

Adsorption Removal of Lead Ions by *Acacia tortilis* Leaves: Equilibrium, Kinetics and Thermodynamics

M. A. Ackacha and L. A. Elsharif

Abstract—In this research, the *Acacia tortilis* leaves was utilized as an adsorbent material for the removal of lead ions from aqueous solution. Batch experiments were used to predict the adsorption capacity of lead ions onto *Acacia tortilis* leaves. Different parameters affecting the adsorption process were tested including initial pH of adsorbate, adsorbent dose, contact time and contact temperature. Three kinetic models, including first order, pseudo-second order and intra-particle diffusion were used to analyze the adsorption process. The adsorption process was investigated using Langmuir and Freundlich isotherm models. The maxima adsorption capacities were 704.8, 632.3, 437 and 332 at 303, 313, 323 and 323 K, respectively. Thermodynamic parameters such as gibbs free energy, enthalpy and entropy were calculated to predict the nature of the adsorption. Langmuir and Freundlich models were applied to describe the adsorption isotherm.

Index Terms—Lead ions, adsorption, acacia tortilis, langmuir isotherm, thermodynamic parameters.

I. INTRODUCTION

Heavy metals such as lead released into the environment due to the industrial activate during the recent years such as batteries and steel industries discharge various concentrations of lead into water media [1], [2]. Because of the high toxicity of lead, its removal from water environment is very important. Lead can accumulates mainly in bones, kidney, muscles and brain. Leads cause too much health problems for instance hypertension, brain damage and kidney damage [3]. Even at low concentration of lead present in waste water, may cause hepatitis and anemia [3]. The recommended levels of lead in waste water as reported by Environmental Protection Agency (EPA) and Water Health Organization (WHO) are 0.05 and 0.01 mg/l, respectively [3].

There are various techniques for reducing heavy metals from water environment including chemical precipitation, membrane filtration, ion exchange, liquid extraction or electrodialysis [4]. Most of these techniques are extremely expensive or inefficient and take too much time [5]. Among these techniques, adsorption using a low cost agriculture material was used due to the presence of polar functional groups such as aldehyde, ketones, phenolic acid and carboxylic in their molecular structure [6]. The following agriculture materials were used in literatures as natural adsorbents: date stones [7], almond green hull [8], olive cake

ash [9], phragmites australis [10], walnut shell [11], rice hull and sawdust [12], peanut shells [13], orange peel [14], crab shell [15] and tea wastes [16].

In this article, the ability of *Acacia tortilis* leaves to remove lead ions from aqueous environment has been studied. Several parameters affecting the adsorption process were studied including initial pH of adsorbate, adsorbent dose, contact time and contact temperature. The adsorption isotherm as well as kinetic adsorption and thermodynamic adsorption have been investigated.

II. EXPERIMENTAL

A. Reagents and Equipments

All chemical reagents grade were obtained from Merck, Germany. A pH meter, model 3505 was delivered from Jenway Felsted, Dunmow, Essex C.46 SLB, United Kingdom. The shaker of orbital shaker model number 501 was purchased from Stuart Scientific, United Kingdom.

B. Adsorbent Preparation

Acacia tortilis leaves were used in this investigation. They were washed several times with distilled water to remove undesirable materials, filtered, dried at 93 °C for 2 hours, then grounded to a very fine powdered (50-125 µm). The obtained fine powder was stored in plastic container to be used later without any pretreatment.

C. Lead Solution Preparation

2 grams of lead acetate was dissolved in one liter of distilled water and used as a stock solution. The work solutions were prepared by dilution of the stock solution to required volume. The pH of the work solutions was controlled using 0.01 M HCl and 0.01 M NaOH.

D. Batch Adsorption

Batch experiments were carried out by shaking a stopper flasks contain 100 ml lead ion solution of specific concentration and 0.04 g of *Acacia tortilis* leaves at 400 rpm for desirable time, temperature and initial pH. The initial lead concentration as well as final lead concentration after adsorption was calculated by titration with EDTA using xylenol orange as indicator. The amount of adsorbed lead ions onto *Acacia tortilis* leaves was determined using mass balance equation [3]:

$$q_e = \frac{(C_o - C_e) \times V}{W} \quad (1)$$

where C_o and C_e are the initial and final concentration of Pb

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(II) ions solution (mg/l), V is the volume of lead ion solution (l) and W is the weight of *Acacia tortilis* leaves (g).

III. RESULTS AND DISCUSSION

A. Effect of Initial pH of Pb (II) Ion Solutions on Adsorption Capacity.

The initial pH of the heavy metal is very important factor in any adsorption process [17]. As shown in Fig. 1, there is too less removal of lead ion from aqueous solution at initial pH lower than 2.9 may be due to high concentration of H⁺ ion. There is a gradual increase of adsorption capacity with increase initial pH. The maximum adsorption capacity was observed at initial pH 4. At pH higher than 4, lead ions may be precipitated and adsorption studies could not be performed.

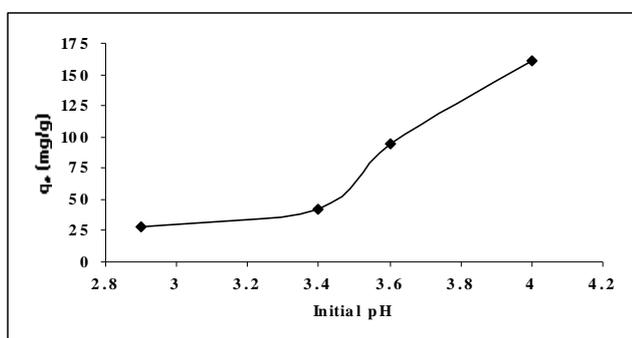


Fig 1. Effect of initial pH on adsorption capacity at adsorption conditions: contact temperature, 30 °C; concentration of lead ions solution, 300 mg/l; contact time, 2 h; *Acacia tortilis* leaves dose, 0.4 g/l; agitation speed, 400 rpm and particles diameter of *Acacia tortilis* leaves, 90-125 µm.

B. Effect of Adsorbent Dose on Adsorption Capacity

Fig. 2 shows the effect of adsorbent doses on adsorption capacity of lead ions onto *Acacia tortilis* leaves. When the adsorbent dose was increased from 0.3 to 1 g/l, the adsorption capacity decreases from 575.3 to 142.2 mg/g. This phenomena is mainly due to overlapping of the adsorption sites because of overcrowding of the adsorbent particles and also may be due to the competition among lead ions onto the *Acacia tortilis* leaves [18].

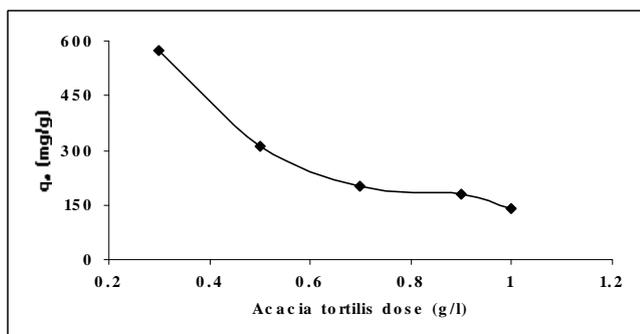


Fig 2. Effect of adsorbent dose on adsorption capacity at adsorption conditions: contact temperature, 30 °C; concentration of lead ions solution, 300 mg/l; contact time, 2 h; initial pH, 4, agitation speed, 400 rpm and particles diameter of *Acacia tortilis* leaves, 90-125 µm.

C. Effect of Contact Time on Adsorption Capacity

Effect of contact time on adsorption capacity of lead is presented in Fig. 3. The obtained results explained that, the adsorption capacity increases with increase of contact time and reach the equilibrium state after 60 minute. These results explained also that, the adsorption capacity depend on the concentration of the lead ions.

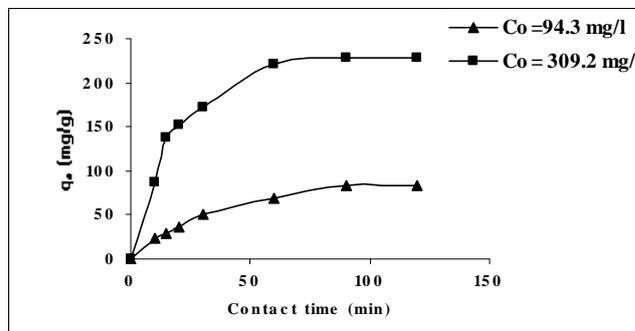


Fig. 3. Effect of contact time on adsorption capacity at adsorption conditions: contact temperature, 30 °C; concentration of lead ions solution, 300 mg/l; initial pH, 4; *Acacia tortilis* leaves dose, 0.4 g/l; agitation speed, 400 rpm and particles diameter of *Acacia tortilis* leaves, 90-125 µm.

D. Kinetic Studies

In order to understand the adsorption kinetic of lead (II) ions, three kinetic models include first-order, pseudo-second-order and intraparticle diffusion, have been applied for the experimental data. The intergrated form of the Lagergren [19], pseudo-second-order [19] and Weber & Morris [20] equations are expressed as:

$$\log(q_e - q_t) = \log q_e - \frac{K_1}{2.303} t \quad (2)$$

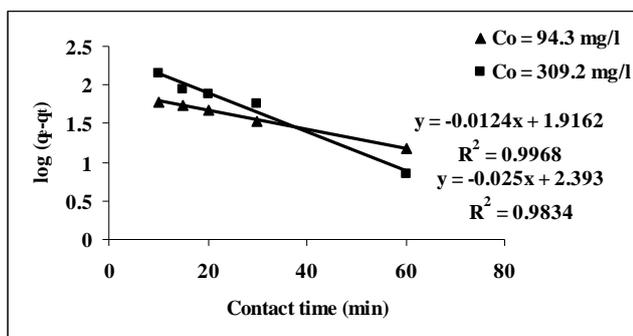
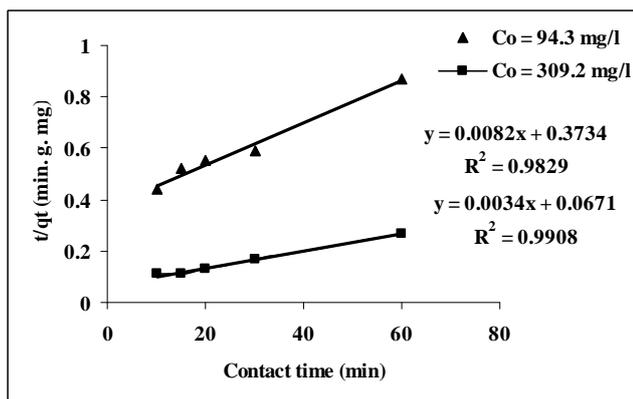
$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{1}{q_e} t \quad (3)$$

$$q_t = k_p t^{1/2} + C \quad (4)$$

where K1 is the first-order constant, K2 is the pseudo-second-order constant and Kp is the intra-particle diffusion constant. qe calculated and qt are adsorption capacity at equilibrium and at any time, respectively. C give an indication about the thickness of the boundary layer.

K₁ (min⁻¹) values can be determined from the slop of the linear plots of log (q_e-q_t) versus t (Fig. 4), K₂ (g/mg. min) was calculated from the linear plots of $\frac{t}{q_t}$ against t (Fig. 5).

q_e calculated (mg/g) values for both first- order and pseudo second order were calculated respectively from the linear plots of log (q_e-q_t) versus t (Fig. 4) and linear plots of $\frac{t}{q_t}$ against t (Fig. 5).


 Fig. 4. Lagergren plots for the adsorption of lead ions onto *Acacia tortilis* leaves, first-order model.

 Fig. 5. Pseudo-second-order kinetic plots for the adsorption of lead ions onto *Acacia tortilis* leaves.

The constants K_1 and K_2 , q_e experimental (q_e exp.) and q_e calculated (q_e calc.) and liner correlation coefficient (R^2) for the first order and pseudo second order reaction kinetics are summarized in Table I. In first order reaction kinetic, calculated values of q_e are closer to q_e experimental values more than pseudo second-order. Therefore, the adsorption kinetic could well be explained by first order kinetic.

 TABLE I: COMPARISON OF ADSORPTION RATE CONSTANTS, EXPERIMENTAL AND CALCULATED ADSORPTION CAPACITIES VALUES FOR FIRST AND SECOND ORDER REACTION KINETICS OF LEAD IONS ONTO *ACACIA TORTILIS* LEAVES

C_o (mg/l)	q_e exp.	First order			Pseudo second order		
		K_1	q_e calc.	R^2	K_2	q_e calc.	R^2
94.3	82.5	0.03	82.5	0.9968	0.00018	122	0.9829
309.2	227	0.06	247	0.9834	0.000017	294	0.9908

According to the equation 4, a plot of qt versus $t^{1/2}$ (Fig. 6) should be straight line when adsorption mechanism follows the intraparticle diffusion process. The values of K_p and C were obtained respectively from the slop and intercept of the plot of qt versus $t^{1/2}$. These values as well as the correlation coefficient (R^2) are listed in Table II. The high values of R^2 proved that, the adsorption mechanism of lead ions onto *Acacia tortilis* leaves follows the intraparticle diffusion process. Because of the deviation of the curves from the origin point, intraparticle diffusion cannot be accepted as the only rate-determining step for the adsorption of lead ions onto *Acacia tortilis* leaves [20].

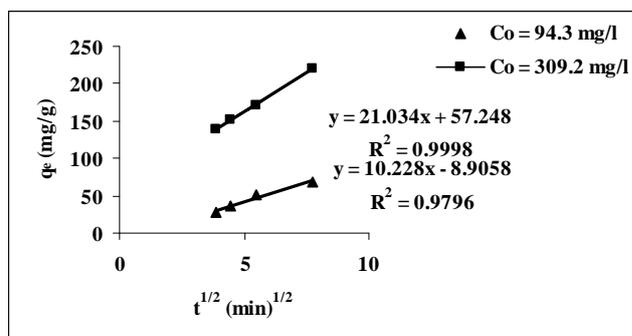
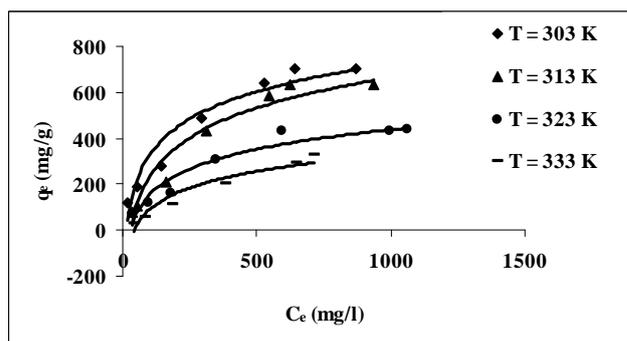

 Fig. 6. Intraparticle diffusion plots for the adsorption of lead ions onto *Acacia tortilis* leaves.

 TABLE II: RATE PARAMETERS OF INTRAPARTICLE DIFFUSION OF LEAD IONS ONTO *ACACIA TORTILIS* LEAVES

C_o (mg/l)	C	R^2
94.3	8.9	0.9796
309.2	57.2	0.9998

E. Adsorption Isotherm Studies

The adsorption isotherm of lead ions onto *Acacia tortilis* leaves at different contact temperatures are presented in Fig. 7.


 Fig. 7. Adsorption of lead ions onto *Acacia tortilis* leaves at different contact temperatures.

Several isotherm equations are available and two important isotherms are applied in this work include Langmuir [21] and Freundlich [22] isotherms. The adsorption isotherms were obtained for contact temperatures 303, 313, 323 and 333 K, while keeping all other parameters constants at optimum conditions.

The Langmuir equation expressed as follows:

$$\frac{C_e}{q_e} = \frac{1}{q_{\max} \cdot b} + \frac{1}{q_{\max}} C_e \quad (5)$$

where q_{\max} (mg/g) and b (l/mg) are related to the maximum adsorption capacity and energy of adsorption, respectively.

These constants were obtained from the plots of $\frac{C_e}{q_e}$ versus C_e (Fig. 8) and used to calculate the Langmuir constant (K_L) according to the following equation:

$$K_L = q_{\max} \times b \quad (6)$$

The Langmuir model can be expressed in terms of an equilibrium parameter (R_L) given by the following equation:

$$R_L = \frac{1}{1 + b \times C_0} \quad (7)$$

The values of R_L give an idea about the shape of isotherm (Table III) [23]. The R_L values at different temperatures are illustrated in Table IV. The values lie between 0 and 1 indicating that, the adsorption of lead ions onto *Acacia tortilis* leaves at different temperatures is favorable.

TABLE III: RELATION BETWEEN R_L VALUES AND TYPE OF ISOTHERM

R_L value	Type of isotherm
$R_L > 1$	Unfavorable
$R_L = 1$	Linear
$0 < R_L < 1$	Favorable
$R_L = 0$	Irreversible

TABLE IV: R_L VALUEES BASED ON LANGMUIR EQUATION

C_0 (mg/l)	R_L values			
	303 K	313 K	323 K	333 K
75.80	0.01310	0.01320	0.01320	0.01320
113.8	0.00875	0.00876	0.00876	0.00878
227.6	0.00437	0.00438	0.00438	0.00439
441.9	0.00231	0.00258	0.00226	0.00226
720.7	0.00138	0.00138	0.00138	0.00139
815.6	0.00122	0.00122	0.00122	0.00122
1126	0.00884	0.00089	0.00089	0.00089

The Freundlich equation can be expressed as follows:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \quad (8)$$

where K_F and n are the Freundlich constants which determined from the plots of $\log q_e$ versus $\log C_e$ (Fig. 9).

Table V and Table 6 presented respectively, the isotherm parameters for both Langmuir and Frundlich models. It is noted from these Tables that, the linear coefficients (R^2) of the Freundlich isotherm model showed a better fit to the present work. The values of n (1-10), indicating that, the adsorption of Pb (II) ions onto *Acacia tortilis* leaves is favorable [20].

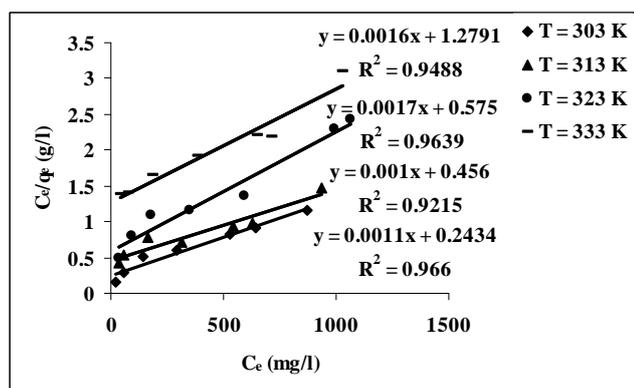


Fig. 8. Langmuir adsorption isotherm of lead ions onto *Acacia tortilis* leaves at different contact temperatures.

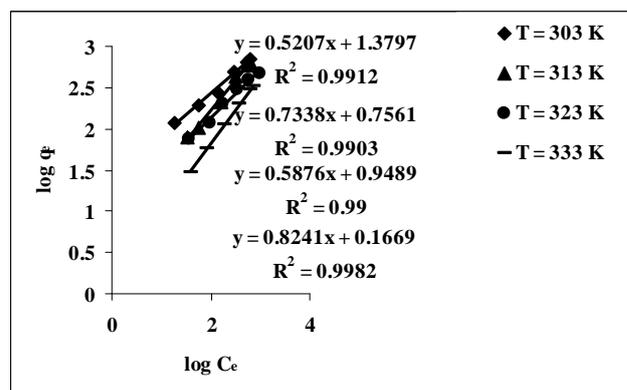


Fig. 9. Freundlich adsorption isotherm lead ions onto *Acacia tortilis* leaves at different contact temperatures.

TABLE V: THE LANGMUIR ISOTHERM PARAMETERS AT DIFFERENT TEMPERATURES

T (K)	Langmuir isotherm			
	q_{\max} exp. (mg/g)	b (l/mg)	K_L (l/g)	R^2
303	704.8	0.0045	4.11	0.9660
313	632.3	0.0022	2.20	0.9215
323	437.0	0.0031	1.76	0.9639
333	332.0	0.0012	0.75	0.9488

TABLE 6: THE FREUNDLICH ISOTHERM PARAMETERS AT DIFFERENT TEMPERATURES

T (K)	Freundlich isotherm		
	K_F	n	R^2
303	23.97	1.97	0.9912
313	5.70	1.36	0.9903
323	8.90	1.70	0.9900
333	1.47	1.21	0.9982

F. Thermodynamic Studies

The type of the adsorption can be determined through the quantities of thermodynamic parameters such as Gibbs free energy ΔG° , standard enthalpy ΔH° and entropy change ΔS° for the adsorption of lead ions onto the surface of *Acacia tortilis* leaves. These parameters are given in Table 6. ΔG° was calculated using the following equation:

$$\Delta G^\circ = -RT \ln K_L \quad (9)$$

where R is the universal gas constant (8.314 j/mol k) ΔH° and ΔS° were calculated respectively from the slop and intercept of the plots of $\frac{1}{T}$ versus $\ln K$ (Fig. 10) using the Van't Hoff equation [24]:

$$\ln k = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT} \quad (10)$$

The negative values of ΔG° showed that, the adsorption process was spontaneous thermodynamically. However, the decrease of the values of ΔG° with increase temperatures

proved that, the adsorption was not favorable at higher temperatures. The negative value of ΔH° indicated the exothermic nature of the adsorption process. The negative value of ΔS° suggest the decrease of randomness through the interface during the adsorption of lead ions onto the surface of *Acacia tortilis* leaves.

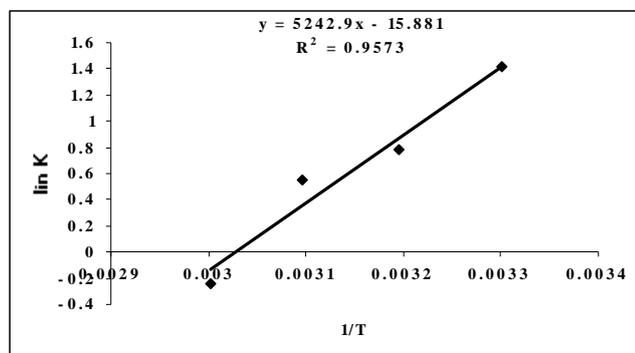


Fig. 10. Plot of lnK vs. 1/T

TABLE VI: THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF LEAD IONS ONTO *ACACIA TORTILIS* LEAVES THE FREUNDLICH ISOTHERM PARAMETERS AT DIFFERENT TEMPERATURES

	ΔG°		ΔH°	ΔS°		
	(Kj/mol.K)		(Kj/mol.K)	(Kj/mol.K)		
	303 k	313 K	323 K	333 K		
	-3.55	-2.04	-1.48	-0.62	-43.56	-0.13

G. Comparison of Adsorption Capacity of *Acacia tortilis* Leaves with Other Agriculture Adsorbents

In order to test the performance of *Acacia tortilis* leaves as effective adsorbent for removal of lead ions from aqueous solutions, a comparison with other adsorbents was made (Table 7). All adsorbents showed lower removal of lead ions from aqueous solutions than *Acacia tortilis* leaves [24], [25].

TABLE VII: ADSORPTION CAPACITY OF LEAD IONS BY DIFFERENT AGRICULTURE ADSORBENTS

Adsorbent	pH	q _e (mg/g)
Oil mill residue	5.6	21.65
Cocoa shells	2	6.2
Nile rose plant powder	5	27.4
Palm shell activated carbon	5	95.5
Modified peanut sawdust	4	29.1
Pseudomonas aeruginose	5.5	68.4
Grap stalks	5.5	49.7
Rice husk	5.5	4
Hazelnat shell	6.6	1.78
Syzygium Cumin L	6	32.47
C. inophyllum	4	34.51
This study	4	704.8

IV. CONCLUSION

The results can be summarized as follows:

- 1) The adsorption capacity was initial pH dependent and the optimum pH was 4.
- 2) The adsorption of lead ions onto the *Acacia tortilis* leaves was very fast within 15 min and reached equilibrium after 60 min.

- 3) Freundlich adsorption isotherm was better fitted for adsorption of lead ions than Langmuir adsorption isotherm.
- 4) The process is exothermic in nature due to the negative value of ΔH° .
- 5) At temperatures ranged from 303-333 K, the system was spontaneous and the spontaneously decrease as the temperature increase.
- 6) The randomness is decrease through the interface during the adsorption of lead ions onto the surface of *Acacia tortilis* leaves.
- 7) Kinetically, the adsorption kinetic could well be explained by first order kinetic.

REFERENCES

- [1] R. Muhammad, N. Raziya, A. H. Muhammad, M. A. Tariq and R. Khalil, "Pb (II) biosorption from hazardous aqueous streams using *Gossypium hirsutum* (Cotton) waste biomass," *Journal of Hazardous Materials*, vol. 161, pp. 88-94, March 2008.
- [2] A. R. Kul and H. Koyuncu, "Adsorption of Pb (II) ions from aqueous solution by native and activated bentonite: Kinetic, equilibrium and thermodynamic study," *Journal of Hazardous Materials*, vol. 179, pp. 332-339, March 2010.
- [3] H. Lalhrualtuanga, K. Jayaram, M. N. V. Prasad, and K. K. Kumar, "Lead (II) adsorption from aqueous solutions by raw and activated charcoals of *Melocanna baccifera* Roxburgh (bamboo)-A comparative study," *Journal of Hazardous Materials*, vol. 175, pp. 311-318, October 2010.
- [4] Q. Li, J. Zhai, W. Zhang, M. Wang, and J. Zhou, "Kinetic studies of adsorption of Pb (II), Cr (III) and Cu (II) from aqueous solution by sawdust and modified peanut husk," *Journal of Hazardous Materials*, vol. 141, pp. 163-167, July 2006.
- [5] Y. Jiang, H. Pang, and B. Liao, "Removal of copper (II) ions from aqueous solution by modified bagasse," *Journal of Hazardous Materials*, vol. 164, pp. 1-9, August 2008.
- [6] F. Qin, B. Wen, X. Q. Shan, and Y. N. Xie, "Mechanisms of competitive adsorption of Pb, Cu and Cd on peat," *Environmental Pollution*, vol. 144, pp. 669-680, December 2005.
- [7] N. M. Haimour and S. Emeish, "Utilization of date stones or production of activated carbon using phosphoric acid," *Waste Management*, vol. 26, pp. 651-660, October 2005.
- [8] A. Ahmadpour, M. Tahmasbi, T. Rohani, and J. Amel Besharati, "Rapid removal of cobalt ion from aqueous solutions by almond green hull," *Journal of Hazardous Materials*, vol. 166, pp. 925-930, December 2008.
- [9] Z. Elouear, J. Bouzid, N. Boujelben, M. Feki, and A. Montiel, "The use of exhausted olive cake ash (EOCA) as a low cost adsorbent for the removal of toxic metal ions from aqueous solutions," *Fuel*, vol. 87, pp. 2582-2589, February 2008.
- [10] B. Southichak, K. Nakano, M. Nomura, N. Chiba, and O. Nishimura, "phragmites australis: A novel biosorbent for the removal of heavy metals from aqueous solution," *Water Research*, vol. 40, pp. 2295-2302, April 2006.
- [11] M. Zabihi, A. Ahmadpour, and A. Haghghi Asi, "Removal of mercury from water by carbonaceous sorbents derived from walnut shell," *Journal of Hazardous Materials*, vol. 167, pp. 230-236, December 2008.
- [12] F. Asadi, H. Shariatmadari, and N. Mirghaffari, "Modification of rice husk and sawdust sorptive characteristics for remove heavy metals from synthetic solutions and wastewater," *Journal of Hazardous Materials*, vol. 154, pp. 451-458, October 2007.
- [13] K. Wilson, H. Yang, C. W. Seo, and W. E. Marshall, "Select metal adsorption by activated carbon made from peanut shells," *Bioresource Technology*, vol. 97, pp. 2266-2270, December 2005.
- [14] X. Li, Y. Tang, X. Cao, D. Lu, F. Luo, and W. Shao, "Preparation and evolution of orange peel cellulose adsorbents for effective removal of cadmium, zinc, cobalt and nickel," *Colloid and surfaces A*, vol. 317, pp. 512-521, November 2007.
- [15] D. S. Kim, "The removal by crab shell of mixed heavy metal ions in aqueous solution," *Bioresource Technology*, vol. 87, pp. 355-357, October 2002.
- [16] B. M. W. P. K. Amarasinghe, and R. A. Williams, "Tea waste as a low cost adsorbent for the removal of Cu and Pb from wastewater,"

- Chemical Engineering Journal*, vol 132, 299-309, January 2007.
- [17] M. Madhava, A. Ramesh, G. Purna Chandra Rao, and K. Seshiah, "Removal of copper and cadmium from the aqueous solutions by activated carbon derived from ceiba pentandra hulls" *Journal of Hazardous Materials B*, vol. 129, pp. 123-129, September 2005.
- [18] A. R. Ifikhar, H. N. Bhatti, M. A. Hanif, and R. Nadeem, "Kinetic and thermodynamic aspects of Cu (II) and Cr (III) removal from aqueous solutions using rose waste biomass," *Journal of Hazardous Materials*, vol. 161, pp. 941-947, April 2008.
- [19] R. Nadeem, M. H. Nasir, and M. S. Hanif, "Pb (II) sorption by acidically modified cicer arietinum biomass," *Chemical Engineering Journal*, vol. 150, pp.40-48, December 2009.
- [20] W. S. Wan Ngah and K. M. Hanafiah, "Adsorption of copper on rubber (*Hevea brasiliensis*) leaf powder: Kinetic, equilibrium and thermodynamic studies," *Biochemical Engineering Journal*, vol. 39, pp. 521-530, November 2007.
- [21] Y. S. Ho and A. E. Ofomaja, "Biosorption thermodynamics of cadmium on coconut copra meal as biosorbent," *Biochemical Engineering Journal*, vol. 30, pp. 117-123, February 2006.
- [22] M. A. Ackacha, "Removal of Zn (II) ions from aqueous solution by new adsorbent: *Calligonum comosum*," *International Journal of Chemical Environment and Engineering*, vol. 1, no. 1, pp. 18-22, July 2010.
- [23] P. Chakravarty, N. S. Sarma, and H. P. Sarma, "Removal of lead (II) from aqueous solution using heartwood of *Areca catecha* powder," *Desalination*, vol. 256, pp. 16-21, March 2010.
- [24] O. S. Lawal, A. R. Sanni, I. A. Ajai, and O. O. Rabi, "Equilibrium, thermodynamic and kinetic studies for the biosorption of aqueous lead (II) ions onto the seed husk of *calophyllum inophyllum*," *Journal of Hazardous Materials*, vol. 177, pp. 829-835, January 2010.
- [25] G. Issabayeva, M. K. Aroua, and N. M. N. Sulaiman, "Removal of lead from aqueous solutions on palm shell activated carbon" *Bioresource Technology*, vol. 97, pp. 2350-2355, November 2005.



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The experience in the field of removal of heavy metals and dyes from aqueous media using agriculture materials.

At the current time, some researches include the use of agriculture adsorbents treated with natural activators were tried for heavy metals removal from aqueous solutions, reuse of some agriculture adsorbents for heavy metals removal from aqueous solutions and removal of heavy metals from hard aqueous media by agriculture adsorbents.

He is Associate Prof. of analytical chemistry and supervised about ten M. Sc thesis and two M. Sc work under preparation.