



## Removal of Cadmium II, Chromium II and Copper II from Aqueous Solution by Adsorption on Palm Kernel Shell Carbon

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**ABSTRACT**

A novel approach for the removal of heavy metals from aqueous solutions was carried out using agricultural adsorbent (palm kernel shell charcoal) and UV-visible detection. This technique was applied for the recovery of cadmium (Cd), chromium (Cr) and copper (Cu) species. Percentage recoveries for cadmium at buffer 0.1M ranged from 98.01-98.63% while at buffer 0.2 M the percentage recovery of cadmium ranged from 99.15-99.42%. For chromium the percentage recovery at buffer 0.1 M ranged from 98.83-99.48% while at a buffer of 0.2 M the percentage recovery of chromium ranged from 99.01-99.18%. For copper adsorption the percentage recovery at buffer 0.1 M ranged from 99.62-99.91% and at buffer 0.2 M the percentage recovery ranged from 99.32-99.98%. Copper recovery was higher at buffer 0.1 M than at buffer 0.2 M, while chromium and cadmium had higher recovery rates at buffer 0.2 M. This is plausibly due to the higher ionic strength of Cu compared to Cd and Cr. The method can be used to conveniently remove Cd, Cr and Cu in aqueous media.

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### 1. INTRODUCTION

Toxic heavy metal contamination of industrial waste water is an important environmental problem. Many industries such as electroplating, pigments, metallurgical processes, and mining and leather industries release various concentrations of heavy metals. Metal ion, such as cadmium, chromium, copper, lead, zinc, manganese and iron are commonly detected in both natural and industrial effluents [1]. The commonly used procedures for removing metal ions from effluents include

filtration [1], chemical precipitation [2], chemical coagulation [3], flocculation [4], ion exchange [5], and solvent extraction [6].

The processes may be ineffective or expensive, especially when the heavy metal ions are present in high concentrations. The use of adsorbents of biological origin has emerged in the last decade as one of the most promising alternatives to conventional heavy metal management strategies [2]. Biosorption is a fast and reversible reaction of the heavy metals with biomass. The by-products

obtained from biomaterials production are a cheap source of biosorbents. Several agricultural waste materials have been studied and developed for the effective removal of heavy metals like maize brain [7], rice straw [8], cocoa shell [9], oak sawdust [10], peanut hull [11], palm kernel fibre and grape stalks [12]. The problems of the ecosystem are increasing with developing technology with heavy metal pollution being one of the main problems. There is a great concern for the effective treatment of waste water contaminated with heavy metals. Most of the heavy metals are highly toxic even in trace concentration.

Use of agricultural by-products as adsorbents for heavy metal removal from industrial waste water has been increasing nowadays. Most of the studies were focused on plant wastes such as rice husk, and neem bark [13], waste tea, Turkish coffee, walnut shell, teak leaf powder, peanut hull pellets [7]. The benefits of using agricultural waste, for waste water treatment include easy techniques, modest processing, superior adsorption ability, selective adsorption of heavy metal ions, economical, easy availability and easy regeneration. On the other, the use of untreated agricultural wastes can also fetch a number of problems, such as small absorption ability, elevated chemical oxygen demand and biological chemical demand, due to discharge of soluble organic compounds contained in the plant materials [14].

New products such as rice husk, maize cob or husk are also used as adsorbents for heavy metal elimination after chemical modification. Chemically modified agricultural wastes have been found to have enhanced chelating efficiency and to be a good adsorbent for removal of many types of heavy ions which eventually results in better efficiency of adsorption. Factors like pH, temperature, contact period, initial concentration of metal, agitation rate, dosage of adsorbent affects the adsorption capacity of adsorbents [15].

The aim of this work is to remove Cu (II), Cd (II) and Cr (II) from aqueous solutions by adsorption on

activated palm kernel shell carbon.

## 2. MATERIALS AND METHOD

The palm kernel shell was collected from Odolu in Igalamela Local Government of Kogi State, Nigeria. The palm kernel shell was washed with distilled water, air dried and burnt in limited supply of air to obtain the charcoal (carbon) which was washed with distilled water, air dried and finally ground into particles sizes.

The materials used in this study are Memmert 854 Oven Schwabach Germany, Mettler Toledo PR 2002 analytical top balance, Hanna pH211 Microprocessor pH meter, Water bath (B & T Searle company Greenfield Oldham). All reagents and chemicals used are analytical grade. The chemicals used are 0.02 M HNO<sub>3</sub>, distilled water, CuSO<sub>4</sub>, CoCl<sub>2</sub> and CdCl<sub>2</sub>.

The standard solutions were prepared by dissolving appropriate weight of the standard chemicals to achieve a 1000 ppm solution.

### 2.1 Activation of palm kernel shell charcoal

Hundred gram of palm kernel shell was weighed and soaked in 100 ml of concentrated H<sub>2</sub>SO<sub>4</sub> for 24 hours for activation. The activated palm kernel shells was washed with excess distilled water to remove the acid and dried in the laboratory for 72 hours. Afterwards, they were soaked in 100 ml of NaHCO<sub>3</sub> for 24 hours. The NaHCO<sub>3</sub> was washed off the activated palm kernel shell with excess distilled water and oven dried for 40 minutes at a temperature of 110°C.

Batch sorption studies were conducted to investigate the effect of contact time (30minutes, 1hour, 1 $\frac{1}{2}$  hour and 2 hours), initial metal ion concentration buffered at 0.1 M and 0.2 M. Effect of contact time was investigated by adding 25 ml of solution into 100 ml Erlenmeyer flask containing 1000 mg/L of initial metal concentration and 10 mg of the activated palm kernel shell adsorbent and

constantly shaking using mechanical shaker at different time duration, that is 30 minutes, 1 hour, 1  $\frac{1}{2}$  hour and 2 hours respectively. Different particle sizes of activated palm kernel shell (particle size 10, 20 and 40 microns) were mixed with 10 ml of prepared standard solution (1000 ppm) of some heavy metals (Cd, Cr and Cu) to investigate the adsorptive capacities of activated palm kernel shell carbon as the adsorbent. The analysis was carried out using UV – visible spectrometer to detect the quantity of absorbed heavy metals (Cd, Cr and Cu).

## 2.2 Adsorption capacity

The adsorption capacity was calculated using the equation

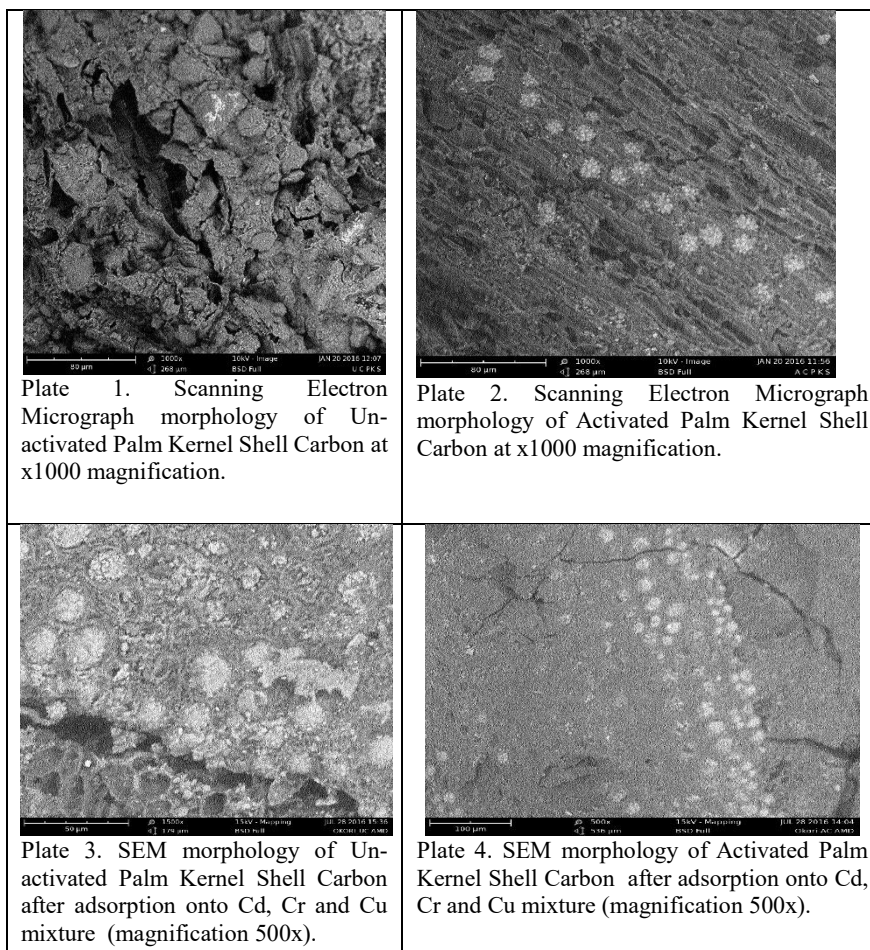
$$q_{eq} = (C_i - C_{eq})V/m \quad (1)$$

Where  $C_i$  and  $C_{eq}$  are the initial and equilibrium concentrations of metal ion (mg/L) respectively.  $V$  is the volume of solution (mL), and  $m$  is the mass of the adsorbent.

## 3. RESULTS AND DISCUSSION

### 3.1 Results

The results of removal of Cd, Cr and Cu from aqueous solution by adsorption on palm kernel shell are presented in Tables 1-6. Tables 1 -3 shows the percentage recovery at different contact times of adsorption using a 0.1 M buffer. While Tables 4-6 are the percentage recovery of the study elements using a 0.2 M buffer. Plates 1-4 show the scanning electron micrograph of the adsorbents before and after adsorption.



**Table 1: Result of the recovery of cadmium metal at buffer 0.1M using activated palm kernel shell carbon**

Particle size (microns)	Contact time	Buffer	Initial Conc. (ppm)	Abs	Amount unadsorbed (ppm)	Amount adsorbed (ppm)	% recovery	Adsorption capacity, mg/g
10	30 mins	0.1	1000	0.155	18.5	981.5	98.15	2453.75
10	1 hr	0.1	1000	0.118	14.8	985.5	98.52	2463.0
10	1½ hr	0.1	1000	0.110	14.0	986.0	98.0	2465.0
10	2 hr	0.1	1000	0.112	14.2	985.8	98.58	2464.4
20	30 mins	0.1	1000	0.105	13.5	986.5	98.65	2466.25
20	1 hr	0.1	1000	0.146	17.6	982.4	98.24	2456.0
20	1½ hr	0.1	1000	0.167	19.7	980.3	98.03	2450.75
20	2 hrs	0.1	1000	0.169	19.9	980.1	98.01	2450.25
40	30 mins	0.1	1000	0.152	18.2	981.8	98.18	2454.50
40	1 hr	0.1	1000	0.152	18.2	981.8	98.18	2454.50
40	1½ hr	0.1	1000	0.156	18.6	981.4	98.14	2453.50
40	2 hrs	0.1	1000	0.107	13.7	986.3	98.63	2465.75

$$Y = -0.03 + 0.01x, \quad (r = 0.9686), \quad Y = \text{absorbance}, \quad X = \text{concentration of unadsorbed metal}$$

**Table 2: Result of the recovery of chromium metals at buffer 0.1M using activated palm kernel shell charcoal.**

Particle size (microns)	Contact time	Buffer	Initial Conc. (ppm)	Abs	Amount unadsorbed (ppm)	Amount adsorbed (ppm)	% recovery	Adsorption capacity, mg/g
10	30 min	0.1	1000	0.166	11.6	988.4	98.84	2471.0
10	1 h	0.1	1000	0.167	11.7	988.3	98.83	2470.75
10	1½ hr	0.1	1000	0.108	5.8	994.2	99.42	2485.50
10	2 hrs	0.1	1000	0.120	7.0	993.0	99.30	2482.50
20	30 min	0.1	1000	0.102	5.2	994.8	99.48	2487.0
20	1 h	0.1	1000	0.138	8.8	991.2	99.12	2478.0
20	1½	0.1	1000	0.124	7.4	992.6	99.20	2481.50
20	2 hrs	0.1	1000	0.138	8.8	991.2	99.12	2478.0
40	30 min	0.1	1000	0.108	5.8	994.2	99.42	2485.50
40	1 hr	0.1	1000	0.104	5.4	994.6	99.46	2486.50
40	1½	0.1	1000	0.102	5.2	994.8	99.48	2487.0
40	2 hrs	0.1	1000	0.108	5.8	994.2	99.42	2485.50

$$Y = 0.05 + 0.01 X, \quad (r = 0.7728), \quad Y = \text{absorbance}, \quad X = \text{concentration of unadsorbed metal}$$

**Table 3: Result of recovery of copper metal at buffer 0.1M using activated palm kernel shell charcoal.**

Particle size (microns)	Contact time	Buffer	Initial Conc. (ppm)	Abs	Amount unadsorbed (ppm)	Amount adsorbed (ppm)	% recovery	Adsorption capacity, mg/g
10	30min	0.1	1000	0.118	1.40	998.6	99.86	2496.50
10	1 hr	0.1	1000	0.118	1.40	998.6	99.86	2496.50
10	1 1/2hr	0.1	1000	0.125	1.75	998.25	99.83	2495.63
10	2 hrs	0.1	1000	0.111	1.05	998.95	99.90	2497.38
20	30min	0.1	1000	0.136	2.30	997.7	99.77	2494.25
20	1hr	0.1	1000	0.165	3.75	996.25	99.63	2490.63
20	1 1/2hrs	0.1	1000	0.166	3.80	996.2	99.62	2490.50
20	2hrs	0.1	1000	0.167	3.85	996.15	99.62	2490.38

40	30min	0.1	1000	0.111	1.05	998.95	99.90	2497.38
40	1hr	0.1	1000	0.108	0.9	999.1	99.91	2497.75
40	1 1/2hr	0.1	1000	0.128	1.9	998.1	99.81	2495.25
40	2hrs	0.1	1000	0.127	1.85	998.15	99.82	2495.38

$Y = 0.09 + 0.02X$ , ( $r = 0.9218$ ),  $Y$  = absorbance,  $X$  = concentration of unadsorbed metal

**Table 4: Result of the recovery of cadmium metals at buffer 0.2M using activated palm kernel shell charcoal.**

Particle size (microns)	Contact time	Buffer	Initial Conc. (ppm)	Abs	Amount unadsorbed (ppm)	Amount adsorbed (ppm)	% recovery	Adsorption capacity, mg/g
10	30 mins	0.2	1000	0.132	7.2	992.8	99.28	2482.0
10	1 hr	0.2	1000	0.139	7.9	992.1	99.21	2480.25
10	1 1/2 hr	0.2	1000	0.133	7.3	992.7	99.27	2481.75
10	2 hrs	0.2	1000	0.136	7.6	992.4	99.24	2481.0
20	30m ins	0.2	1000	0.136	7.6	992.4	99.24	2481.0
20	1 hr	0.2	1000	0.142	8.2	991.8	99.18	2479.50
20	1 1/2	0.2	1000	0.145	8.5	991.5	99.15	2478.75
20	2 hrs	0.2	1000	0.145	8.5	991.5	99.15	2478.75
40	30 mins	0.2	1000	0.121	6.1	993.9	99.39	2484.75
40	1 hr	0.2	1000	0.141	8.1	991.9	99.19	2479.75
40	1 1/2	0.2	1000	0.118	5.8	994.2	99.42	2485.50
40	2 hrs	0.2	1000	0.125	6.5	993.5	99.35	2483.75

$Y = 0.06 + 0.01X$ , ( $r = 0.6698$ ),  $Y$  = absorbance,  $X$  = concentration of unadsorbed metal

**Table 5: Result of the recovery of chromium metals at buffer 0.2M using activated palm kernel shell charcoal.**

Particle size (microns)	Contact time	Buffer	Initial Conc. (ppm)	Abs	Amount unadsorbed (ppm)	Amount adsorbed (ppm)	% recovery	Adsorption capacity, mg/g	Y
10	30 min	0.2	1000	0.122	8.2	991.8	99.18	2479.50	
10	1 hr	0.2	1000	0.138	9.8	990.2	99.02	2475.50	
10	1 1/2 hr	0.2	1000	0.126	8.6	991.4	99.14	2478.50	
10	2 hrs	0.2	1000	0.133	9.3	990.7	99.07	2476.75	
20	30 min	0.2	1000	0.139	9.9	990.1	99.01	2475.25	
20	1 hr	0.2	1000	0.131	9.1	990.9	99.09	2477.25	
20	1 1/2 hr	0.2	1000	0.128	8.8	991.2	99.12	2478.0	
20	2 hrs	0.2	1000	0.132	9.2	990.8	99.08	2477.0	
40	30 min	0.2	1000	0.132	9.2	990.8	99.08	2477.0	
40	1 hr	0.2	1000	0.134	9.4	990.6	99.06	2476.50	
40	1 1/2 hr	0.2	1000	0.136	9.6	990.4	99.04	2476.0	
40	2 hrs	0.2	1000	0.137	9.7	990.3	99.03	2475.75	

$Y = 0.04 + 0.01X$ , ( $r = 0.8114$ ),  $Y$  = absorbance,  $X$  = concentration of unadsorbed metal

**Table 6: Result of the recovery of copper metals at buffer 0.2M using activated palm kernel shell.**

Particle size (microns)	Contact time	Buffer	Initial Conc. (ppm)	Abs	Amount unadsorbed (ppm)	Amount adsorbed (ppm)	% recovery	Adsorption capacity, mg/g
10	30 mins	0.2	1000	0.103	5.3	994.7	99.47	2486.75
10	1 hr	0.2	1000	0.118	6.8	993.2	99.32	2483.0
10	1½hr	0.2	1000	0.109	5.9	994.1	99.41	2485.25
10	2 hrs	0.2	1000	0.111	6.1	993.9	99.39	2484.75
20	30 mins	0.2	1000	0.112	6.2	993.8	99.38	2484.50
20	1 hr	0.2	1000	0.106	5.6	994.4	99.44	2486.0
20	1½	0.2	1000	0.106	5.6	994.4	99.44	2486.0
20	2 hrs	0.2	1000	0.111	6.1	993.9	99.39	2484.75
40	30 mins	0.2	1000	0.108	5.6	994.4	99.44	2486.0
40	1 hr	0.2	1000	0.107	5.7	994.3	99.43	2485.75
40	1½ hr	0.2	1000	0.101	5.1	994.9	99.49	2487.25
40	2 hrs	0.2	1000	0.113	6.3	993.7	99.37	2484.25

$Y=0.05 + 0.01 X$  ( $r=0.7451$ ),  $Y$  = absorbance,  $X$  = concentration of unadsorbed metal

### 3.2 Discussion

The results of the adsorptions of Cd, Cr and Cu using activated palm kernel shell charcoal as adsorbents and at different particle size and contact time indicates a percentage recovery in the range of 98.01-98.65%. The highest percentage recovery was observed at 98.5% for Cd and at a particles size of 20 microns and contact time of 30 minutes. From the result presented in Cd at 0.1 M buffer and 10 microns particle size, the percentage recovery increased with increase in contact time. Similarly at 40 microns the percentage recovery increased progressively with increase in contact time. The higher percentage recovery observed with 10 microns particles size was ascribed to increase in the surface area thereby exposing the metallic ions to more adsorption sites.

For Cr adsorption, the percentage recovery was higher than that observed for Cd with a percentage of recovery range of 98.83-99.48%. Similarly the percentage of Cr recovered increased with contact time. Copper adsorption had a much higher percentage recovery than Cd and Cr at buffers 0.1 M. The percentage recovery ranged from

99.62-99.91%. However, the percentage recovery increased with increase in the contact time. At buffer 0.2 M, Cd had a percentage recovery in the range of 99.15-99.42%, while at 0.2 M buffer, Cr had a percentage recovery range of 99.01-99.18%. For copper adsorption at buffer 0.2 M, the percentage recovery ranged from 99.32-99.43%.

From the above results, it was observed that at buffer 0.2 M more of the metallic ions were adsorbed on the activated palm kernel shell charcoal than at buffer 0.1 M. This is evident by the higher percentage recovery observed for buffer 0.2 M than buffer 0.1 M. Works from previous author agreed with this discovery [13]. The high percentage recoveries for all the metallic species has significantly led to a high adsorption capacity for each of the particle sizes used. The adsorption capacity ranged from 2465-2497.75 mg/g.

### 4 CONCLUSION

From the work carried out it can be deduced that activated palm kernel shell charcoal can serve as alternatives to activated carbon for the recovery of heavy metal from industrial effluent. Recoveries

were in the range of >98%. This method can conveniently be applied for the recovery of heavy metals and other ionic and non-ionic species from industrial effluents.

### COMPETING INTERESTS

There are no competing interests in this work.

### AUTHORS CONTRIBUTIONS

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### REFERENCES

- [1] Bessbousse, H., Rhalou, T., Verchere, J.F. and Lebrun, L. (2008). Removal of heavy metal ions from aqueous solution by filtration with the novel complexing membrane containing poly (ethylenimine) in a poly (vinylalcohol) matrix. *J. Membrane Sci.*, **307**: 249-259. DOI: 10.1016/j.memsci.2007.09.027.
- [2] Esaiah, J.O., Weber, M.E. and Vera, J.H. (2000). Removal of lead from aqueous solutions by precipitation with sodium di-(n-octyl) phosphinate. *Separation and Purification Technology*. **18**: 25-36. DOI: 10.1016/S1383-5866(99)00046-5.
- [3] El-Samram, N.G., Lartige, B.S. and Villieras, F. (2008). Chemical coagulation of combined sewer overflow heavy metal removal and treatment optimization. *Water Research*, **42**: 951-960. DOI: 10.1016/j.watres.2007.09.009.
- [4] Ofir, E., Oren, Y. and Adin, A. (2007). Comparing pretreatment by iron of electro-flocculation and chemical flocculation. *Desalination*, **204**: 87-93. DOI: 10.1016/j.desal.2006.01.037.
- [5] Lin, L.C., Lj, J.K. and Juang, R.S. (2008). Removal of Cu (II) and Ni(II) from aqueous solutions using batch and fixed-bed ion exchange processes. *Desalination*, **225**: 249-259. DOI: 10.1016/j.desal.2007.03.017.
- [6] Gupta, S.K., Rathore, N.S., Sonawane, J.Y., Pabby, A.K., Janardan, P., Changrani, R.D. and Dey, P.K. (2007). Dispersion free solvent extraction of u (VI) in macro amount from nitric acid solutions using hollow fibre contactor. *J. Membrane Science*, **300**: 131-136. DOI: 10.1016/j.memsci.2007.05.018
- [7] Hasan, S.H., Singh, K.K., Prakash, O., Talat, M. and Ho, Y.S. (2008). Removal of cr (vi) from aqueous solution using agricultural waste maize bran. *J. Hazard. Mater.*, **152**: 356-365. DOI: 10.1016/j.jhazmat.2007.07.006.
- [8] Gao, H., Liu, Y., Zeng, G., Xu, W., Li, T. and Xia, W. (2008). Characterization of Cr (vi) removal from aqueous solution by a surplus agricultural waste. Rice straw. *J. Hazardous Materials*, **150**: 446-452. DOI: 10.1016/j.jhazmat.2007.04.126
- [9] Zhu, C.S., Wang, L.P. and Chen, W.B. (2009). Removal of Cu (II) from aqueous solution by agricultural by-product: peanut hull. *J. Hazard. Mater.*, **168**: 739-746. DOI: 10.1016/j.jhazmat.2009.02.085.
- [10] Demirbas, O., Karadag, A., Alkan, M. and Dogan, M. (2008). Removal of Copper Ions from Aqueous Solutions by Hazelnut shell. *J. Hazard. Mater.*, **153**: 677-684. DOI: 10.1016/j.jhazmat.2007.09.012
- [11] Ho, Y.S. and Wang, C.C. (2007). Pseudo-isotherms for the sorption of cadmium ion onto tree fern. *Process Biochemistry*, **39**: 761-765.

DOI: 10.1016/S0032-9592(03)00184-5.

- [12] Fiol, N., Escidero, C. and Villaecusa, I. (2008). Chromium sorption and Cr (VI) reduction to Cr (III) by grape stalks and yohimbe bark. *Bioresources Technology*, **99**: 5030-5036. DOI: 10.1016/j.biortech.2007.09.007
- [13] El-sayed, H.A., Dessouki, A. and Ibrahim, S.S. (2011). Removal of Zn II, Cd II and Mn II from Aqueous solution by adsorption on maize stalks. *The Malaysian J. Anal. Sci.*, **15** (1):8.21. <http://pkukmweb.ukm.my/mjas>
- [14] Gaballah, I., Goy, D., Allain, E., Kibertus, G. and Thauront, J. (2006). Recovery of copper through decontamination of synthetic solutions using modified barks. *Met. Metal Trans, B*, **28**: 13-23. DOI: 10.1007/s11663-997-0122-3.
- [15] Parmar, M. and Thakur, S.L. (2013). Heavy metal Cu, Ni, and Zn: toxicity health hazards and their removal techniques by low cost adsorbent: a short overview. *Inter. J. Plant, Animal and Environ. Science*, **3**: 143-147.