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### **Original Research Article**

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## REMOVAL OF COPPER ION FROM AQUEOUS SOLUTION USING SEEDS OF SUGAR APPLE (ANNONA SQUAMOSA L.)

R. Sivakumar<sup>1</sup>\*, P. Sri Renganathan<sup>2</sup>, H. Mary Helan<sup>3</sup>, T. Rajachandrasekar<sup>4</sup>

- 1. Department of Chemistry, Lekshmipuram College, Nagercoil. Tamilnadu, India
- 2. Department of Chemistry, Rani Anna Govt. College (W), Tirunelveli, Tamilnadu, India.
  - 3. Department of Chemistry, S.T. Hindu College, Nagercoil, Taminadu, India.
  - Department of Chemistry, M. R. Govt. Arts College, Mannargudi, Tamilnadu, India.
     <sup>1,2,3</sup>(Affiliated to Manonmaniam Sundaranar University, Tirunelveli)
     <sup>4</sup>(Affiliated to Bharathidasan University, Tirunelveli)

**ABSTRACT:** Copper pollution in the environment is a serious problem. Removal of it is a great concern for the researchers. In the present work, the removal of copper ion from aqueous solution was investigated by treating with activated carbon prepared from the seeds of Sugar Apple (*Annona squamosa* L.) (ASAC). Batch study was conducted to assess the adsorption efficiency of ASAC at different pH, contact time, adsorbent dose, temperature, initial concentration of adsorbate. Adsorption kinetics studies using pseudo-first order, pseudo-second order and intraparticle diffusion models revealed that the data were best fitted to pseudo-second order. The equilibrium adsorption data was analyzed using Langmuir and Freundlich isotherm models.

**KEYWORDS:** Isotherm, Adsorption, Heavy metal, Kinetics, Activated Carbon.

Corresponding Author: Dr. R. Sivakumar\* Ph.D. Department of Chemistry, Lekshmipuram College, Nagercoil. Tamilnadu, India Email Address: lcrsivakumar1971@gmail.com

## **1. INTRODUCTION**

Increase of human population and the corresponding industrialization has caused huge damage to the ecosystem. Various human activities like agriculture, mining, industrialization, etc. have polluted the environment. Heavy metals are one among the pollutants that are harmful to the living things[1],[2],[3]. Copper is one such metal creates serious problems. Copper has many applications

Sivakumar et al RJLBPCS 2019 www.rjlbpcs.com Life Science Informatics Publications in the world, and an excess of it can affect the environment and humans negatively. Copper metal is an excellent conductor of heat and electricity. All living organisms need copper in traces. It is the primary constituent in the respiratory enzyme cytochrome oxidase. Human's bones, muscles, and liver contain minute amounts of copper. Copper in the environment comes from natural sources and anthropogenic activities. The extraction of copper from the ores, manufacture of pesticides, fungicides and other products containing copper and electrical appliances discharge their effluents in to the water bodies. Excess copper in the soil affect most of the micro-organisms. It also inhibits the mineralization of nutrients such as phosphorus and nitrogen. Excess of copper in the water has adverse effects on aquatic life damaging the kidneys, nervous systems, and livers[4]. Many researchers have conducted research works for the removal of metal ions from solutions including the ion-exchange[5],[6],[7],[8],[9] precipitation[10],[11] reverse osmosis[12] electrochemical treatments[13] redox[14] methods, etc.,. Most of them are very expensive. Adsorption studies have been now focused by the researchers because of its simplicity in design, cost and efficiency. The aim of the present work is to investigate the efficiency of adsorption of copper from aqueous solution using activated carbon prepared from the seed of sugar apple. The seeds are waste product of the fruit. The removal efficiency of the ASAC was studied by kinetic and adsorption.[15],[16]. The effect of pH, contact time, temperature, adsorbent dose and initial concentration of the adsorbate were also studied. Batch method of the experiment was conducted.

#### 2. MATERIALS AND METHODS

#### Experimental

#### **Adsorbent Preparation**

The seeds of sugar apple were cut into small pieces and dried for 8 hours under sunlight. This was soaked in conc. sulphuric acid at the ratio of 1:1 (w/v). for 48 hrs and activated at 600° C in an air oven for 6 hrs. The carbons thus prepared was called activated sugar apple seed carbon (ASAC). It was washed thoroughly with distilled water until the pH of the wash water became neutral. The carbon was dried at 100° C for 2hours and it was free from moisture. The dried carbon was ground to fine powder and sieved. The particle with the average pore size of 2.86 nm was taken for analysis. The unused carbon was kept in a desiccator.

#### Preparation of Cu (II) ions solution

The stock solution was prepared daily by dissolving 1000mg/L in deionized water.

#### **Characterization of adsorbent**

The activated carbon was subjected to analysis for the determination of moisture, ash, volatile matter and fixed carbon content [17].

#### **Batch adsorption experiments**

Batch experiments were carried out to study the adsorption efficiency of the adsorbent. The studies were performed in a 100 ml iodine flask by mixing 50 mL of different initial concentrations (20

Sivakumar et al RJLBPCS 2019 www.rjlbpcs.com Life Science Informatics Publications mg/L, 30 mg/L, 40 mg/L and 50 mg/L) with 50 mg/50mL of the adsorbent. The mixture was agitated at 130 rpm in rotary shaker for pre-determined time. After equilibrium was attained the mixture was filtered and the adsorption of the dye solutions was measured using UV/Visible spectra photometer [18],[19]. The percentage removal and the amount of adsorbate adsorbed at equilibrium was calculated using the equations (1) and (2)

% removal = 
$$100(C_o - C_e)/C_o$$
 -----(1)  
 $q_e = (C_o - C_e)V/M$  -----(2)

where  $q_e$  is the amount of dye adsorbed at equilibrium (mg/g),  $C_o$  and  $C_e$  are the liquid phase concentrations of adsorbate at initial and equilibrium concentration (mg/L) respectively. M is the weight of the adsorbent used (g) and V is the volume of solution (L).

#### Adsorption kinetics studies and equilibrium isotherms

The isotherm provides relationship behaviors of concentration of the dye in solution and the amount of dye adsorbed on the solid phase when both phases are in equilibrium. The equilibrium of experimental data for adsorbed dye on adsorbent is studied by using the Freundlich [20] and Langmuir[21]. The possibility of intra particle diffusion was investigated using the expression described by Weber and Morris[22]. In this study the best fit isotherm model from the experimental data were determined using the value of correlation co-efficient ( $\mathbb{R}^2$ ).

#### **3. RESULTS AND DISCUSSION**

#### Influence of pH

The pH of solution has a significant impact on metal uptake since it determines the surface charge of adsorbent, solubility of the metal ion, concentration of counter ions on functional groups of the biomass and the degree of ionization and speciation of adsorbate[23],[24]. The effect of pH on the removal of copper ion from solution was carried out at a initial concentration of 20 mg/L with the adsorbent dose 50 mg/50 mL. The effect of initial pH on the removal of metal ion of concentration is shown in the Figure 1 and Table 1. It shows that the percentage removal was maximum (81 %) at pH 5. Above pH 6 the Cu (II) ion is precipitated as mono hydroxyl species[25],[26].

#### **Influence of Temperature**

The effect of temperature on the removal efficiency of copper ion from aqueous solution using ASSC. The results are shown in Figure 2 and Table 2. From the results it was found that 90.4% of copper ions were removed at 333K at the initial concentration of 20mg/L and the percentage removal of copper ion decreased with the increase of initial concentration and temperature.

#### Influence of contact time

The increase of contact time increase the percentage removal of metal ions. It continues till equilibrium is reached. In the present study it was observed that the percentage removal of copper ion increased as a function of time Figure 3 and Table 3. The percentage removal of copper ion was high at the initial stage and equilibrium is reached within 100 minutes for all concentrations. This could be explained by the fact that all the adsorbent sites were vacant at the initial stage and the concentration of the solute was high as the time increases. The percentage removal of the metal decreases significantly indicated the saturation of adsorbent surface with the metal ion molecules[27],[28]. It indicates the possible mono layer formation of metal ion on the outer surface of the adsorbent.

#### Effect of adsorbent dose

The effect of adsorbent dose on the removal of copper ion is shown in the Figure 4 and Table 4. The adsorbent of metal ion increased from 41.32 % to 89.5% as the adsorbent dose increased from 10 mg to 100 mg/50 mL at the initial concentration of 20 mg per liter of Cu ion. But when the dose increased from 50mg/50mL the difference in percentage removal was very low. It is clear that as the adsorbent dose increases the active sites on the adsorbent increases naturally the removal of metal ion increase.

#### Effect of initial concentration

The effect of initial concentration of the metal ion on the adsorption efficiency of adsorbent is given in the Figure 5 and Table 5. The percentage and removal of metal ion decreases with the increase of initial concentration for a given amount of adsorbent[29],[30].

#### Adsorption kinetics

The kinetic models are useful in understanding the mechanism of metal ion removal and the efficiency of the adsorbent. The most popular kinetic models used are Lagergren[31], first order kinetics and Ho's[32], Pseudo- second order kinetic model. The results are given in the Figure 10 & 11 and Table 8. The calculated  $q_e$  value very well and agreed with the experimental values and the R<sup>2</sup> values indicated that the pseudo – second order model could be applied for the adsorption of copper metal ion.

#### Sorption Isotherms

Adsorbent isotherms play a key role in suggesting the adsorbent-adsorbate interaction mechanism. Freundlich and Langmuir isotherm were applied to explain the experimental data. The calculated values of Freundlich and Langmuir parameters for the removal of Cu (II) ion is presented in the Figure 7-9 and Table 9. It was confirmed from the R<sup>2</sup> values that the Cu metal ion adsorption followed Freundlich isotherm.

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## Table:1 Effect of pH for the % removal of Cu(II) ions

Ci :20 mg/L Dose :50 mg/50 mL Time: 4 hrs

рН	% R
2	45.3
3	66.1
4	79.4
5	80.9

## Table: 2 Effect of temperature on the % removal of Cu(II) ions

Ci	Temperature	0/ D	<i></i>	
( <b>mg/L</b> )	( <b>K</b> )	70 <b>K</b>	qе	
	303	82.4	13.73	
20	313	85	14.17	
20	323	88.25	14.71	
	333	90.4	15.07	
	303	75.03	18.76	
20	313	79.07	19.77	
50	323	82.87	20.72	
	333	85.63	21.41	
	303	69.1	23.03	
40	313	74.63	24.88	
40	323	77.7	25.9	
	333	81.73	27.24	
	303	63.5	26.46	
50	313	68.92	28.72	
50	323	74.36	30.98	
	333	76.58	31.91	

# Table: 3 Effect of Contact time for the % removal of Cu(II) ions onto CFC[Dose:30 mg/L; pH: 5; Temp:303K]

Time	C <sub>i</sub> :20	mg/L	<b>C</b> <sub>i</sub> : 3	30mg/L	C <sub>i</sub> :40	)mg/L	C <sub>i</sub> :50	mg/L
(min)	%R	$\mathbf{q}_{\mathbf{t}}$	%R	qt	%R	$\mathbf{q}_{\mathbf{t}}$	%R	qt
10	50.85	8.48	42.97	10.74	37.03	12.34	33.08	13.78
20	60.60	10.10	50.20	12.55	44.63	14.88	39.14	16.31
30	70.40	11.73	60.13	15.03	53.88	17.96	48.18	20.08
40	75.05	12.51	65.13	16.28	58.40	19.47	53.10	22.13
60	77.80	12.97	70.03	17.51	62.53	20.84	56.98	23.74
80	80.05	13.34	72.13	18.03	65.28	21.76	59.46	24.78
90	80.70	13.45	73.47	18.37	66.78	22.26	60.22	25.09
100	81.40	13.57	73.97	18.49	67.15	22.38	61.32	25.55
120	81.75	13.63	74.27	18.57	67.55	22.52	62.16	25.90
140	82.05	13.68	74.63	18.66	68.70	22.90	62.96	26.23
160	82.40	13.73	75.03	18.76	69.10	23.03	63.50	26.46
180	82.40	13.73	75.03	18.76	69.10	23.03	63.50	26.46
200	82.40	13.73	75.03	10.74	69.10	23.03	63.50	26.46

Dose (mg/ 50 mL)	Percentage of Removal
10	41.3
20	56.8
30	69.5
40	75.6
50	80.3
60	82.85
70	84.2
80	85.3
90	87.5
100	89.5

Table: 4 Effect of dose for the % removal of Cu(II) ions

Ci ;20 mg/L pH:5 Time :4 hrs

Table: 5 Effect	of initial concentration	n at different temi	peratures for the <sup>o</sup>	% removal of Cu	(II) ions
Table, 5 Effect	or minima concentratio	at uniterent temp	jui aturus ior the	/o i chiovai oi Cu	(11) 10115

Temperature (K)	Initial Concentration (mg/L)	Concentration at equilibrium	Percentage of removal	Quantity adsorbed at equilibrium (mg/g)
	20	3.52	82.40	13.7
202	30	7.49	75.03	18.8
303	40	12.36	69.10	23.0
	50	18.25	63.50	26.5
	20	3.00	85.00	14.2
212	30	6.28	79.07	19.8
515	40	10.15	74.63	24.9
	50	15.54	68.92	28.7
	20	2.35	88.25	14.7
222	30	5.14	82.87	20.7
323	40	8.92	77.70	25.9
	50	12.82	74.36	31.0
	20	1.92	90.40	15.1
222	30	4.31	85.63	21.4
222	40	7.31	81.73	27.2
	50	11.71	76.58	31.9

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Table: 6 Separation factor (RL) values for the % removal of metal ions adsorption

Temp.	Ci(mg/L)	R <sub>L</sub>
	20	0.22
202	30	0.16
303	40	0.13
	50	0.10
	20	0.22
212	30	0.16
515	40	0.12
	50	0.10
	20	0.19
222	30	0.14
323	40	0.11
	50	0.09
	20	0.16
222	30	0.11
333	40	0.08
	50	0.07

$C_i$ (mg/L)	<b>Temperature</b> (K)	<b>k</b> d	$\Delta G^{\circ}(kJ/mol)$	$\Delta H^{\circ}(kJ/mol)$	$\Delta S^{\circ}(J/K mol)$
	303	4.68	-3.8895		
20	313	5.67	-4.5147	10.0202	78.4
	323	7.51	-5.4156	19.9203	/8.4
	333	9.42	-6.2096		
	303	3.01	-2.7725		
20	313	3.78	-3.4589	10 2051	72.9
30	323	4.84	-4.2335	19.3051	/2.8
	333	5.96	-4.9432		
	303	2.24	-2.0278		(0.0
40	313	2.94	-2.8076	10.0645	
40	323	3.48	-3.3527	18.8043	69.0
	333	4.47	-4.1476		
	303	1.74	-1.3952		
	313	2.22	-2.0728	10 10 77	647
50	323	2.90	-2.8599	18.182/	04./
	333	3.27	-3.2806		

Table: 7 Therm	odynamic	Parameters	for the %	removal of	Cu(II) ions
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 Table 8: Adsorption kinetic parameters under different conditions for the % removal of Cu(II) ions removal

			First	order kine	tics		Second order kinetics					Intra-particle
Parame	neters (Lagergren plot)				(Ho plot)				diffusion parameters			
Conc.	nН	$k_1$ (10 <sup>-2</sup> min <sup>-</sup>	$q_{e(cal)}$	$q_{e(exp)}$	ام ما	MSSE	k <sub>2</sub> (10 <sup>-2</sup>	$q_{e(cal)} \\$	$q_{e(exp)}$	ام ما	MSSE	k <sub>p</sub>
(mg/L)	pn	<sup>1</sup> )	(mg/g)	(mg/g)	Iq <sub>e</sub> ΔI	MODE	min <sup>-1</sup> )	(mg/g)	(mg/g)	Iq <sub>e</sub> ΔI	WISSE	(mg/g.min)
20	2	3.66	7.6	13.7	6.1		1.12	14.3	13.7	0.5		0.06
30	3	3.62	12.4	18.8	6.4	3.39	0.6	19.7	18.8	1	0.63	0.1
40	4	3.25	16.1	23	6.9		0.4	24.4	23	1.4		0.26
50	5	3.06	18.8	26.5	7.6		0.31	28.2	26.5	1.8		0.35

	Langmuir Freundlich				Temkin			Dubinin-Raduskevich				
Temp.	$Q_0$	b	<b>D</b> <sup>2</sup>		$K_{\mathrm{f}}$	<b>D</b> 2	$b_{\mathrm{T}}$	a <sub>T</sub>	<b>D</b> 2	Е	$q_{\rm D}$	<b>D</b> <sup>2</sup>
	(mg/g)	(L/mg)	K-	п	(mg/g)	K-	(J/mol)	(L/g)	K-	(kJ)	(mg/g)	K-
303	34.4	0.17	0.9947	2.49	8.3	0.9992	326.2	1.6170	0.9951	0.5000	24.6	0.9377
313	38.8	0.18	0.9958	2.29	8.8	0.9966	291.4	1.5693	0.9941	0.7071	26.8	0.9431
323	41.3	0.21	0.9855	2.30	10.1	0.9992	286.5	1.9225	0.9947	0.8452	28.1	0.9459
333	41.5	0.27	0.9948	2.38	11.5	0.9972	295.2	2.4795	0.9953	1.000	29.2	0.9350

Table 9: Langmuir, Freundlich, Temkin, Dubinin isotherms for the % removal of Cu(II) ions

Table 10: Thermodynamic Parameters for the % removal of Cu(II) ions

C <sub>i</sub> (mg/L)	Temperature (K)	k <sub>d</sub>	ΔG° (kJ/mol)	ΔH° (kJ/mol)	ΔS° (J/K mol)	
	303	4.68	-3.8895			
20	313	5.67	-4.5147	10.0202	70 /	
20	323	7.51	-5.4156	19.9203	/8.4	
	333	9.42	-6.2096			
	303	3.01	-2.7725			
20	313	3.78	-3.4589	10 2051	72.8	
30	323	4.84	-4.2335	19.3051		
	333	5.96	-4.9432			
	303	2.24	-2.0278			
40	313	2.94	-2.8076	10.0645	(0.0	
40	323	3.48	-3.3527	18.8645	69.0	
	333	4.47	-4.1476			
50	303	1.74	-1.3952			
	313	2.22	-2.0728	10 10 77	$(\Lambda \neg$	
	323	2.90	-2.8599	18.1827	64./	
	333	3.27	-3.2806			



Figure 1: Effect of pH on the % of removal of Cu(II) ions



Figure 2: Effect of temperature on the % of removal of Cu(II) ions



Figure 3: Effect of contact time on the % of removal of Cu(II) ions



Figure 4: Effect of initial concentration on the % of removal of Cu(II) ions



Figure 5: Effect of dose on the % of removal of Cu(II) ions



Figure 6: Langmuir isotherms for Cu(II) ions



Figure 7: Freundlich isotherms for Cu(II) ions



Figure 8: Temkin isotherms for Cu(II) ions



Figure 9: D-R isotherms for Cu(II) ions



Figure 10: Lagergren plots for Cu(II) ions



Figure 11: Ho plots for Cu(II) ions



Figure 12: Intra-particle diffusion plots for Cu(II) ions



Figure 13: Van't Hoff plots for Cu(II) ions

## 4. CONCLUSION

The adsorption of Cu(II) ions from aqueous solution on the adsorbent prepared from the seeds of Sugar Apple was depend on pH and maximum metal ion was removed at pH 5. The best fitting of experimental equilibrium data for Freundlich isotherm revealed the adsorption surface was heterogeneous and multilayer adsorption was possible. The kinetic study of the adsorption process was found to be pseudo-second order.

## **CONFLICT OF INTEREST**

Authors have no conflict of interest.

## REFERENCES

- Fu F, Wang Q, Removal of heavy metal ions from waste waters: a review. J. Environ, Manag. 2011; 92:407 – 408.
- Hua H, Zhang S, Pan B, Zhang W, Zhang Q. Heavy metal removal from water/waste water by nanosized metal oxides: a review. J. Hazard. Mat. 2012; 211: 317 – 331.
- 3. Kurniawan TA, Chan GYS. Lo WH, Babel S. Physico-chemical treatment techniques for waste water laden with heavy metals. Chem. Eng. J. 2006; 118: 83–98.
- 4. Vassilev SV, Baxter D, Anderson LK, Christina G. Vassileva, Trevor J. Morgan. An overview of the organic and inorganic phase composition of biomass. Fuel. 2012; 94: 1 33.
- Suteu D, Bilba D, Gorduza VM. Removal of reactive dye brilliant red HE 3 B from aqueous solutions by hydrolyzed polyacrylonitrile fibers: Equilibrium and Kinetics modelling. Bull. I.P. lassy (Romania). 1997; 43:61-66.

Sivakumar et al RJLBPCS 2019 www.rjlbpcs.com Life Science Informatics Publications

- 6. Suteu D, Bilba D, Nachu Al. Adsorption for Removal of Various Dyes from Aqueous solution using Activated Carbons and Kinetics. Revista de Chime (Bucharest). 1998; 9: 45-248.
- Suteu D, Bilba D, Cristian Gh. Equilibrium and Kinetic study of Reactive Dye Brilliant Red HE – 3 B Adsorption by Activated Cherwell. Cell. Chem. Technol.1999; 33:397-403.
- 8. Suteu D, Bilba D, Zaharia C. Sorption of water soluble dyes using inorganic materials as sorbents. Hung. J. Chem. 2002; 30:7-11.
- 9. Arslan A, Kornmuller MR, Jekel, A review of the effects of dye assisting Chemicals on advanced oxidation of reactive dyes in wastewater. Color Technol. 2002; 118: 185-190.
- Nourbakhsh NM, Kilic S, Arslan S. Ilhan, Ozdag H. Biosorption of Cr<sup>6+</sup>, Pb<sup>2+</sup> and Cu<sup>2+</sup> ions in industrial waste water on *Bacillus sp*. Chemical Engineering J. 2002;85:351-355.
- 11. Chakravarty P, sarma NS, Sarma HP. Biosorption of cadmium (II) from queous solution of heartwood powder of *Areca carechu*. Chem. Eng. J.. 2010; 162: 949-955.
- Montazer-Rahmati NM, Rabbani P, abdolali A, Keshtkar AR. Kinetics and equilibrium studies on biosorption of cadmium, lead and nickel ions from aqeous solutions by intact and chemically modified brown algae. J Hazard Mater. 2011; 185: 401-407.
- 13. Saeed A, Iqbal M. Bioremoval of cadmium from aqeous solution by black gram husk (*Cicer arientinum*). Water Res.2003; 37: 3472-3480.
- 14. Chu HC, Chen KM. Reuse of activated sludge biomass II. The rate processes for the adsorption of basic dyes on biomass. Process Biochem.2002; 37: 1129-1134.
- Weatherley LR, Walker GA, Al-Duri B. Ion Exchange Developments and Applications", J.A. Greig, Ed., The Royal Society of Chemistry, Cambridge, 1996; 120–127.
- 16. Hwang MC, Chen KM, The removal of color from effluents using polyamide epichlorohydrin cellulose polymer ill. Use in anionic dye removal in batch process. J. Appl. Polym. Sci. 1993; 49:975–989.
- Aravindhan R, Roa JR, Nair BU. Preparation and Characterization of activated Carbon from MarineMarco-Algal Biomass. J. Hazard. Mater. 2009; 2-3:688-694.
- Say R, Yilmaz N, Denizli A. Biosorption of cadmium, lead, mercury and arsenic ions by the fungus *Penicillium purpurogenum*. Sep. Sci. Technol. 2003; 38: 2039-2053.
- 19. Nadeem R, Hanif MA, Shaheen F, Perveen S, Zafar MN, Iqbal T. Physical and chemical modification of distillery sludge for Pb (II) biosorption. J Hazard Mater. 2008; 150:335-342.
- 20. Freundlich HM. Over the adsorption in solution. J Phys Chem. 1906; 57: 385-470.
- 21. Langmuir I. The adsorption of gases on plane surfaces of glass, mica and platinum. J Am Chem soc. 1918;40(9):1361-1403.
- 22. Weber WJ, Morris JC. Kinetics of adsorption on carbon from solution. J saint Eng Div Am Soc Chem Eng. 1963; 89:31-59.

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- Annadurai G, Juang RS, Lee JDJ. Use of Cellulose based wastes for adsorption of dyes from aqueous solutions. J. Hazard. Mater. 2002; 92: 263-274.
- 24. Gupta V, Agarwal A, Singh MK, Singh NB, Removal of torque blue dye from aqueous solution by kail sawdust. Asian J. Water Environ. Pollu. 2016; 13: 59-67.
- 25. Danish M, Hashim R, Ibrahim MNM, Sulaiman O. Response surface methodology approach for methyl orange dye removal using optimized Acacia mangium wood activated carbon. Wood Sci. Technol. 2014; 48: 1085-1105.
- 26. Voudrias E, Fytianos K, Bozani E. Sorption Desorption isotherms of Dyes from Aqueous solutions and wastewaters with Different sorbent materials. Global Nest: the Int. J.2002;4:75–83.
- 27. Namasivayam C, Kanchana N. Removal of direct red and acid brilliant blue by adsorption on to banana pith. Chemosphere 1992; 25: 1691–1696.
- McKay G, Blair HS, Findon A. Studies on Electrochemical Behavior of Bromideat Chitosan Modified Glassy Carbon Electrode. Indian J. Chem. 1989; 28A: 356–360.
- 29. Say R, Yilmaz N and Denizli A, Removal of Heavy metal ions using the Fungus *Penicillium canescens* Sep. Sci. Technol (2003)., 38, 2039 2053.
- Nadeem R, Hanif M A, Shaheen F, Perveen S, Zafar M N and Iqbal T, Removal of Lead and Cobalt using lignocellulosic fiber derived from Citrus reticulata waste biomass Hazard J. Mater (2008)., 150, 335 – 342).
- Lagergren S. About the theory of so-called adsorption of soluble substances. K Sven Vetensk Akad Handl.1998; 24:1-39.
- Ho YS. Isotherm for the sorption of lead onto peat: comparison of linear and non-linear methods. Pol J Environ Stud.2006; 15(1):81-86.