmuir isotherm model and Freundlich isotherm model it was found that R_L value and Langmuir isotherm Constants: K_A = 0.154,R_L = 0.074 and Freundlich Isotherm Constants: 1/n= 0.143, K_F = 0.016 , which shows favouable for adsorption of chromium on *Acacia Nilotica* activated carbon.

Table 3 : Data for Langmuir isotherm for chromium removal

Sl.No	Weight of adsorbent added (m) mg	Weight of Cadmium adsorbed at equilibrium Concentration (X) mg	Equilibrium Cadmium concentration (Ce) mg/L	1/Ce(L/mg)	X/m(g/kg)	[1/(x/m)] (kg/g)
1	100	3.418	57.2	0.0175	0.0342	29.24
2	200	5.367	44.2	0.0226	0.0268	37.31
3	300	9.235	18.4	0.0543	0.0308	32.47
4	400	10.58	9.4	0.1063	0.0264	37.88
5	500	10.69	8.7	0.1149	0.0214	46.73
6	600	10.73	8.4	0.1190	0.0179	55.86
7	700	10.76	8.2	0.1219	0.0154	64.93
8	800	10.79	8.0	0.125	0.0135	74.07

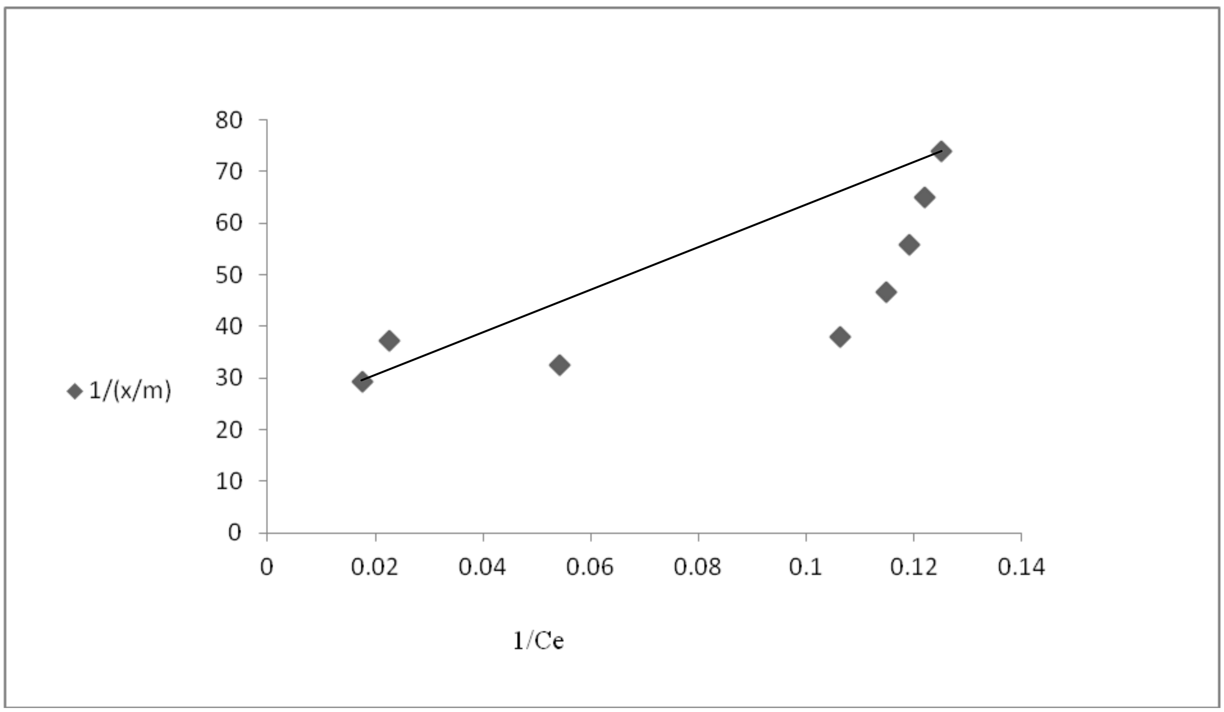

Fig- 5 : Langmuir isotherm for Chromium removal

Table 4 : Data for Freundlich isotherm for chromium removal.

Sl.No	Weight of adsorbent added (m) mg	Weight of Cadmium adsorbed at equilibrium	Equilibrium Cadmium concentration (Ce)	X/m * 10^{-3} (g/kg)	Log Ce	Log (x/m)

		Concentration (X) mg	**mg/L**			
1	100	3.418	57.2	0.0342	1.757	-1.466
2	200	5.367	44.2	0.0268	1.645	-1.572
3	300	9.235	18.4	0.0308	1.265	-1.511
4	400	10.58	9.4	0.0264	0.973	-1.578
5	500	10.69	8.7	0.0214	0.939	-1.669
6	600	10.73	8.4	0.0179	0.924	-1.747
7	700	10.76	8.2	0.0154	0.914	-1.812
8	800	10.79	8.0	0.0135	0.904	-1.870

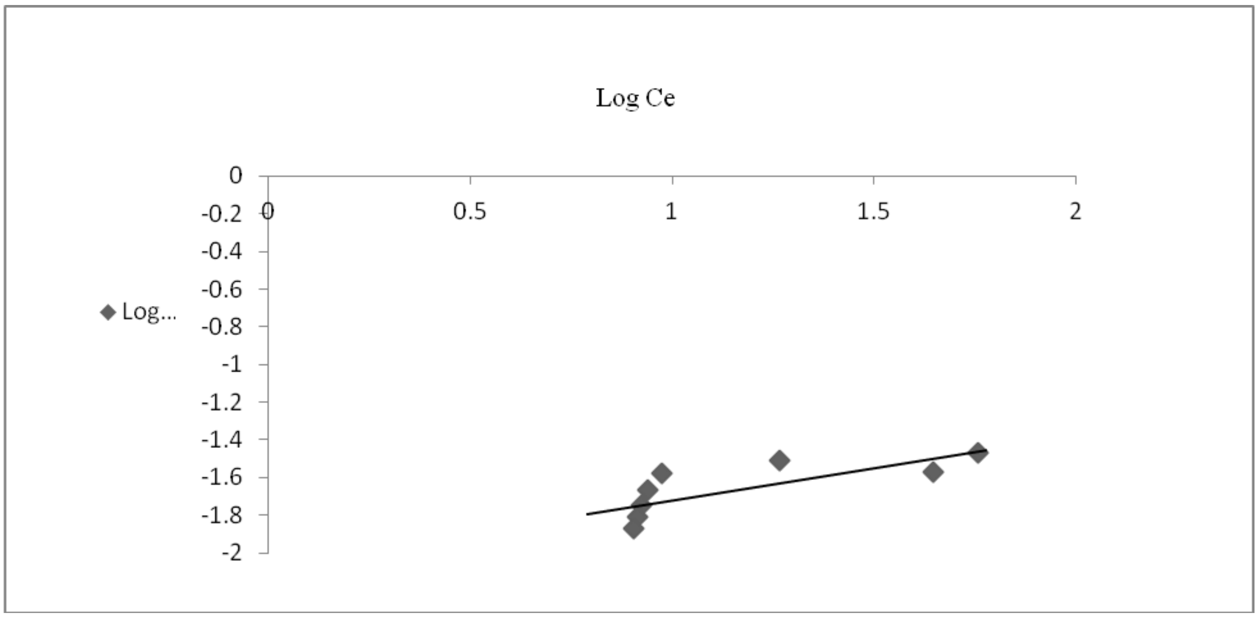

Figure-6 : Freundlich isotherm for Chromium removal

4.0 Conclusion

Activated carbon was made from *Acacia Nilotica* wood .Experiments were done in batch reactors to check the adsorption potential of this carbon to remove chromium from wastewater. The conclusions are listed below from the studies on chromium removal capability on wood of *Acacia Nilotica* based activated carbon .

1) Optimum dosage for the removal of 80 mg/L chromium in aqueous solution is 0.4g/150 ml at an optimum contact time of 20 minutes .
2) Optimum pH was original pH(3.37) itself.
3) Maximum concentration of chromium that can be removed is 80 mg/L
4) No chemical modification was done. This may be done and the removal capabilities may be compared.

Conflict of Intrests: The authors have no conflict of intrests

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