Macrothink Institute™

Aquatic Science and Technology
ISSN 2168-9148
2013, Vol. 1, No. 2

Removal of Cu^{2+} & Fe^{3+} Ions from Oil Wells by Local Activated Carbon in Batch Adsorption Process

Abbas Sabah Thajeel (Corresponding author)
Chemical Engineering Department, College of Engineering, University of Basrah
Basrah, Iraq
E-mail: abbas_amery2002@yahoo.com

Mustafa M. Al-Faize
Chemical Engineering Department, College of Engineering, University of Basrah
Basrah, Iraq

A. Z. Raheem
Petroleum Engineering Department, College of Engineering, University of Basrah
Basrah, Iraq

Received: April 19, 2013 Accepted: June 1, 2013 Published: July 1, 2013
doi:10.5296/ast.v1i2.3815 URL: http://dx.doi.org/10.5296/ast.v1i2.3815

Abstract

In this study the efficiency of activated carbon produced from rice husk (RHAC) was studied to remove of Cu^{2+} & Fe^{3+}ions from waste oil water which comes out from the oil industry in Basrah city, and the efficiency of RHAC has been compared with efficiency of raw rice husk(RH) and commercial activated carbon(CAC). The effects of operating parameters were studied such as (contact time, adsorbent size, adsorbent dose, initial concentration of adsorbate, temperature, pH and rotation speed). The adsorption efficiency is arranged by (RHAC > CAC >RH) which removed 96.588, 92.9, 69.3% of Cu^{2+} ions, and 94.54, 92.23, 72.66% of Fe^{3+} ions onto RHAC, CAC & RH, respectively. The FTIR results showed that a different in functional groups was scattered in surface of adsorbent material, that causing the different in adsorption efficiencies of heavy metal ions.

Keywords: Adsorption, Activated carbon, Rice husk, Commercial activated carbon, Heavy metals, Waste oil water, FTIR

1. Introduction

The heavy metals are of special concern because they are non-degradable and therefore persistent. Commonly encountered metals of concern include Pb^{2+}, Cu^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+} *etc*. These metals are toxic both in their chemically combined forms and in the elemental form (Al-tameemi et al., 2011). Conventional methods of removing toxic heavy metal ions include chemical precipitation, chemical oxidation or reduction, filtration, ion exchange, electrochemical treatment, application of membrane technology and evaporation recovery. However, these processes have considerable disadvantages such as incomplete metal removal, expensive equipment and monitoring system, high reagent or energy requirements, generation of toxic sludge and other waste products that require disposal (Rao & Prabhakar, 2011). Among all the methods adsorption is highly effective, economical, technological, environmental and biological importance. Furthermore the practical applications of adsorption process in industry and environmental protection are important. Adsorption is a method for separation of mixtures that based on the change in concentration of components at the interface (Prabakaran & Arivoli, 2012; Shanthi & Selvarajan, 2012). Though the use of commercial activated carbon is a well-known adsorbent for the removal of heavy metals from water and wastewater, the high cost of activated carbon limits its use as an adsorbent in developing countries. Hence, it is a growing need to derive the activated carbon from cheaper and locally available waste materials. Several workers used different low-cost adsorbents from agriculture (Shanthi & Selvarajan, 2012) such as seed shell of palm tree (Gueu et al., 2006) dates stones (Alhamed & Bamufleh, 2008) apricot stones (Philip & Girgis,1996) oil palm fibre (Nwabanne & Igbokwe, 2012) pine, oak woods, olive seeds (Skodras, 2007) apricot stones (Philip & Girgis, 1996) waste seeds husks of Moringaoleifera (Warhurst, 1996) coconut shell (Satya, 1997) ArundoDonax canes (Basso, 2002) pistachio-nut shells (Yang, 2003) and coir pith (Adekola & Adegoke, 2005) sun flower (Surchi, 2011).

In this study, the efficiency of AC produced previously from rice husk (RHAC) to removal of Cu^{2+} & Fe^{3+} was investigated, and compared with raw rice husk (RH) and commercial activated carbon (CAC). The effect of operating parameters was studied such as (contact time, initial concentration of adsorbate, adsorbent size, temperature, adsorbent dose, pH and rotation speed).

2. Experimental Section

2.1 Materials

Copper chloride anhydrous with purity (99%) was supplied from BDH (Chemicals) Company. Iron nitrate (ferric nitrate) with purity (99%) was supplied from MERCK Company. Hydrogen chloride with purity (37 %) was supplied from Scharlab. S. L Company. Sodium Hydroxide with purity (97.5%) was supplied from THOMAS BAKER (Chemicals) Company.

2.2 Adsorbent

Activated carbon produced from rice husk by physical method (RHAC) was used as an adsorbent material in this study, the efficiency of RHAC was compared with raw rice husk

(RH) and commercial activated carbon (CAC). The preparation method was described following:

After well washing the RH with distilled water and dried in electrical oven for 24 hr at 120Ċ, the carbonization step was carried out in electrical furnace for 2hr at 500Ċ and heating rate of 30 ºC/min in absence air using nitrogen at flow rate is 200 L/min. The product from carbonization step was activated by passing carbon dioxide (CO_2) instead of nitrogen for 2hr at 700Ċ.

Table 1. Characteristics of the adsorbent

Adsorbent	BET surface area m^2/g	Bulk density g/ cm^3	Particle density g/ cm^3	Porosity	Pore Volume cm^3/g	pH
CAC	-	0.5103	1.2203	0.5819	1.2367	9.4
RH	0.9672	0.3533	1.1048	0.6802	2.2341	7.1
RHAC	201.1518	0.2553	1.4369	0.8223	3.6876	9.3

2.3 Source of Waste Oil Water

After measuring the concentrations of heavy metals ions in waste oil water from different locations (West Qurna, NahranBinUmer, Barjessia) by using atomic absorption were found that different concentrations as shown in Table 2.

Table 2. Heavy metal ions concentration (ppm) in different oil location in basrah city.

Location	Cu^{2+}	Fe^{3+}
Nahran Bin Umer	2.3	7.2
West Qurna	0.5	2.4
Barjessia	4	3.6

For simulated waste oil water, solutions were prepared with lower and higher concentrations of these two heavy metal ions in the locations mentioned above.

2.4 Preparation of Standard Solutions

The stock solutions of 1000 mg/L (ppm) of Cu^{2+} and Fe^{3+} were prepared by dissolving 2.1368 g of $CuCl_2$ and 7.3073 g of $Fe(NO_3)_3$ in 1000 ml volumetric flasks and fill up to the mark with distilled water.

The diluted concentrations were prepared from stock solutions for carrying out experiments.

Following the equation below:

$$N_1 * V_1 = N_2 * V_2 \tag{1}$$

And then a certain volume (10 ml) of oil has been added to all above solution with efficient agitation for simulated waste oil water (1% oil in waste water), because the highest value of oil contains in waste oil water of the locations mentioned above doesn't exceed 1 %.

2.5 The Calibration Curve Method of Analysis.

In 25 ml volumetric flasks were prepared a series of standard solutions containing 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 ppm of heavy metals ions. After determining the absorbance by AAS, making a plot of absorbance vs. concentration using EXCEL software. The results and the equations which were described calibration curve are shown in Figure 1.

2.6 Analyze a Sample of Heavy Metal Ions by Using Atomic Absorption Spectrophotometer (AAS)

The concentration of metal ions was measured by using atomic absorption spectrophotometer (BUCK Scientific, Model 210 VGP). In atomic absorption spectroscopy, metal atoms were vaporized into a flame, and the metal vapor absorbed radiation from the specific hollow cathode lamp in proportion to the number of atoms present. Beer's Law was followed in the part-per-million range (remember that ppm means mg of metal/liter of solution).

2.7 Fourier Transform Infrared Spectroscopy (FTIR)

The surface functional groups of the prepared activated carbon were detected by Fourier Transform Infrared spectroscope in State Company For Petrochemical Industries Basrah using Shimadzu FTIR 8400S, A spectrum was recorded in the mid-IR range from 4000 to 400 cm^{-1} with a resolution of 1 cm^{-1}.

2.8 Batch Adsorption Processes

Adsorption experiments were carried out in double neck(125 ml) flask using 100 mL metal bearing solution with a certain dosage of the AC and installed in the water bath (MemmertGmbh Type WMB 22). The pH values were controlling by adding 0.1N NaOH or 0.1N HCl, and stirred for different rotation speed using Variable-Speed Benchtop, model 5850, Eberbach. Before the metal solution analyzed using AAS was filtered through Whatman*n*4 filter papers.

The efficiency of each bed was measured in the case of batch adsorption with different parameters such as the effect of temperature (8-55Ċ), Contact time (2-30 minutes), pH (3-11), adsorbent Dose (1-5 g), adsorbent Diameter (0.075-1.14 mm), Rotation speed (0-1500 rpm) and initial Concentration of heavy metal ions (10-60 ppm), and comparison between the effect of operating conditions on adsorption of heavy metals ion by CAC, RHAC and RH.

3. Results and Discussion

3.1 Efficiency of Adsorption

The Removal Percentage (R.P.%) which described the efficiency of adsorbent to adsorbed a heavy metals ions is calculated by following equation (Kumar & Gayathri R, 2009):

$$R.P.\% = \frac{C_i - C_f}{C_i} * 100 \tag{2}$$

Where: C_i and C_f are the initial and final concentration in (ppm), respectively.

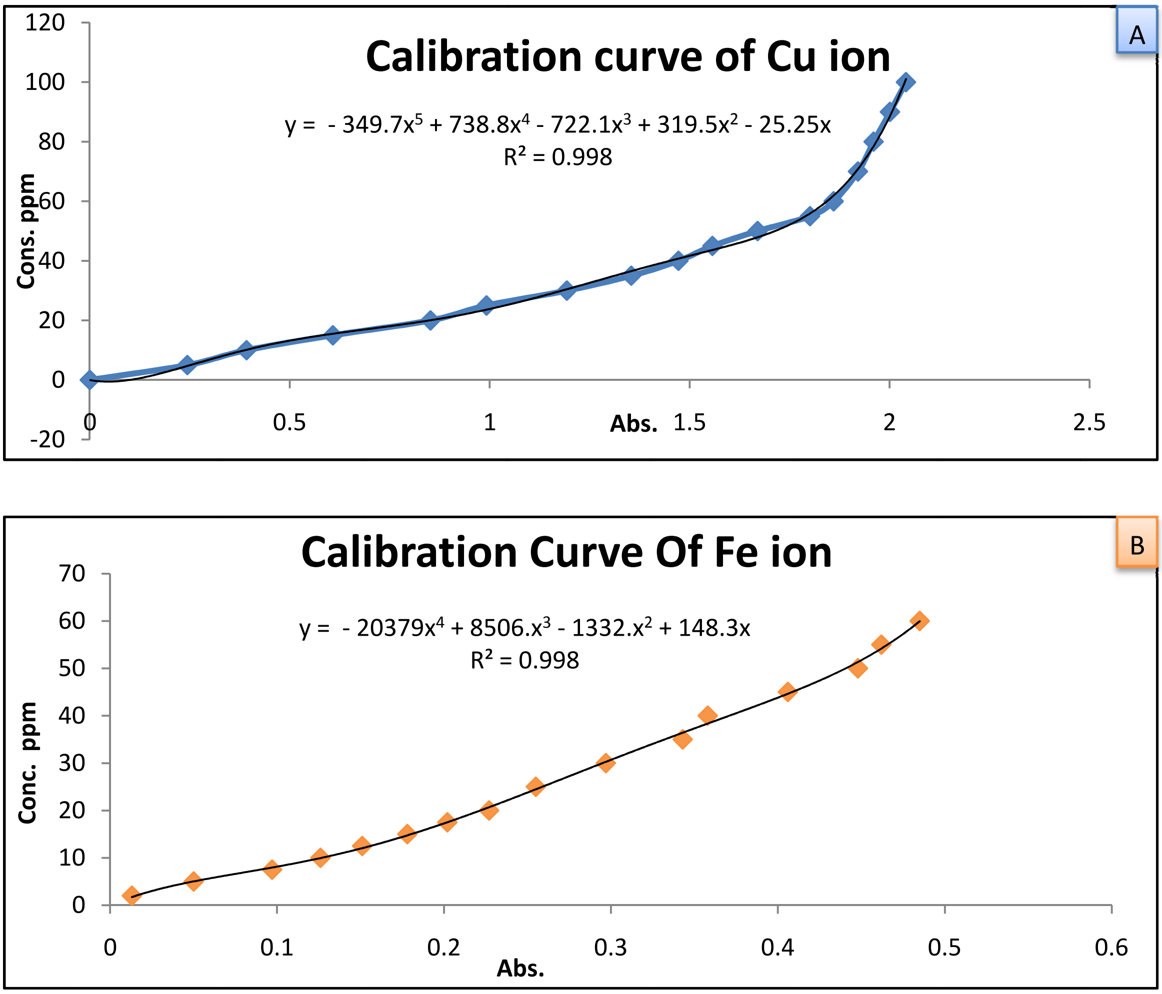

Figure 1. Calibration curves of heavy metal ions

3.2 Effect of Contact Time

The effect of contact time on the adsorption of heavy metal ions (H.M.I.) was investigated. The experimental work was done under the conditions of constant temperature (25Ċ), adsorbent dose (1g), particle size (0.3), rotation speed (600 rpm), PH (2.9), initial concentrations (50ppm) and contact time(0-30 min), the experimental data are presented in Figure 2.

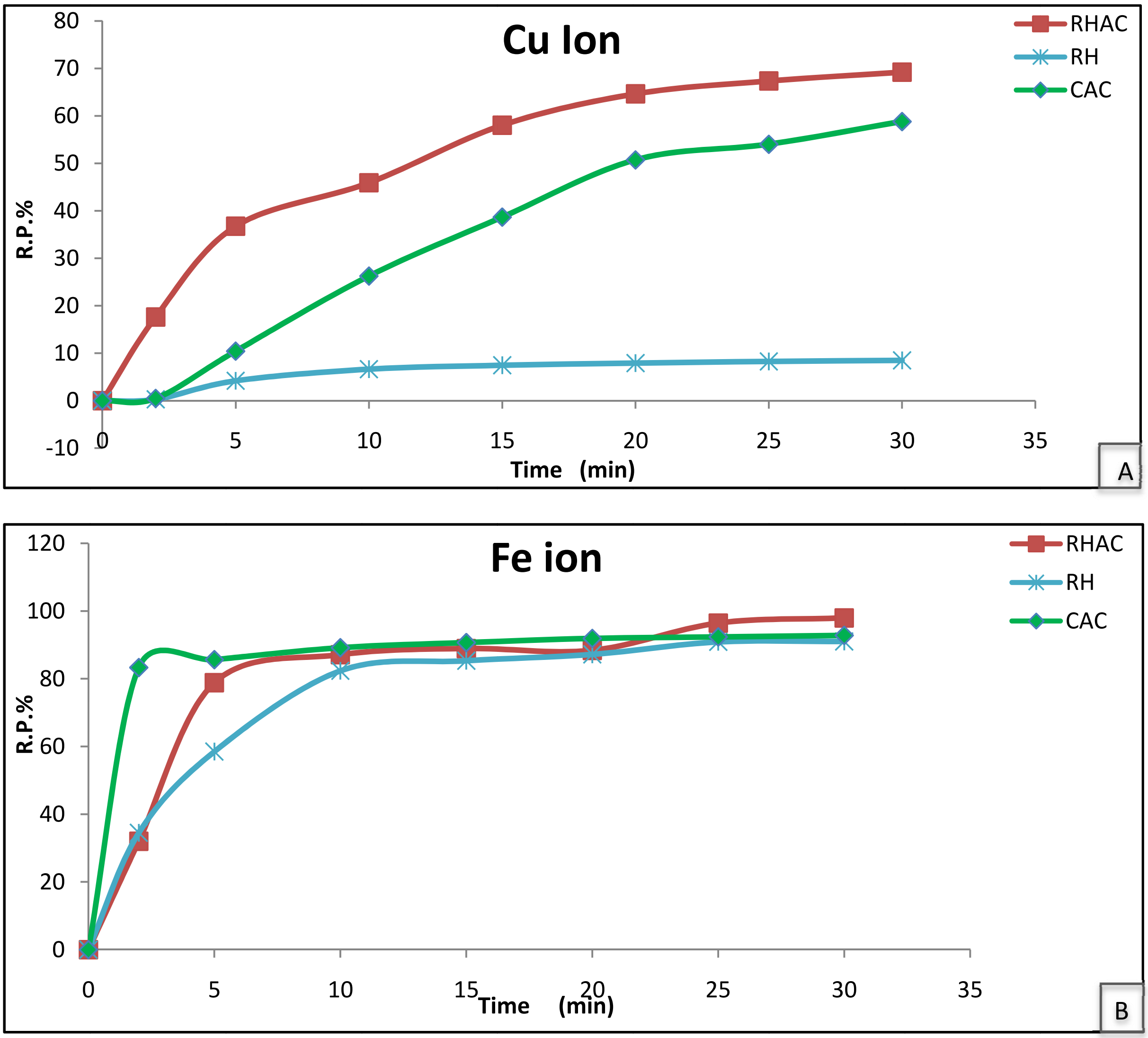

Figure 2. Effect of time contact on the adsorption of heavy metal ions

The results shown that the R.P. of adsorption first increases with increasing in contact time, then remains almost constant. This may be due to the availability of the uncovered surface area of the adsorbents, since the adsorption kinetics depend on the surface area of the adsorbents. The adsorption of heavy metal ions takes place at the more reactive sites. As these sites are progressively filled the more difficult the sorption becomes (BADMUS et al., 2007).

3.3 Effect of Temperature

The efficiency of adsorption of heavy metal ions was studied with different temperature range (8-55ºC), while the other operating parameters were kept constant at initial concentration (50 ppm), rotation speed (600 rpm), pH (3), adsorbent dose (1g), contact time (15min) and adsorbent size (0.3 mm). The experimental data are shown in Figure 3.

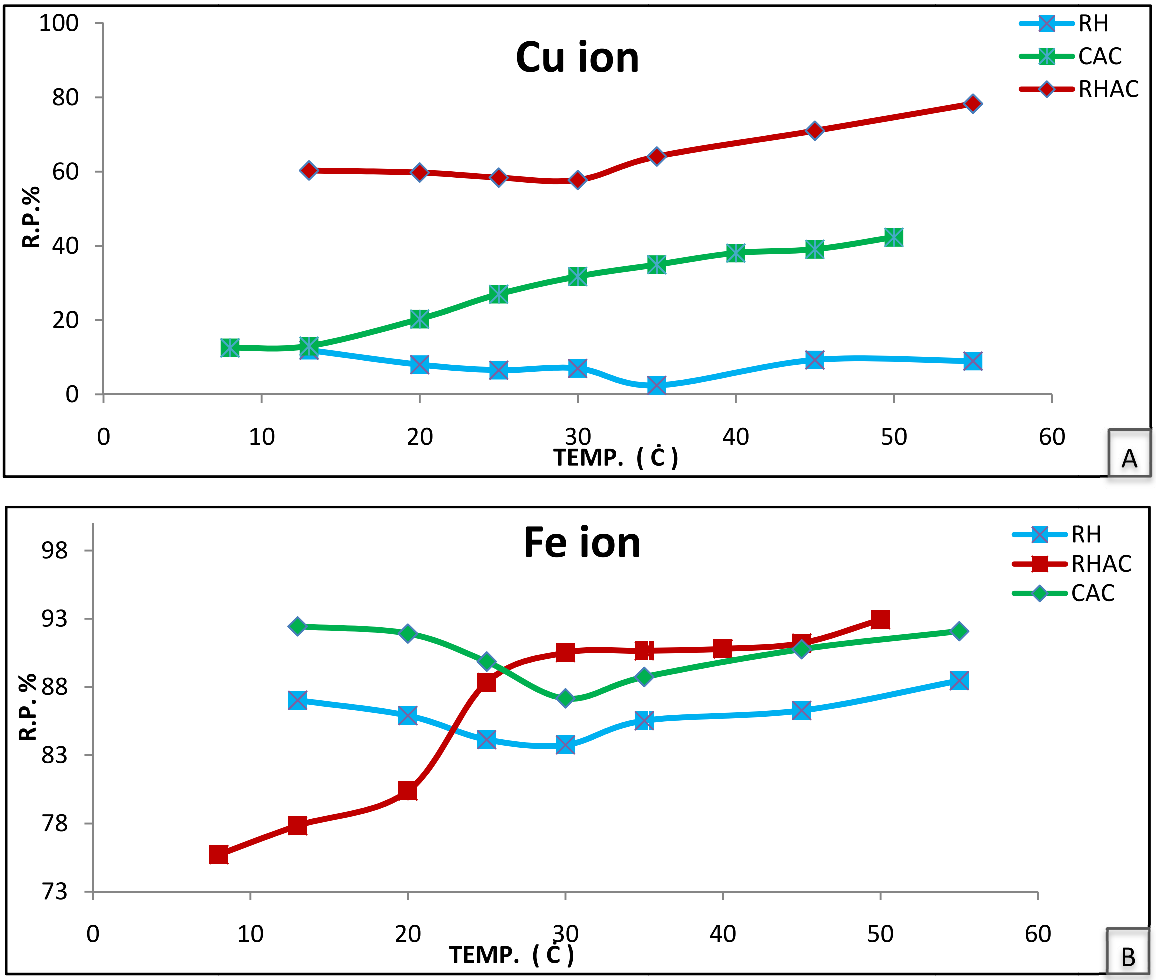

Figure 3. Effect of temperature on the adsorption of heavy metals ions

The plots of R.P. as a function of temperature shows an increasing amount of adsorbed H.M.I with increasing temperature. But the adsorption capacity does not largely depend on temperature. The enhancement in adsorption with rise in temperature may be attributed to increase in the number of active surface sites available for adsorption, increase in the porosity and in the pore volume of the adsorbent (Chowdhury et al., 2010). An increase of temperature increases the rate of diffusion of the adsorbate molecules across the external boundary layer and within the internal pores of the adsorbent particle, due to decrease in the viscosity of the solution (Chowdhury & Saha, 2010; Hameed et al., 2008). This phenomenon is characteristic of a chemical reaction or bonding being involved in the adsorption process (Guo et al., 2002).

3.4 Effect of pH

The pH of the aqueous solution was an important variable. Adsorption experiments were carried out at pH (3-10). The acidic or alkaline of the solutions was maintained by adding the required amounts of dilute HCL or NaOH solutions. The experimental work was done under the conditions of constant temperature (28^{0}C), adsorbent dose(1g), particle size (0.3), rotation speed (600 rpm), initial concentrations (50ppm) and contact time(15 min), the experimental data are presented in Figure 4.

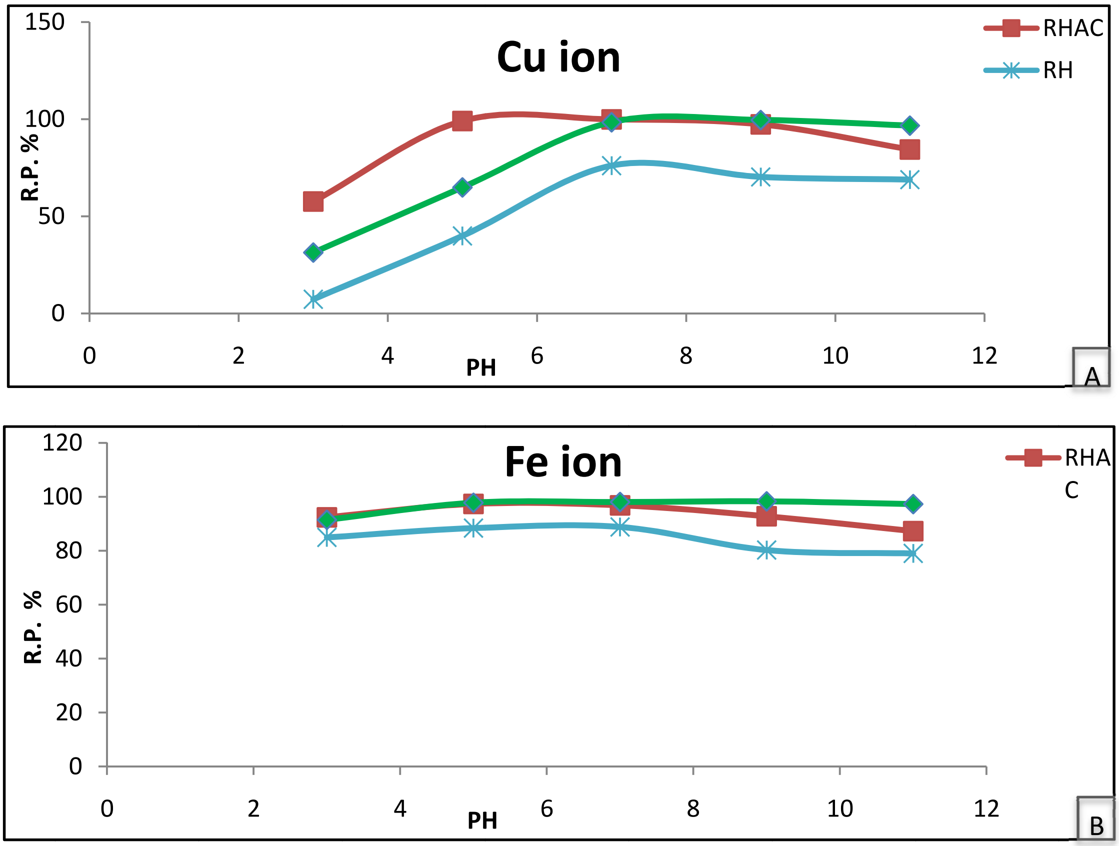

Figure 4. Effect of pH on the adsorption of heavy metals ions

It has been found that the adsorption increases with increase in pH until the optimum pH is reached, the optimum pH of maximum adsorption for H.M.I. on different adsorbent was determined from Figure 4 and the results were listed in Table 3. Increases in R.P. with increased pH can be explained on the basis of decrease in competition between proton and metal cations for same functional groups and by decrease in positive surface charge, which results in a lower electrostatic repulsion between surface and metal ions. Decrease in adsorption at higher pH is due to formation of soluble hydroxyl complexes (Meena et al., 2010).

Table 3. The optimum value of pH of H.M.I. adsorption

H.M.I.	CAC	RHAC	RH
Cu^{2+}	9	7	7
Fe^{3+}	7-9	7	7

3.5 Effect of Initial Concentration

Adsorption experiments were carried out at different initial H.M.I. concentrations ranging from 10 to 60 ppm to study the effect of initial concentration, other conditions of experimental work were kept constant at rotation speed (600 rpm), pH (3.5), adsorbent dose (1g), contact time (15min), temperature (25^0C), and adsorbent size (0.3 mm). All the adsorption efficiencies obtained are shown in Figure 5.

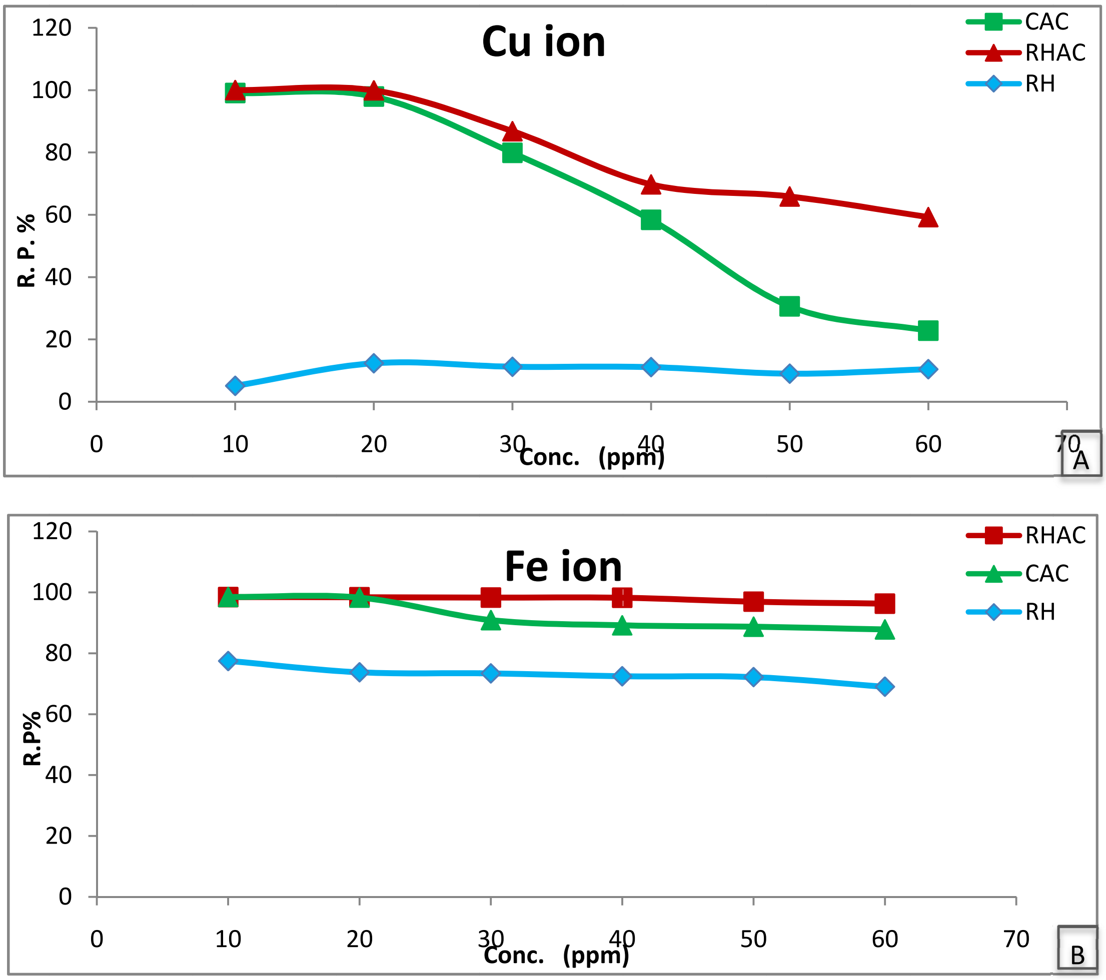

Figure 5. Effect of initial concentration on the adsorption of heavy metals ions

The results are shown that the removal percentage of H.M.I. (efficiency) decreases, with the increase in H.M.I. concentration while the amount of H.M.I. removed will be increased. These data suggests that the removal of metal ions is highly dependent on the concentration. At lower concentrations of metal ions, the number of H.M.I. which is available in the solution is less as compared to the available sites on the adsorbent. However, at higher concentrations the available sites for adsorption become fewer (Mohammadi et al., 2010). In other words at low concentration, most of H.M.I. in the solution might contact with active sites of adsorbent and when the concentration is increased all H.M.I. will not be available to contact with the active surface due to active sites are already filled up (Rahman et al., 2012). And this was due to the fact that a lower concentration gradient caused a slower transport due to a decrease in the diffusion (Tan et al., 2008).

3.6 Effect of Adsorbent Dose

The effect of adsorbent dose on H.M.I. adsorption was investigated with different adsorbent dosage ranging (1-5 g), the other conditions of experimental work were kept constant at contact time (15min), rotation speed (600 rpm), pH (3), temperature (25^0C), initial concentration (50ppm) and adsorbent size (0.3 mm). All the adsorption efficiencies obtained are shown in Figure 6.

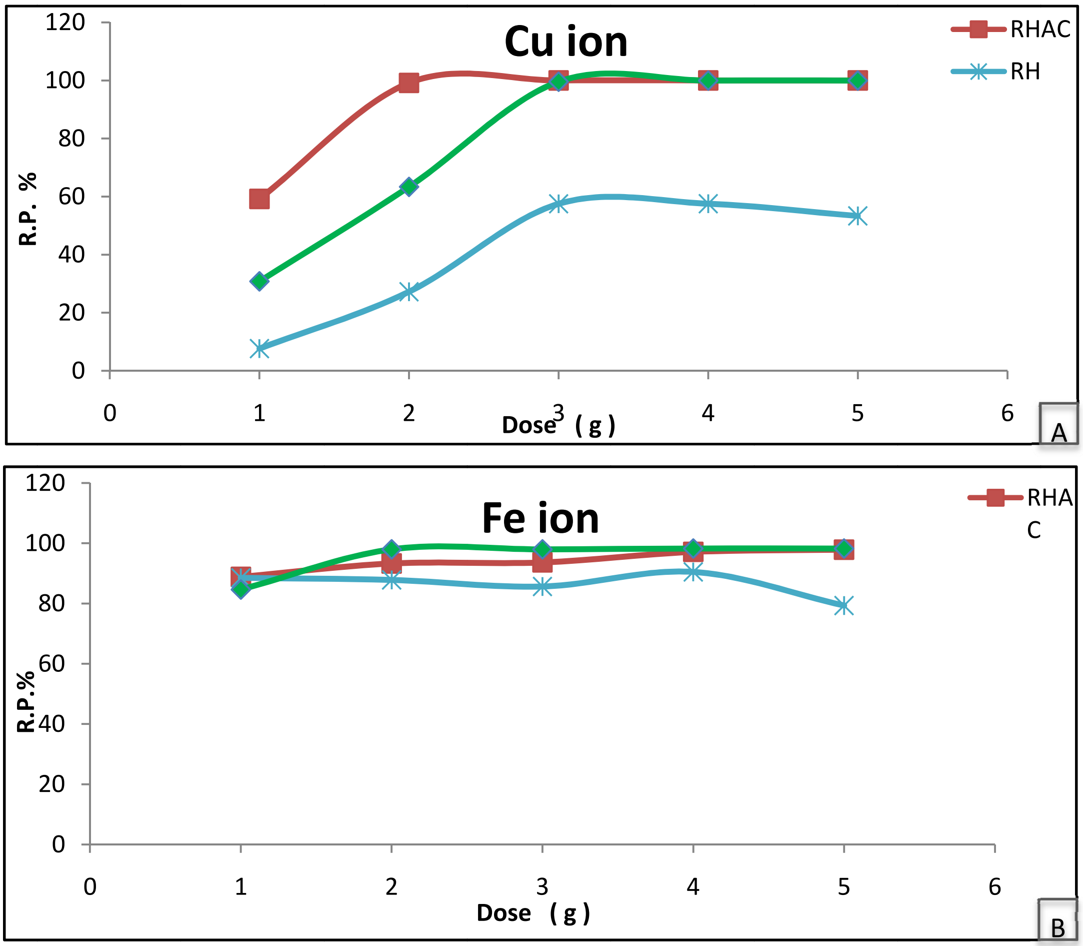

Figure 6. Effect of adsorbent dose on the adsorption of heavy metals ions

The adsorption capacity increased with increasing adsorbent dosage until a certain value , any further addition of the adsorbent beyond this value did not cause any significant change in the adsorption.

The increase in the adsorption percentage with rise in adsorbent dosage is due to increase in active sites on the adsorbent and thus making easier penetration of the metal ions to the sorption sites (Subbaiah et al., 2011), then there was no further increase in adsorption for either metal ions. This may be due to overlapping of adsorption sites as a result of overcrowding of adsorbent particles (Kumar & Gayathri R, 2009).

3.7 Effect of Adsorbent Size

Effect of adsorbent size on adsorption of H.M.I. was investigated by conducting different experiments at different adsorbent diameter (0.075-1.2mm), while the other conditions of experimental work were kept constant at pH (2.97), rotation speed (600 rpm), adsorbent dose (1g), contact time (15min), temperature (25^0C), and initial concentration (50 ppm). The experimental data are presented in Figure (7).

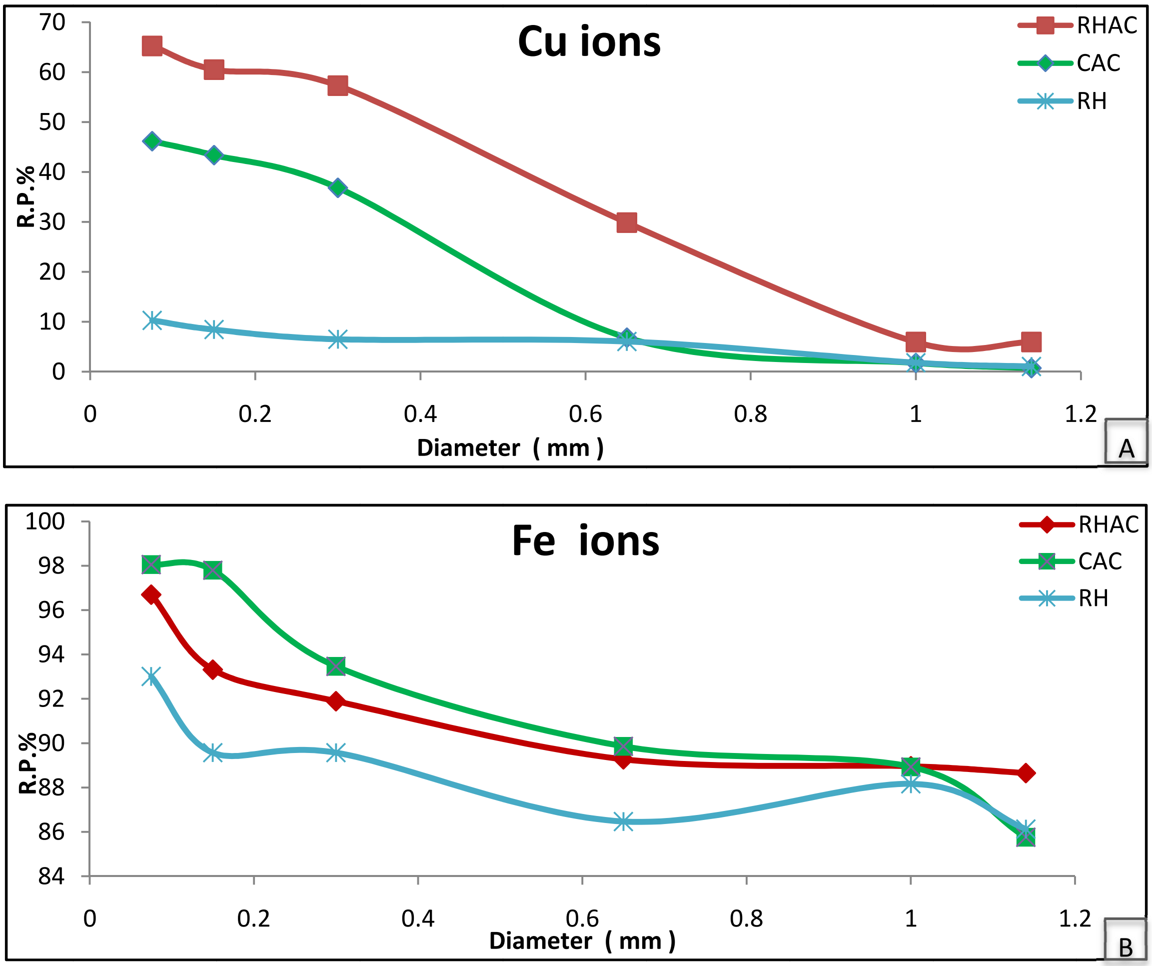

Figure 7. Effect of adsorbate diameter on the adsorption of heavy metals ions

The results shown that the R.P. of H.M.I. increased with decreasing particle size. The particle size of the adsorbent is very important factor. The increase in adsorption capacity may be attributed to large surface area of the smallest particle size of adsorbent and large number of active sites (Safa & Bhatti, 2011).

3.8 Effect of Rotation Speed

The effect of rotation speed on H.M.I. adsorption was investigated. The experimental work was done under the conditions of constant temperature (25^{0}C), adsorbent dose (1g), particle size (0.3), PH(2.95), initial concentrations (50 ppm), contact time(15min) and rotation speed (0-1500 rpm), the experimental data are presented in Figure 8.

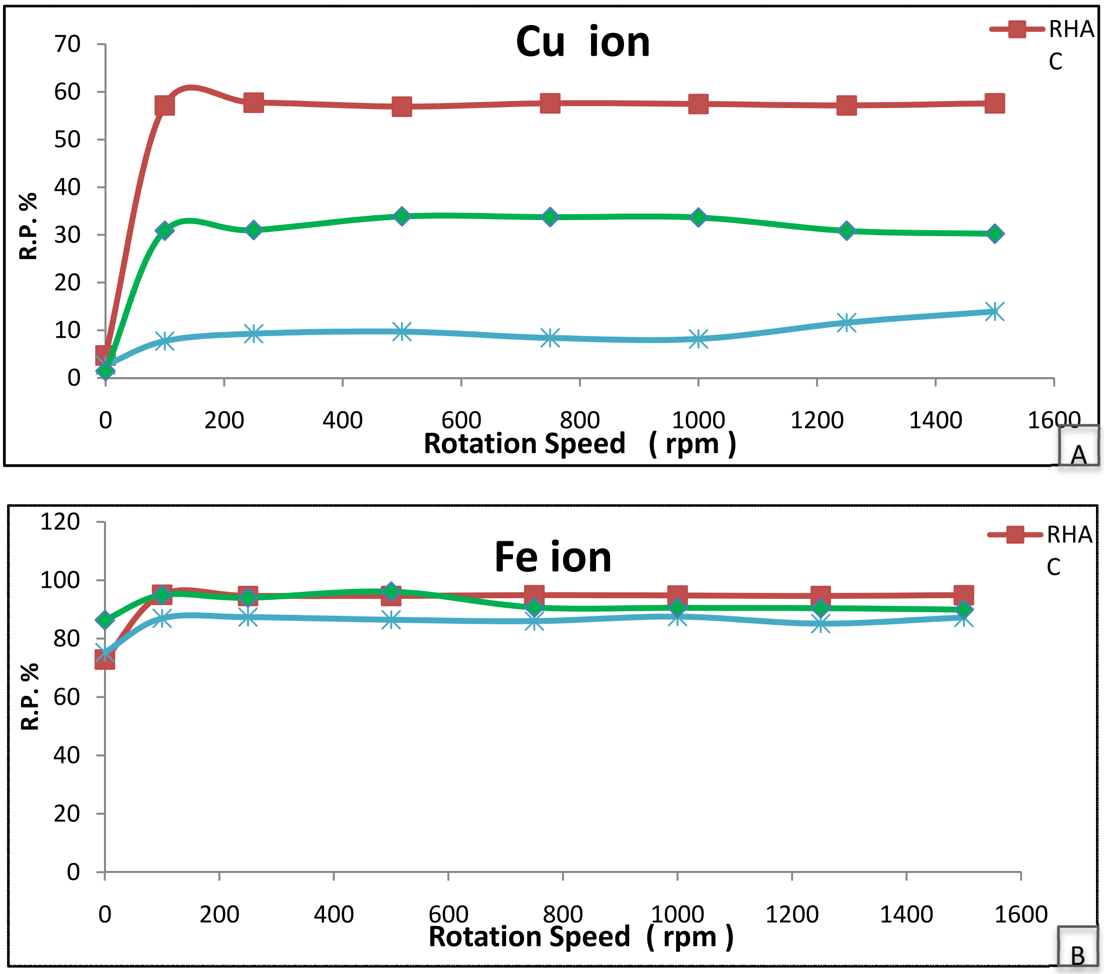

Figure 8. Effect of rotation speed on the adsorption of heavy metals ions

The adsorption capacity increased with increasing rotation speed. Due to the fact that rotation facilitates proper contact between the metal ions in solution and the adsorbent binding sites and consequently promoting effective transfer of adsorbate ions to the sorbent sites (BADMUS et al., 2007). Without rotation speeds the resistance to mass transport is in the bulk solution, and a thin liquid film surrounding the adsorbent particles offered resistance to mass transport by diffusion. As the rotation speeds increased, there would be decrease in the thickness of the boundary film thereby decreasing the effect of film diffusion (Yacob, 2011).

3.9 Fourier Transform Infrared Spectroscopy (FTIR)

From the figures 9 to 11 and results shown below which describe the FTIR analysis, there are a different in functional groups was scattered in surface of adsorbent material, which shows the different in adsorption efficiencies of heavy metal ions. The FTIR spectra obtained were in agreement with the results reported in the study carried out on activated carbons by other researchers (Alhamedand Bamufleh, 2008; Sharma et al., 2011; Markovska & Lyubchev, 2007).

The different offunctional groups on the surface of RACH, RH and CAC were explained following:

The spectra displayed the following bands on the CAC surface:

2350-2400 cm^{-1}: C≡C stretching vibrations, 1600-1800 cm^{-1}: C=O stretching vibrations and 1400-1600 cm^{-1}: C=N, NO_2 stretching vibrations.

The spectrum of RH shows functional groups from O-H (3404cm^{-1}), C–H (2920 cm^{-1}), C=N (1677 cm^{-1}), C-O (1000-1060 cm^{-1}), C=C (1649-1512 cm^{-1}) and Si-O (1081 cm^{-1}). While the spectrum of RHAC shows functional groups from O-H (3409 cm^{-1}), C=C (1660 cm^{-1}), Si-O, C-O (1100 cm^{-1}) and Si-H (800 cm^{-1}).

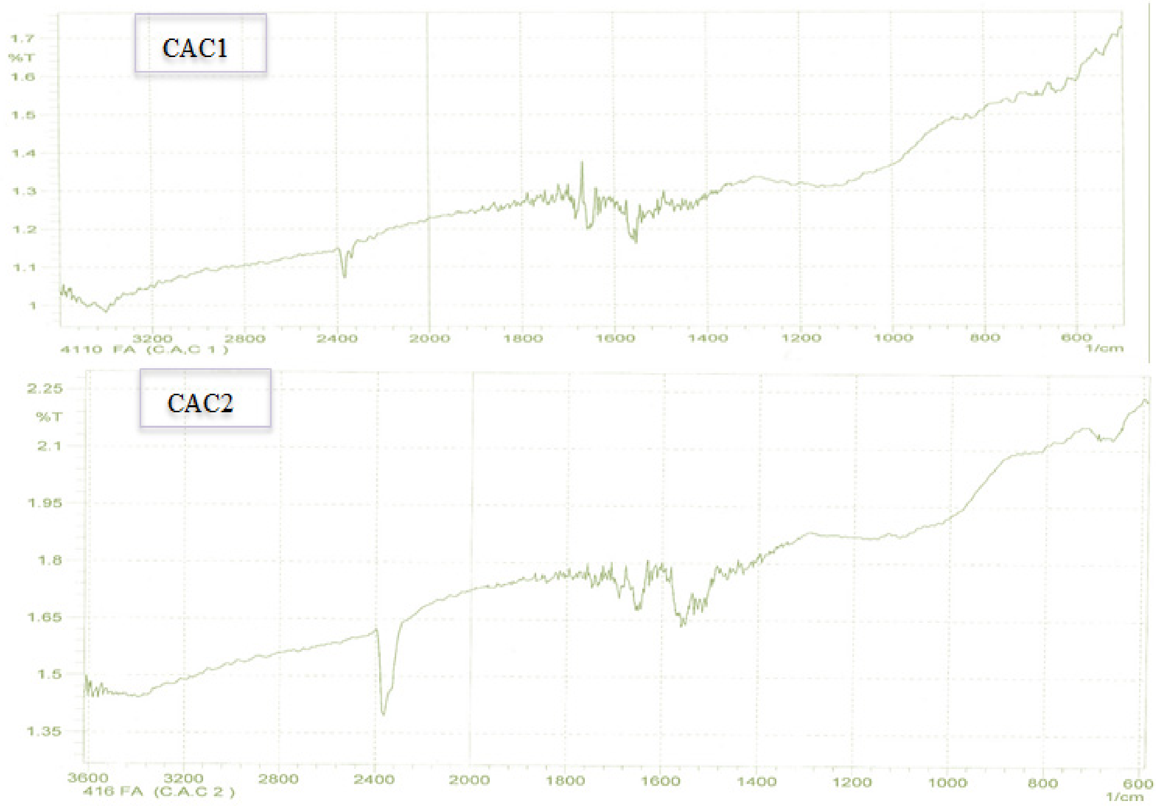

Figure 9. FTIR spectra of CAC before (1) and after (2) adsorption processes

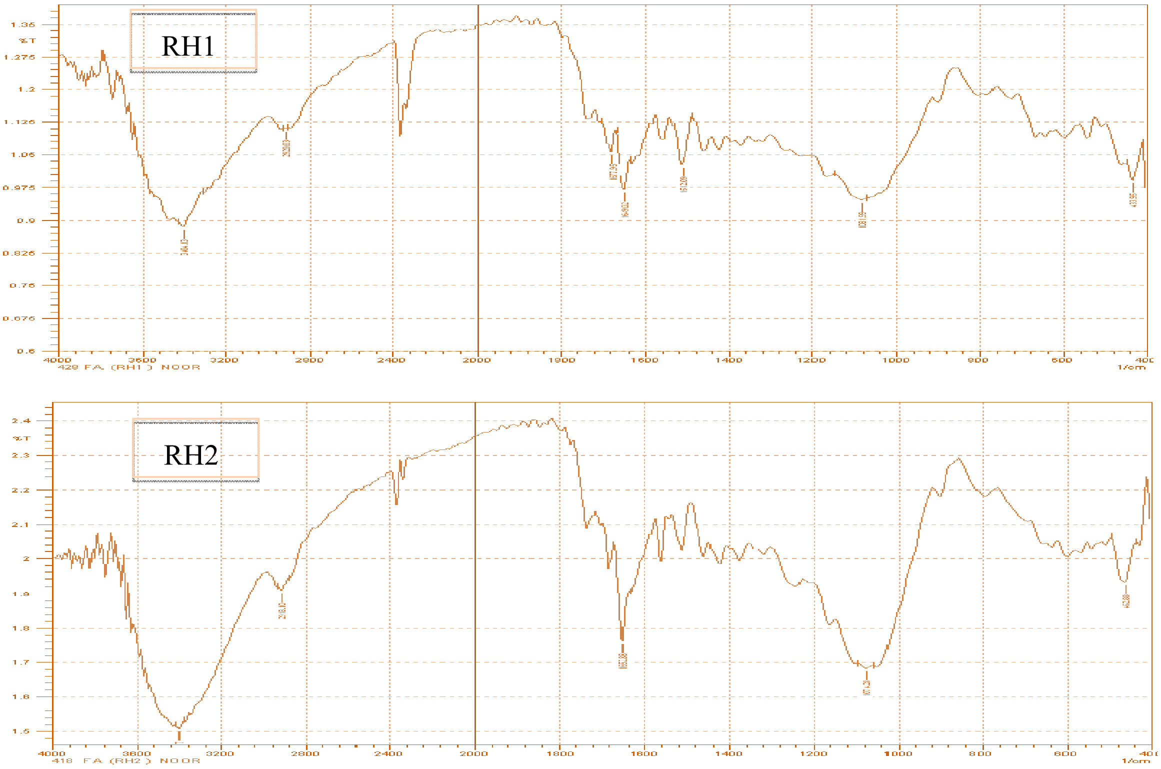

Figure 10. FTIR spectra of RH before (1) and after (2) adsorption processes

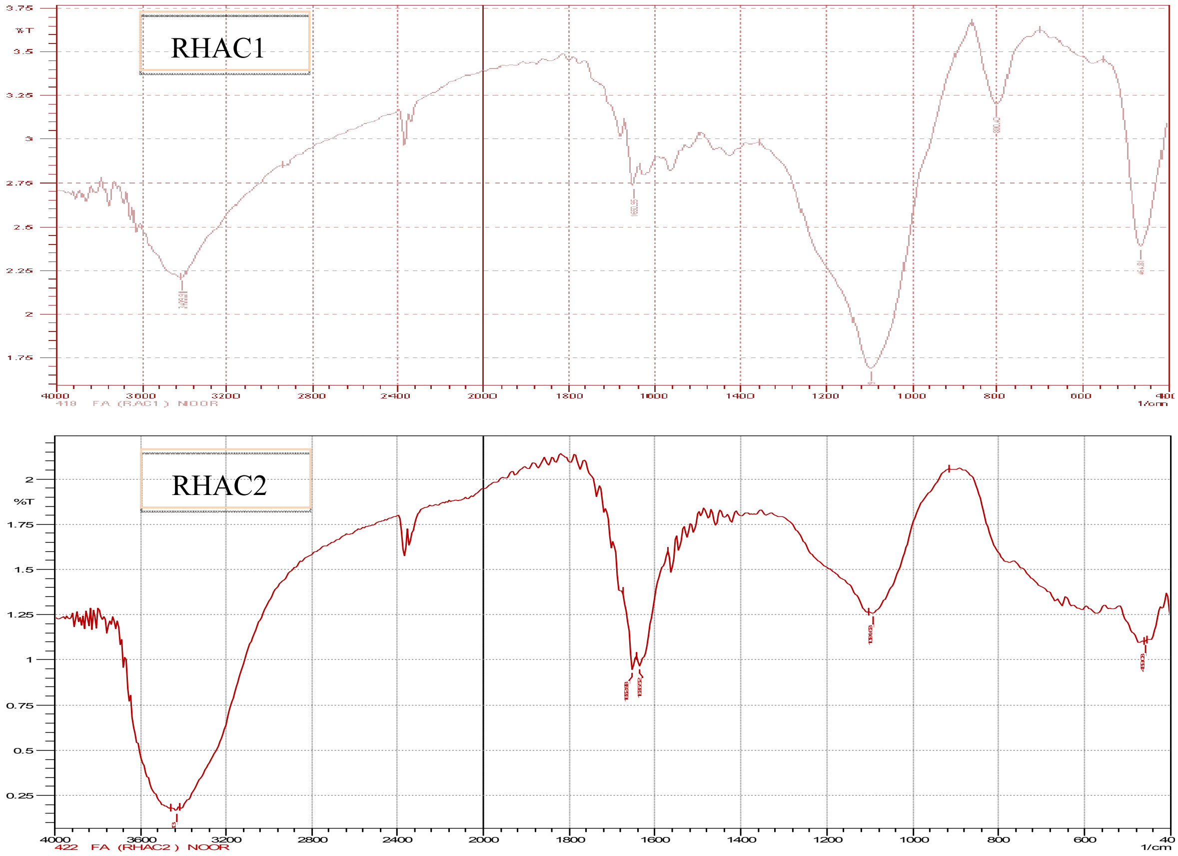

Figure 11. FTIR spectra of RHAC before (1) and after (2) adsorption processes

4. Conclusions

The adsorption capacity increased with increases in contact time until reached the saturation time then remained constant. The pH parameter is very effected on the adsorption capacity which increased with increasing pH until reached the optimum pH value. The efficiency of adsorption increased with rotation speed due to provide a good contact between the H.M.I. in solution and the adsorbent active sites. The adsorption capacity decreased with increased in adsorbent size and initial concentration of heavy metal ions, while the adsorption capacity increased with increasing temperature, and adsorbent dose. The FTIR results showed that a different in functional groups was scattered in surface of adsorbent material, that causing the different in adsorption efficiencies of heavy metal ions.

References

Adekola, F. A., & Adegoke, H. I. (2005). Adsorption of Blue-Dye on Activated Carbons Produced From Rice Husk, Coconut Shell and Coconut Coirpith. *Ife Journal of Science, 7*(1), 151-157. http://dx.doi.org/10.4314/ijs.v7i1.32169

Alhamed, Y. A., & Bamufleh, H. S. (2008). Sulfur Removal From Model Diesel Fuel Using Granular Activated Carbon From Dates' Stones Activated by $ZnCl_2$. *Journal of Fuel, 88*, 87-94. http://dx.doi.org/10.1016/j.fuel.2008.07.019

Al-tameemi, I. A., Nasser, T., & Thuraya, M. A. (2012). Removal of pb (II), cd (II) Ions onto dried Conocarpus erectus leaves using batch adsorption and study the adsorption thermodynamics. *Journal of Chem. Pharm. Res., 12*, 4961-4968.

Badmus, M. A. O., Audu, T. O. K., & Anyata, B. U. (2007). Removal of Lead Ion from Industrial Wastewaters by Activated Carbon Prepared from Periwinkle Shells. *Turkish Journal Eng. Env. Sci., 31,* 251-263.

Basso, M. C., Cerrella, E. G., & Cukierman, A. L. (2002). Activated Carbons from a Rapidly Renewable Biosource for Removal of Cadmium (II) and Nickel (II) Ions from Dilute Aqueous Solutions. *Industrial and Engineering Chemistry Research Journal, 41*, 180-189. http://dx.doi.org/10.1021/ie010664x

Chowdhury, S., & Saha, P. (2010). Pseudo-Second-Order Kinetic Model For Sorption Of Malachite Green Onto Sea Shell: Comparison Of Linear And Non-Linear Methods. *IIOAB Journal, 1*(3), 3-7.

Chowdhury, S., Mishra, R., Saha, P., & Kushwaha, P. (2010). Adsorption thermodynamics, kinetics and isosteric heat of adsorption of malachite green onto chemically modified rice husk. *Journal of Desalination, 265*, 159-168. http://dx.doi.org/10.1016/j.desal.2010.07.047

Gueu, S., Yao, B., Adouby, K., & Ado, G. (2006). Heavy Metals Removal in Aqueous Solution by Activated Carbons Prepared from Coconut Shell and Seed Shell of the Plam Tree. *Journal of Applied Sciences, 6*(13), 2789-2793. http://dx.doi.org/10.3923/jas.2006.2789.2793

Guo, Y., Yang, S., Fu, W., Qi, J., Li, R., Wang, Z., & Xu, H. (2002). Adsorption of malachite green on micro- and mesoporous rice husk-based active carbon. *Dyes and Pigments, 56,* 219-229. http://dx.doi.org/10.1016/S0143-7208(02)00160-2

Hameed, B. H., Ahmad, A. A., & Aziz, N. (2008). Adsorption of Reactive Dye on Palm-Oil Industry Waste: Equilibrium, Kinetic and Thermodynamic Studies. *Journal of Desalination, 247*, 551-560. http://dx.doi.org/10.1016/j.desal.2008.08.005

Kumar, P. S., & Gayathri, R. (2009). Adsorption Of Pb^{2+} Ions From Aqueous Solutions Onto Bael Tree Leaf Powder: Isotherms, Kinetics And Thermodynamics Study. *Journal of Engineering Science and Technology, 4*(4), 381-399.

Markovska, I. G., & Lyubchev, L. A. (2007). A Study On The Thermal Destruction Of Rice Husk In Air And Nitrogen Atmosphere. *Journal of Thermal Analysis and Calorimetry, 89*(3), 809-814. http://dx.doi.org/10.1007/s10973-007-8294-2

Meena, A. K., Kiran, C. R., & Mishra, G. K. (2010). Removal of heavy metal ions from aqueous solutions using chemically (Na2S) treated granular activated carbon as an adsorbent. *Journal of Scientific & Industrial Research, 69*, 449-453.

Mohammadi, S. Z., Karimi, M. A., Afzali, D., & Mansouri, F. (2010). Removal of Pb(II) from aqueous solutions using activated carbon from Sea-buckthorn stones by chemical activation. *Desalination Journal, (2010)*262, 86-93. http://dx.doi.org/10.1016/j.desal.2010.05.048

Nwabanne, J. T., & Igbokwe, P. K. (2012). Adsorption Performance of Packed Bed Column for the removal of Lead (II) using oil Palm Fibre. *International Journal of Applied Science and Technology, 2*(5), 106-115.

Philip, C. A., &Girgis, B. S. (1996). Adsorption Characteristics of Microporous Carbons from Apricot Stones Activated by Phosphoric Acid. *Journal of Chemical Technology and Biotechnology, 67*(3), 248-254. http://dx.doi.org/10.1002/(SICI)1097-4660(199611)67:3<248::AID-JCTB557>3.0.CO;2-1

Prabakaran, R., & Arivoli, S. (2012). Equilibrium Isotherm, Kinetic and Thermodynamic studies of Rhodamine B Adsorption using Thespesiapopulnea Bark. *Journal of Chem. Pharm. Res., 4*(10), 4550-4557.

Rahman, M. A., Ruhul A. S. M., & ShafiqulAlam, A. M. (2012). Removal of Methylene Blue from Waste Water Using Activated Carbon Prepared from Rice Husk. *Dhaka Univ. J. Sci., 60*(2), 185-189. http://dx.doi.org/10.3329/dujs.v60i2.11491

Rao, L. N., & Prabhakar, G. (2011). Equilibrium and kinetic studies for biosorption system of chromium ions from aqueous solution using Ficusbenghalensis L. powder. *Journal of Chem. Pharm. Res., 3*(6), 73-87.

Safa, Y., & Bhatti, H. N. (2011). Kinetic and thermodynamic modeling for the removal of Direct Red-31 and Direct Orange-26 dyes from aqueous solutions by rice husk. *Desalination Journal, 272*, 313-322. http://dx.doi.org/10.1016/j.desal.2011.01.040

Satya, S. P. M., Ahmed, J., & Krishnaiah, K. (1997). Production of Activated Carbon from

Coconut Shell Char in a Fluidized Bed Reactor. *Industrial and Engineering Chemistry Research Journal, 36*(9), 3625-3630. http://dx.doi.org/10.1021/ie970190v

Shanthi, T., & Selvarajan, V. M. (2012). Removal of Cu (II) Ions from Aqueous Solution by Carbon Prepared from Henna Leaves, Pungam Bark and CAC. *Journal of Chem. Pharm. Res., 4*(9), 4296-4306.

Sharma, P., Kaur, R., Baskar, C., & Chung, W. (2010). Removal of methylene blue from aqueous waste using rice husk and rice husk ash. *DesalinationJournal, 259,* 249-257. http://dx.doi.org/10.1016/j.desal.2010.03.044

Skodras, G., Diamantopoulou, Ir., Zabaniotou, A., Stavropoulos, G., & akellaropoulos, G. P. (2007). Enhanced mercury adsorption in activated carbons from biomass materials and waste tires. *Fuel Processing Technology, 88*, 749-758. http://dx.doi.org/10.1016/j.fuproc.2007.03.008

Subbaiah, M. V., Yuvaraja, G., Vijaya, Y., & Krishnaiah, A. (2011). Equilibrium, kinetic and thermodynamic studies on biosorption of Cu(II), Cd(II), Pb(II) and Ni(II) from aqueous solution by chitosanabrusprecatorius blended beads. *Journal of Chem. Pharm. Res., 3*(2), 365-378.

Surchi, K. M. S. (2011). Agricultural Wastes as Low Cost Adsorbents for Pb Removal: Kinetics, Equilibrium and Thermodynamics. *International Journal of Chemistry, 3*(3), 103-112. http://dx.doi.org/10.5539/ijc.v3n3p103

Tan, I. A. W., Ahmad, A. L., & Hameed, B. H. (2008). Adsorption of basic dye using activated carbon prepared from oil palm shell: batch and fixed bed studies. *Desalination Journal, 225*, 13-8. ttp://dx.doi.org/10.1016/j.desal.2007.07.005

Warhurst, A. M., McConnachie, G., & Pollard, S. J. T. (1996). The Production of Activated Carbon for Water Treatment in Malawi From the Waste Seed Husks of MoringaOleifera. *Water Science and Technology Journal, 34*(11), 177-184. http://dx.doi.org/10.1016/S0273-1223(96)00836-0,

Yacob, Z. Y. (2011). *Study the mass transfer characteristics in an oily-water by an Adsorption Process using an Activated Carbon* (M. Sc. Thesis). Chemical Engineering Department, Basrah University.

Yang, R. T. (2003). *Adsorbents: Fundamentals And Applications*. Canada: John Wiley & Sons, Inc. http://dx.doi.org/10.1002/047144409X

Copyright Disclaimer