



Journal of Applied Sciences

ISSN 1812-5654

science
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Sorption and Desorption of Pb(II) from Aqueous Solution using *Triplochiton scleroxylon* Sawdust as Sorbent

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Abstract: Studies on a batch sorption process using *Triplochiton scleroxylon* sawdust as a low cost sorbent produced by wood industry was investigated to remove lead ions from aqueous solution. The sorption process follows a pseudo second-order rate kinetics at different dosage of sawdust and at different Pb(II) initial concentration. The Freundlich and Langmuir sorption models were used for the mathematical description of the equilibrium and isotherm constants were also evaluated, the maximum sorption capacity of Pb(II) in single component system was determined to be 26.38 mg g⁻¹ at 30±2°C and at an initial pH of 4. The sorption process showed that copper, cadmium or both metals in aqueous solutions suppressed the removal of lead ions by sawdust. These results indicated that ion exchange is one of the major sorption mechanisms for binding Pb(II) ions into sawdust.

Key words: Sawdust, ions exchange, desorption, kinetic, isotherm

INTRODUCTION

The increase in the industrial activities has led to more environmental problems leading to pollution and deterioration of several ecosystems due to the accumulation heavy metals. Heavy metal ions are extremely toxic and harmful even at low concentrations; consequently, their drainage from water and wastewater is significant to meet legislative standards and to protect the public health (Kumar *et al.*, 2006).

Lead, a heavy metal, is widely used in many important manufacturing processes such as storage battery, manufacturing, printing, pigments, fuels, photographic materials and explosive manufacturing. It is meanwhile one of the most toxic heavy metals (Martins *et al.*, 2006).

Many physicochemical techniques for removing lead from wastewaters include chemical precipitation, carbon adsorption, ion exchange, evaporation and membrane processes (Bulut and Tez, 2007; Abia *et al.*, 2006). The selection of a particular technique depends notably on a number of factors, such as metal type and its concentration, other constituents, the level of clean-up required and the cost of its use. Precipitation methods are particularly reliable but require large settling tanks for the precipitation of voluminous alkaline sludges and a

subsequent treatment is needed (Dang *et al.*, 2009). Adsorption is an important means for controlling the extent of pollution due to heavy metal ions. Activated carbons are widely used because of their high adsorption abilities for a large number of heavy metal ions. However, the price of activated carbons is relatively high, which limits their use (Oliveira *et al.*, 2005). This situation led many researchers to seek cheaper materials such as, the agricultural by-products.

A number of agricultural waste and by-products have been cited in the literature for their capacity to remove lead from aqueous solutions. These comprise bagasse sugar (Gupta and Ali, 2004), sawdust (Adouby *et al.*, 2007; Li *et al.*, 2007), rice husk (Wong *et al.*, 2003), bark (Nehrenheim and Gustafsson, 2008; Al-Asheh and Duvnjak, 1997), peat (Ho *et al.*, 2002), wheat bran (Nouri *et al.*, 2007), tree fern (Ho *et al.*, 2004), modified corn cobs (Khan and Wahab, 2007) oil palm tree (Zuhairi *et al.*, 2007).

Among low-cost adsorbents, sawdust has been considered promising, due to abundance and availability mostly in wood-based industries (Shukla *et al.*, 2002). Sawdust is a solid waste produced in large quantities at saw mills. It basically contains lignin and cellulose and has a good mechanical stability as well as some other advantages.

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The objective of this study was to obtain the basic information for the design of the process of lead sorption on sawdust, such as kinetic data and equilibrium in batch system. In order to describe the isotherm mathematically, the experimental data of the sorption equilibrium were correlated with Langmuir and Freundlich equations. The kinetics of the process was determined, especially in relation to the effects of lead concentration and sawdust dosage on the sorption. The competitive sorption of lead with copper, cadmium or both metals on sawdust were also investigated. The regenerative capacity and reusability of the sawdust were also assessed in the present study.

MATERIALS AND METHODS

Sorbent: This study was conducted from April 2007 to December 2008. Sawdust was obtained from locally used wood, *Triplochiton scleroxylon*. It was collected from a local sawmill and dried in sunlight for 15 days until almost all the moisture evaporated. It was ground to a fine powder and sieved to 0, 5 mm size then directly used without any pretreatment, as a sorbent for the metal removal from aqueous solutions.

Chemicals: All chemicals used in this study were of analytical grade. Metal solutions were prepared by dissolving $\text{Pb}(\text{NO}_3)_2$, $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$; $\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ (99.5% MERCK), in deionized water to desired initial concentrations. Nitrate salt was selected as a possibly inhibiting anion because of its low tendency for complex formation with most metals.

Sorption kinetics: Batch kinetic experiments were carried out at room temperature ($30 \pm 2^\circ\text{C}$) using 250 mL Erlenmeyer flasks. The experiments were conducted at the initial pH 4; the mixtures were agitated at 300 rpm.

At appropriate time intervals, Sawdust from the samples was separated by vacuum filtration using a 45 μm membrane filter and the metal content of the filtrate was analyzed using a Varian Atomic Absorption Spectrophotometer (AAS) Varian Model AA 20 in an air-acetylene flame.

The effects of sorbent dosage (5-20 g L^{-1}) and of the initial concentrations of lead (100-400 mg L^{-1}) on the sorption rate were studied. The procedure was the same as described above. Each batch experiment was carried out in duplicate.

The concentrations of Pb(II) adsorbed were obtained from the difference between the initial and the final concentration of the metal in the filtrate.

The amount of Pb(II) adsorbed in mg g^{-1} at a given time was computed by using the following equation:

$$q_t = \frac{(C_o - C_t)V}{m} \quad (1)$$

where, C_o and C_t are the metal concentrations (in mg L^{-1}) initially and at a given time t , respectively and V is the volume of the metal solutions in mL and m is the weight of sawdust in g.

The lead percentage of removal was calculated using the following equation:

$$R(\%) = \frac{(C_o - C_t)}{C_o} \times 100 \quad (2)$$

where, C_o and C_t are the initial and final metal concentrations in solution, respectively.

Equilibrium studies for single-metal systems: Batch sorption experiments were performed at room temperature ($30^\circ\text{C} \pm 1$) in 250 mL Erlenmeyer flasks. Accurately weighed amounts (0.2-3 g) of sorbent (sawdust) were agitated at 300 rpm with 100 mL of Pb(II) solution (100 mg L^{-1}) for 45 min. At the end of the equilibrium period, sawdust was separated by vacuum filtration using a 45 μm membrane filter. The metal content of the filtrate was analyzed using an Atomic Absorption Spectrophotometer as indicated earlier.

Equilibrium studies for multiple-metal systems: The competitive sorption experiments were developed from the method described by Han *et al.* (2006). In these experiments, competitive sorption of Pb(II), Cd(II) and Cu(II) ions in binary and ternary solutions was investigated by following a similar procedure as described above. These studies were performed at initial pH of 4.0 and at 30°C . The experiments of competitive sorption of Pb(II), Cd(II) and Cu(II) included two parts: (1) The competitive sorption of Pb(II) with Cd and Cu(II) at binary and ternary system in the total metal concentration was fixed (100 mg L^{-1}); (2) In another binary system, the initial concentration of Pb(II) was constant in 100 mg L^{-1} and the concentration of Cu(II) or Cd(II) were varied from 0 to 100 mg L^{-1} .

Desorption/reuse experiments: For the desorption study, 2.0 g of sawdust was put in contact with 100 mL Pb(II) solution (200 mg L^{-1}). After 45 min, the solution was filtrated on 0.45 μm Millipore filter. Sawdust was collected, washed three times with 500 mL distilled water in order to remove residual Pb (II) on the sorbent surface. The sawdust was dried at 60°C was transferred into 100 mL of desorbing solutions containing: deionised water, 0.2 M HCl, HNO_3 , H_2SO_4 , CaCl_2 , NaCl and EDTA. The mixtures were shaken for 45 min, filtrated and the filtrates were

analyzed for the determination of Pb(II) after desorption. These sorption/desorption studies were repeated four times using the same sawdust.

Desorption ratio was given as:

$$\text{Desorption ratio} = \frac{\text{Amount of Pb(II) desorbed}}{\text{Amount of pb(II) adsorbed}} \quad (3)$$

RESULTS AND DISCUSSION

Kinetic studies: The rate at which sorption takes place is an important factor to consider when designing batch sorption systems. It is therefore important to establish the time dependence of such systems under various process conditions. Many authors have studied the sorption kinetics in bivalent metal with several sorbent materials by the kinetics of pseudo second order (Ofomaja and Ho, 2007; Khormaei *et al.*, 2007; Wang *et al.*, 2006). The rate equation for the reaction may be represented by the following expression:

$$\frac{dq_t}{dt} = k(q_e - q_t)^2 \quad (4)$$

where, k is the sorption rate constant ($\text{g mg}^{-1} \text{min}$), q_e the amount of metal ion sorbed at equilibrium (mg g^{-1}) and q_t is the amount of metal ion on the sorbent surface at any time t (mg g^{-1}).

Separating the variables in Eq. 4 gives:

$$\frac{dq_t}{(q_e - q_t)^2} = kdt \quad (5)$$

Integrating this for the boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$; gives:

$$\frac{t}{q_t} = \frac{1}{kq_e^2} + \frac{1}{q_e}t \quad (6)$$

The plot of t/q_t versus t should give a straight line if second-order kinetics is applicable and q_e and k can be determined from the slope and intercept of the plot, respectively.

The initial sorption rate h ($\text{mg g}^{-1} \cdot \text{min}$) is given by the following equation:

$$h = kq_e^2 \quad (7)$$

Effect of initial concentration: Figure 1 show the plot of the experimental data points for the sorption of lead ions on sawdust for 20 g L^{-1} of biomass concentration and pH 4 as a function of time. The sorption increased rapidly

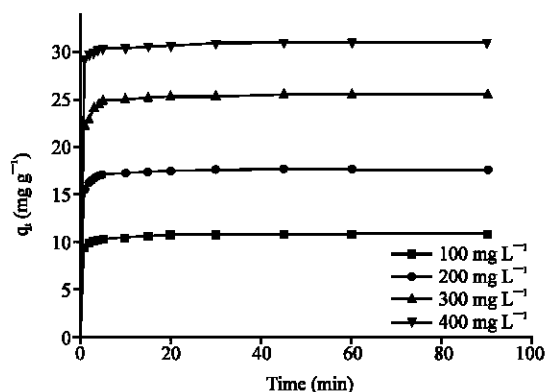


Fig. 1: Effect of initial concentration of metal on the sorption of Pb(II) by *Triplochiton scleroxylon* sawdust for 20 g L^{-1} of biomass concentration and pH 4

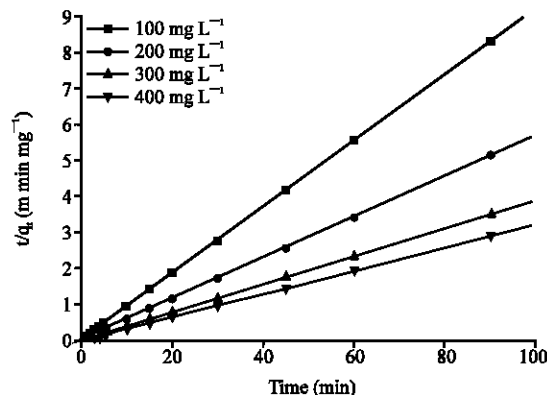


Fig. 2: Pseudo-second-order sorption kinetics of Pb(II) by sawdust at different initial concentration of metal for 20 g L^{-1} of biomass concentration and pH 4

at the beginning, then became slow until it reached the equilibrium. We observed that the metal uptake varied with varying initial lead concentration. The equilibrium uptake of Pb(II) was found to be $10.837, 17.593, 25.601$ and 31.046 mg g^{-1} at $100, 200, 300$ and 400 mg L^{-1} initial Pb(II) concentrations respectively. Equilibrium time for sorption of Pb(II) at different concentrations was found to be 45 min showing that equilibrium time is not dependent of initial concentration of Pb(II).

By plotting t/q_t against t , a straight line was obtained in all cases. The values of the second-order rate constants k and q_e were determined from the plots of the Eq. 6 (Fig. 2). These constants, the initial rate h of sorption at various initial concentrations and the regression coefficients for the linear plots are summarized in Table 1. The equilibrium sorption capacity (10.83 to 31.04 mg g^{-1})

Table 1: Pseudo-second order parameters for the sorption of Pb(II) by *Triplochiton scleroxyton* sawdust

Variables	q_e (mg g ⁻¹)	k (g mg ⁻¹ min)	h (mg g ⁻¹ min)	R ²
Pb concentration (mg L⁻¹)				
100	10.837	0.0720	8.460	0.9999
200	17.593	0.0520	16.094	0.9998
300	25.601	0.0340	22.283	0.9999
400	31.046	0.0290	27.954	0.9999
Sawdust dose (mg g⁻¹)				
5	22.270	0.0417	20.680	0.9998
10	17.608	0.0376	11.670	0.9995
15	13.200	0.0594	10.340	0.9997
20	10.837	0.0720	8.460	0.9999

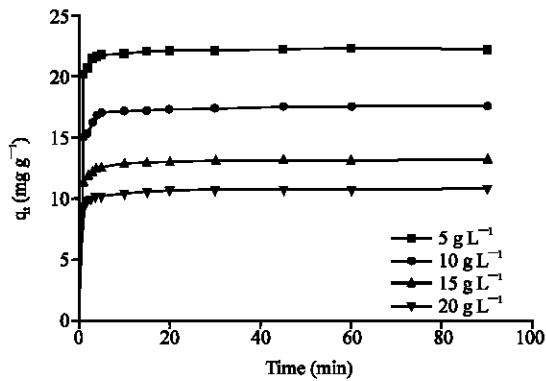


Fig. 3: Effect of sawdust dosage on the sorption of Pb(II) for 100 mg L⁻¹ of metal solution and pH 4

and the initial sorption rate (8.46 to 27.95 mg g⁻¹ min) increased with an increase in the initial lead ion concentration.

Effect of the quantity of sawdust: The effect of sawdust dosage on the kinetics of Pb(II) sorption is shown by Fig. 3. The results indicated that the amount of lead sorbed per unit mass of sorbent decreased with increase in sorbent dosage. The maximum uptake of Pb(II) was found to be 12.27, 17.60, 13.20 and 10.84 mg g⁻¹ for 5, 10, 15 and 20 g L⁻¹ of sawdust dosage (II). The decrease in the amount of lead sorbed with increasing sorbent dosage is due to the split in the flux or the concentration gradient between solute concentration in the solution and the solute concentration in the surface of the sorbent (Ghodbane *et al.*, 2008). Thus with increasing sorbent mass, the amount of lead sorbed onto unit weight of sorbent is reduced leading to a decrease in sorption capacity with increasing sorbent dose.

By plotting t/q_t against t , a straight line was obtained in all cases. The values of the second-order rate constants k and q_e were determined from the plots of the Eq. 6 (Fig. 4).

The coefficients of determination, R² (varying between 0.9995 and 0.9999, Table 1) are all higher than

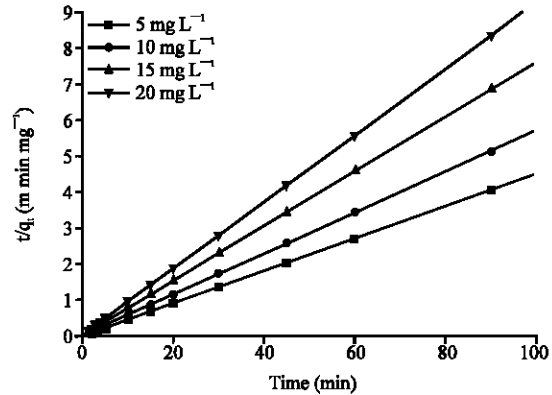


Fig. 4: Pseudo-second-order sorption kinetics of Pb(II) by sawdust at different dosage for 100 mg L⁻¹ of metal solution and pH 4

0.9995 indicating that the sorption of Pb(II) by sawdust was well represented by the pseudo-second-order kinetic equation. The equilibrium sorption capacity q_e decreased from 22.27 to 10.84 mg g⁻¹, when the sorbent dose of the system is changed from 5 to 20 g L⁻¹.

Ions exchanges: Ion exchange was proven the main mechanism involved in the sorption by biomass and there was a strong ionic balance between adsorbed (H⁺ and M²⁺) and released ions (Ca²⁺, Mg²⁺, K⁺ ...) from the biomass.

The study of the removal of the cations on the sawdust in the metal ions solutions and of water at pH 4 is showed an ion-exchange phenomenon. The concentrations at different time of Ca²⁺ (6.34-11.29 mg L⁻¹), Mg²⁺ (2.57- 4.09 mg L⁻¹) and K⁺ (22.83 -24.23 mg L⁻¹) leached in water (used as control) and in metal solution are shown in Table 2. In bidistilled water, the sawdust leaching is done according to the following order: (K⁺ > Ca²⁺ > Mg²⁺). In the metal solutions, the sawdust leaching is higher than the leaching in bidistilled water; showing an additional leaching during the metal sorption by sawdust. The obtained order of leaching was: K⁺ > Ca²⁺ >> Mg²⁺.

The net release at different time of Ca²⁺ (varying from 9.98 to 14 mg L⁻¹), Mg²⁺ (2.64 - 4.66 mg L⁻¹) and K⁺ (0.92-1.84 mg L⁻¹) due to the sorption process was calculated by subtracting the amount of cations released with water (control) to the amount of cations measured in the metal solutions after metal sorption process (Table 2). It appears that there was more Ca²⁺ cations released followed by Mg²⁺ and finally by K⁺ which takes tiny part in the ionic exchange (Ca²⁺ >> Mg²⁺ > K⁺).

We observed that the pH varies very little; from 4 to 4.5 in water and from 4 to 5.4 in lead solution. This

Table 2: Cations release during sorption of Pb(II) into *Triplochiton scleroxyton* Sawdust pH = 4, $C_o = 100 \text{ g L}^{-1}$

Time (min)	In double distilled water			In Pb(II) solution			Net released in Pb(II) solution		
	Ca ²⁺	Mg ²⁺	K ⁺	Ca ²⁺	Mg ²⁺	K ⁺	Ca ²⁺	Mg ²⁺	K ⁺
5	6.34	2.57	23.47	20.09	5.21	25.23	13,75	2,64	1,76
10	7.22	3.18	23.22	21.22	7.61	24.14	14,00	4,43	0,92
15	10.56	2.95	22.83	20.82	7.61	24.5	10,26	4,66	1,67
20	9.86	2.72	24,23	20.59	5.89	26.07	10,73	3,17	1,84
30	10.34	3.18	23.88	20.22	7.18	25.23	9,98	4,00	1,53
45	10.96	3.85	24.64	22.32	8.49	26.42	11,36	4,64	1,78
60	11.29	4.09	24.12	21.45	7.56	25.71	10,16	3,47	1,59
90	9.32	2.95	24.07	20.52	7.18	25.62	11,2	4,23	1,55
120	8.26	3.26	24.08	20.27	7.56	25.23	12,01	4,3	1,15

variation of pH is due to a reduction of the metal ions in solution but especially to the leaching of ions (Ca²⁺, Mg²⁺, K⁺) in solution by the sawdust (Adouby *et al.*, 2007).

Equilibrium studies

Single component system: The sorption isotherm represents the relationship between the amount adsorbed by a unit mass of solid sorbent and the amount of solute remaining in the solution at equilibrium.

Sorption data for wide range of adsorbate concentration are most conveniently described by sorption isotherms, such as the Langmuir and Freundlich isotherms. Langmuir sorption isotherm is the most widely used model for the sorption process and is based on monolayer coverage of sorbate on the surface of adsorbents. According to Langmuir theory, it has been assumed that adsorption occurs at a specific homogenous site within adsorbent; each site is occupied only by an adsorbate molecule, all sites are equivalent and there are no interactions between adsorbate molecules (Langmuir, 1918).

The non-linear form of Langmuir isotherm model can be represented by Eq. 8:

$$q_e = \frac{q_o b C_e}{1 + b C_e} \tag{8}$$

where q_e is the amount of metal sorbed per unit mass of sorbent, q_o is the maximum metal uptake per unit mass of sorbent (mg g^{-1}), C_e is the equilibrium concentration of sorbate in solution (mg L^{-1}) and b is the Langmuir constant related to energy of sorption (L mg^{-1}) which reflects quantitatively the affinity between the sorbent and the sorbate.

Linearization of Eq. 8 gives:

$$\frac{C_e}{q_e} = \frac{1}{b q_o} + \frac{1}{q_o} C_e \tag{9}$$

The values of the Langmuir constants b and maximum metal uptake q_o were calculated from the slope and intercept of the plot of C_e/q_e versus C_e .

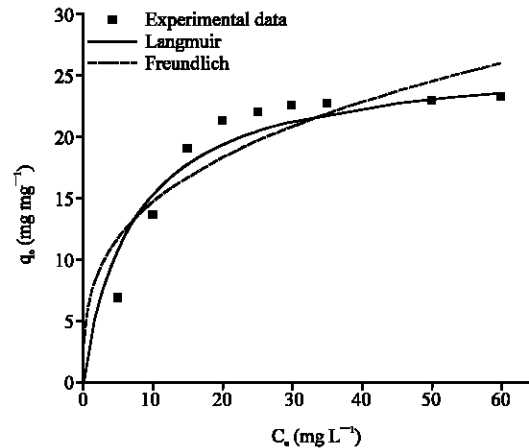


Fig. 5: Isotherms for the sorption of Pb(II) using sawdust for 100 mg L^{-1} of metal solution, *Triplochiton scleroxyton* sawdust dosage (2-25 g L^{-1}) and pH 4

Concerning the Freundlich equation, its empirical form is applicable to monolayer adsorption (Van der Waals adsorption) and multilayer adsorption (chemisorptions) (Fiol *et al.*, 2006). In this model, lateral interaction between the adsorbed molecules and energetic surface heterogeneity are taken into account.

The non-linear form of Freundlich isotherm model can be represented by Eq. 10:

$$q_e = K_f C_e^{1/n} \tag{10}$$

Linear form is:

$$\text{Ln}q_e = \text{Ln}K_f + \frac{1}{n} \text{Ln}C_e \tag{11}$$

where, K_f and $1/n$ are empirical constants relative to sorption capacity and sorption intensity, respectively. The values of K_f and n were calculated from the intercept and slope of the plot of $\text{Ln}q_e$ versus $\text{Ln}C_e$.

Figure 5 shows the Comparison of experimental equilibrium points with the theoretical equilibrium curves

Table 3: Langmuir and Freundlich isotherms constants for the sorption of Pb(II) by *Triplochiton scleroxylon* sawdust in single component

Constants	Non-linear model	Linear model
Langmuir		
q_0 (mg g ⁻¹)	26.3700	26.380
b (L mg ⁻¹)	0.1367	0.092
$\epsilon\%$	12.6600	10.050
R^2	0.9510	0.987
Freundlich		
K_f (mg g ⁻¹)	7.0100	5.010
$1/n$	0.3200	0.370
$\epsilon\%$	15.8100	13.810
R^2	0.7610	0.937

obtained from the non-linearized Langmuir and Freundlich sorption isotherms.

The average percentage errors ($\epsilon\%$) between the experimental and calculated values for the sorption isotherm models were evaluated using Eq. 12:

$$\epsilon\% = \frac{\sum_{i=1}^N \frac{|q_{e,exp} - q_{e,cal}|}{q_{e,exp}}}{N} \times 100 \quad (12)$$

The constants related to linear and non-linear form were calculated and listed in Table 3.

The average percentage error ($\epsilon\%$) and the coefficient of correlation (R^2) are the criteria used to select the most suitable isotherm model for a sorption process. According to Table 3, the correlation coefficients of the Langmuir isotherm (0.987) for linear model are high compared to those of non-linear models (0.951). It was also observed that the average percentage errors were smaller for linear model. These results indicated that Langmuir isotherm was more suitable for the experimental data compared to Freundlich isotherm because of the higher value of the coefficient of correlation and the smaller average percentage errors.

There is no remarkable difference between the values of q_0 calculated for the two Langmuir models; 26.37 mg g⁻¹ for non-linear model and 26.38 mg g⁻¹ for linear model. Similar results were found by two teams of researchers who studied Pb(II) uptake by sawdust. Li *et al.* (2007) under different conditions obtained maximum uptake of 21.05 mg g⁻¹ for Pb(II) with poplar sawdust while Taty-Costodes *et al.* (2003) found Pb(II) maximum uptake of 15.77 and 22.22 mg g⁻¹, respectively at pH 4 and 5 with Pine sawdust.

Effect of the presence of Cd(II) or Cu(II) in binary system:

Wastewaters usually contain more than single metal. The presence of more than one metal in wastewater is expected to cause interactive effects depending on reasons such as the number of metals competing for binding sites; the metal concentrations; the nature and dosage of the sorbent (Abu-Al-Rub *et al.*, 2006).

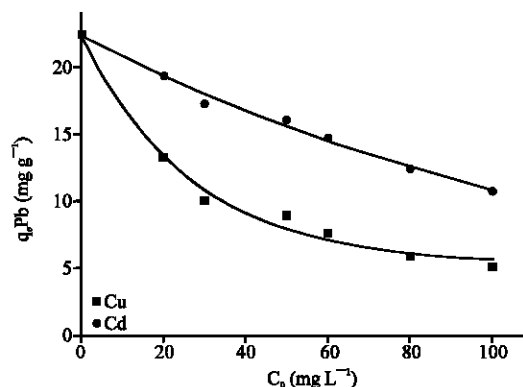


Fig. 6: The effect on sorption of lead when copper or cadmium in existence for 100 mg L⁻¹ of initial lead solution and pH 4

These studies were carried out in order to investigate the competitive effects in binary systems ((Pb-Cu) and (Pb-Cd)). The concentration of lead was maintained constant (100 mg L⁻¹) while varying the concentrations of other metal ions. The results (Fig. 6) showed that Pb(II) uptake decreases with the increasing of Cd(II) or Cu(II) initial concentration. Pb(II) uptake decreases from 22,43 to 5,1 mg g⁻¹ when the initial concentration of Cu(II) ranged from 0 to 100 mg L⁻¹. Pb(II) uptake decreases from 22,43 to 10,66 mg g⁻¹ when the initial concentration of Cd(II) ranged from 0 to 100 mg L⁻¹.

These results indicated that Pb(II) uptake is moderately affected by the presence of Cd(II) while the presence of Cu (II) affected to a significant degree Pb(II) uptake, even at relatively low concentrations of Cu(II).

The simultaneous sorption of Pb(II) with Cd(II) or Cu(II) by the sawdust was studied using a solution containing 100 mg L⁻¹ of each metal ion. The maximum uptake of Pb(II) (16.83 and 9.06 mg g⁻¹) in the binary system were shown in Table 4.

In binary system (Pb-Cd), the presence of the Cd(II) lead to the inhibition of the Pb(II) maximum uptake which decreased from 26.38 to 16.83 mg g⁻¹ (reduction of approximately 36%). This inhibition was more pronounced with (Pb-Cu) system; the capacity was reduced to 60%.

The observed reduction of Pb(II) maximum uptake in binary mixture can be due to the chemical interactions between these metals and also with the biomass resulting in the metal ions competition for the sorption sites on the surfaces of sawdust (Ziagova *et al.*, 2007).

A similar phenomenon had been observed in binary sorption of Pb(II) and Cu(II) on *Aspergillus flavus* (Akar and Tunali, 2006). This study revealed that Pb(II) and Cu(II) are in competition each other and that the capacities of biosorption of the metal ions of the binary

Table 4: Langmuir isotherms constants for the sorption of Pb(II) by *Triplochiton scleroxylon* sawdust in single, binary and ternary component

System	q_e (mg g^{-1})	b (L mg^{-1})	R^2
Pb	26.38	0.092	0.987
Pb(Pb-Cd)	16.83	0.077	0.963
Pb(Pb-Cu)	9.06	0.050	0.975
Pb(Pb-Cd-Cu)	8.33	0.065	0.917

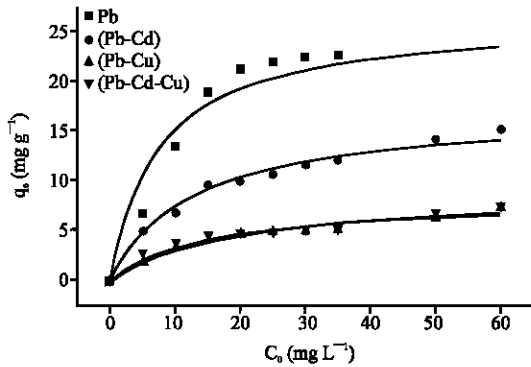


Fig. 7: Effect of the presence of copper or cadmium on lead sorption isotherm for 100 mg L⁻¹ of metals solutions, *Triplochiton scleroxylon* sawdust dosage (2-25 g L⁻¹) and pH 4

mixture were lower than the capacities of these same cations under non competitive conditions.

Effect of the presence of other metals in ternary system:

The results of the sorption of the ternary (Pb-Cd-Cu) system on sawdust are shown in Fig. 7 also the Langmuir constants and coefficient of correlation (R^2) is summarized in Table 4. In ternary solution, the maximum uptake of Pb(II) was 8.33 mg g⁻¹ whereas it was 26.38 mg L⁻¹ in single system. This value is close to that obtained in binary solution with Cu(II) (9.06 mg g⁻¹). This result shows once more that the presence of Cd(II) has little effect on the maximum uptake of Pb(II). Similar results were obtained with Al-Asheh and Duvnjak (1997), who compared the capacity of several metal cations (Cd, Cu, Pb and Ni) in binary, ternary and quaternary mixtures. This study showed that in binary mixture Cd(II) has little effect on the capacity of sorption of Pb(II) compared to Cu(II) and that in ternary mixture (Pb-Cd-Cu), the maximum uptake of Pb(II) was close to that found in binary mixture with Cu(II).

Desorption of Pb(II) and regeneration of the sawdust: The metal sorbed on the sawdust can be desorbed by a suitable solution of desorption, thus the sawdust can be employed in successive sorption/desorption cycles. Various solutions of desorption: double distilled water and 0.2 M of HCl, HNO₃, H₂SO₄, CaCl₂, NaCl and EDTA)

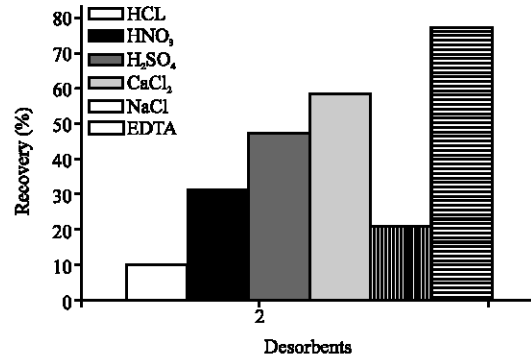


Fig. 8: Recovery of lead from *Triplochiton scleroxylon* sawdust using different desorbents

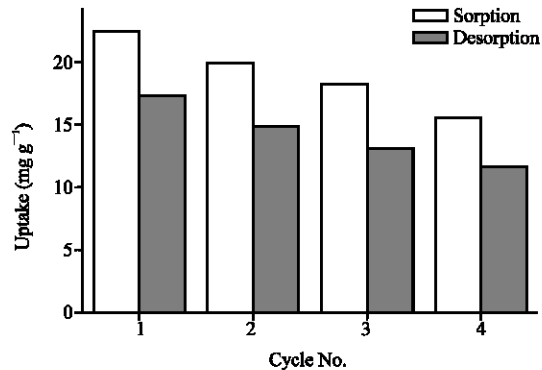


Fig. 9: Adsorption/desorption cycles of lead for *Triplochiton scleroxylon* sawdust

were used for desorption of Pb(II) off the sawdust. The effectiveness of desorption is expressed by the difference between Pb(II) quantity in solution after desorption and the quantity adsorbed by the sawdust.

Figure 8 expresses the percentage of Pb(II) (2.11, 9.87, 20.82, 31.28, 58.61 and 77.29% with H₂O, HCl, NaCl, HNO₃, H₂SO₄, CaCl₂ and EDTA respectively) desorbed after treatment with the various solutions. It was observed that the EDTA (77.29% of recovery) was the most effective among all the studied desorbents while desorption with double distilled water (2.11%) was almost negligible (Vijayaraghavan *et al.*, 2006).

The Pb(II) sorbed on the sawdust were desorbed with 0,2 M of EDTA, this process was repeated four times. The results (Fig. 9) show that the sawdust could be employed on several occasions for sorption process without significant losses of its initial capacity of adsorption. It was observed that the quantity of Pb(II) absorbed decreases with each reuse of the sawdust. This is due to the non leaching of previously sorbed ions that resisted to the desorption process.

CONCLUSION

This study showed the potentiality offers by the sawdust of *Triplochiton scléroxylon* for the sorption of Pb(II) in wastewater. The kinetic study of Pb(II) on the sawdust was fast and proved to obey to a pseudo-second kinetic order. The rate of Pb(II) sorption on sawdust was determined as a function of the initial metal concentrations and sawdust dose.

Ion exchange was proven to be the main mechanism involved in the sorption of Pb(II) by sawdust.

The obtained coefficient of correlation and the average percentage error indicated that the sorption of lead by the sawdust was described better by applying linear Langmuir model. The maximum uptake of sorption is 26.38 mg g⁻¹ in single component. In binary system the presence of the Cd(II) and Cu(II) resulted in the inhibition of the Pb(II) maximum uptake which decreased from 26.38 mg g⁻¹ to 16.83 mg g⁻¹ with Cd(II) and to 9.06 mg g⁻¹ in the presence of Cu.

This study shows that sawdust of *Triplochiton scléroxylon* is a suitable material for the removal of the lead from a liquid waste in successive cycles of sorption/desorption after the optimization of various physicochemical parameters of the effluent.

REFERENCES

- Abia, A.A., O.B. Didi and E.D. Asuquo, 2006. Modeling of Cd²⁺ sorption kinetics from aqueous solutions onto some thiolated agricultural waste adsorbents. J. Applied Sci., 6: 2549-2556.
- Abu-Al-Rub, F.A., M.H. El-Naas, I. Ashour and M. Al-Marzouqi, 2006. Biosorption of copper on *Chlorella vulgaris* from single, binary and ternary metal aqueous solutions. Process Biochem., 41: 457-464.
- Adouby, K., L.C. Koffi Akissi, N. Eboua Wandan and B. Yao, 2007. Removal of heavy metal ions (Pb²⁺, Cu²⁺) in aqueous solutions by pterygota macrocarpa sawdust. J. Applied Sci., 7: 1864-1872.
- Akar, T. and S. Tunali, 2006. Biosorption characteristics of aspergillus flavus biomass for removal of Pb(II) and Cu(II) ions from an aqueous solution. Bioresour. Technol., 97: 1780-1787.
- Al-Asheh, S. and Z. Duvnjak, 1997. Sorption of cadmium and other heavy metals by pine bark. J. Hazard. Mater., 56: 35-51.
- Bulut, Y. and Z. Tez, 2007. Adsorption studies on ground shells of hazelnut and almond. J. Hazard. Mater., 149: 35-41.
- Dang, V.B.H., H.D. Doan, T. Dang-Vu and A. Lohi, 2009. Equilibrium and kinetics of biosorption of cadmium(II) and copper(II) ions by wheat straw. Bioresour. Technol., 100: 211-219.
- Fiol, N., I. Villaescusa, M. Martinez, N. Miralles, J. Poch and J. Serarols, 2006. Sorption of Pb(II), Ni(II), Cu(II) and Cd(II) from aqueous solution by olive stone waste. Sep. Purification Technol., 50: 132-140.
- Ghodbane, I., L. Nouri, O. Hamdaoui and M. Chiha, 2008. Kinetic and equilibrium study for the sorption of cadmium(II) ions from aqueous phase by eucalyptus bark. J. Hazard. Mater., 152: 148-158.
- Gupta, V.K. and I. Ali, 2004. Removal of lead and chromium from wastewater using bagasse fly ash-a sugar industry waste. J. Colloid Interface Sci., 271: 321-328.
- Han, R., H. Li, Y. Li, J. Zhang, H. Xiao and J. Shi, 2006. Biosorption of copper and lead ions by waste beer yeast. J. Hazard. Mater., 137: 1569-1576.
- Ho, Y.S., J.F. Porter and G. McKay, 2002. Equilibrium isotherm studies for the sorption of divalent metal ions onto peat: Copper, nickel and lead single component. Water Air Soil Pollut., 141: 1-33.
- Ho, Y.S., W.T. Chiu, C.S. Hsu and C.T. Huang, 2004. Sorption of lead ions from aqueous solution using tree fern as a sorbent. Hydrometallurgy, 73: 55-61.
- Khan, M.N. and M.F. Wahab, 2007. Characterization of chemically modified corncobs and its application in the removal of metal ions from aqueous solution. J. Hazard. Mater., 141: 237-244.
- Khormaei, M., B. Nasernejad, M. Edrisi and T. Eslamzadeh, 2007. Copper biosorption from aqueous solutions by sour orange residue. J. Hazard. Mater., 149: 269-274.
- Kumar, Y.P., P. King and V.S.R.K. Prasad, 2006. Zinc biosorption on *Tectona grandis* L.f. leaves biomass: Equilibrium and kinetic studies. Chem. Eng. J., 124: 63-70.
- Langmuir, I., 1918. The adsorption of gases on plane surfaces of glass, mica and platinum. J. Am. Chem. Soc., 40: 1361-1403.
- Li, Q., J. Zhai, W. Zhang, M. Wang and J. Zhou, 2007. Kinetic studies of adsorption of Pb(II), Cr(III) and Cu(II) from aqueous solution by sawdust and modified peanut husk. J. Hazard. Mater., 141: 163-167.
- Martins, B.L., C.V.C. Cruz, S.L. Aderval and C.A. Henriques, 2006. Sorption and desorption of Pb²⁺ ions by dead *Sargassum* sp. biomass. Biochem. Eng. J., 27: 310-314.
- Nehrenheim, E. and J.P. Gustafsson, 2008. Kinetic sorption modelling of Cu, Ni, Zn, Pb and Cr ions to pine bark and blast furnace slag by using batch experiments. Bioresour. Technol., 99: 1571-1577.

- Nouri, L., I. Ghodbane, O. Hamdaoui and M. Chiha, 2007. Batch sorption dynamics and equilibrium for the removal of cadmium ions from aqueous phase using wheat bran. *J. Hazard. Mater.*, 149: 115-125.
- Ofomaja, A.E. and Y. Ho, 2007. Effect of pH on cadmium biosorption by coconut copra meal. *J. Hazard. Mater.*, 139: 356-362.
- Oliveira, E.A., S.F. Montanher, A.D. Andrade, J.A. Nobrega and M.C. Rollemberg, 2005. Equilibrium studies for the sorption of chromium and nickel from aqueous solutions using raw rice bran. *Process Biochem.*, 40: 3485-3490.
- Shukla, A., Y.H. Zhang, P. Dubey, J.L. Margrave and S.S. Shukla, 2002. The role of sawdust in the removal of unwanted materials from water. *J. Hazard. Mater.*, 95: 137-152.
- Taty-Costodes, V.C., H. Fauduet, C. Porte and A. Delacroix, 2003. Removal of Cd(II) and Pb(II) ions, from aqueous solutions by adsorption onto sawdust of *Pinus sylvestris*. *J. Hazard. Mater.*, B105: 121-142.
- Vijayaraghavan, K., K. Palanivelu and M. Velan, 2006. Biosorption of copper(II) and cobalt(II) from aqueous solutions by crab shell particles. *Bioresour. Technol.*, 97: 1411-1419.
- Wang, X., Y. Qin and Z. Li, 2006. Biosorption of zinc from aqueous solutions by rice bran: Kinetics and equilibrium studies. *Separat. Sci. Technol.*, 41: 747-756.
- Wong, K.K., C.K. Lee, K.S. Low and M.J. Haron, 2003. Removal of Cu and Pb by tartaric acid modified rice husk from aqueous solutions. *Chemosphere*, 50: 23-28.
- Ziagova, M., G. Dimitriadis, D. Aslanidou, X. Papaioannou, E.L. Tzannetaki and M. Liakopoulou-Kyriakides, 2007. Comparative study of Cd(II) and Cr(VI) biosorption on *Staphylococcus xylosus* and *Pseudomonas* sp. in single and binary mixtures. *Bioresour. Technol.*, 98: 2859-2865.
- Zuhairi, A.A., B. Salamatinia and A.H. Kamaruddin, 2007. Removal of Zn and Cu from wastewater by sorption on oil palm tree-derived biomasses: A Preliminary study. *J. Applied Sci.*, 7: 2020-2027.