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Isotherms studies for the removal of Pb(II) from aqueous solutions using by activated carbon prepared from Banana peel

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Abstract

In the present work the ability to remove Pb (II) from aqueous solutions has been studied using by Banana peel (BP) as adsorbent. Effects of pH, concentration of the Pb (II), contact time and adsorbent dosage have been studied. The optimum conditions of biosorption were found to be: pH 5, initial Pb (II) concentration: 20 mg.L^{-1}, contact time of 60 min and a BP dose of 0.48 g L^{-1}, respectively. In optimum condition, removal efficiency was 88.45%.Equilibrium isotherms for the adsorption of the Pb (II) were measured experimentally. Results were analyzed by the Langmuir and Freundlich equations at different temperatures and determined the characteristic parameters for each adsorption isotherm. The results showed that the equilibrium adsorption of Pb (II) onto banana peel was best described by Langmuir isotherm model and the Langmuir model was found to fit the data significantly better than Freundlich model. The maximum biosorption capacity of BP for Pb(II) was found to be 400.0 mg g^{-1}at 45 °C

Key words: Banana peel, Adsorption, Pb (II), Isotherm, Langmuir, Freundlich, aqueous solutions

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1. Introduction

Toxic heavy metals are released into the biosphere through industrial activities and spread into the environment. Their presence in the environment can be detrimental to people, plants and animals. These inorganic micro-pollutants are nonbiodegradable, highly toxic and have a suspected carcinogenic effect [1]. They can accumulate in water, soil, plants and living tissues, thus becoming concentrated throughout the food chain. Lead is one of these toxic heavy metals largely disseminated in atmosphere, soils and waters [2]. Toxicological studies have shown that the ingestion and inhalation effects of Pb (II) on human health, includes red blood cells and nervous systems attack and kidneys damage as reported by Burriel et al. [3], Moore et al. [4], and Shujing et al. [5]. As Pb (II) does not degrade biologically, its removal from wastewaters remains an important challenge. Adsorption of lead on appropriate adsorbents among other expensive methods such as chemical precipitation, ultrafiltration, electrochemical deposition, is highly efficient because of its simplicity of feasibility, low consumption of energy and great adsorption capacity for metal ions. The generalization in the entire world of the use of commercial activated carbons is knocked against their high cost. Therefore, to obtain activated carbons of low-cost and always available, many raw materials from the agricultural biomass and woodwork wastes were tested for their potential in the adsorption process. Activated carbons prepared from coconut shell and sawdust have been used [6-9].

In this work, batch experiments were carried out to evaluate the adsorption characteristics of the modified PB for Pb(II) removal from aqueous solutions.

2. Material and Methods

2.1 Preparation of adsorbent

Banana peel (BP) was first washed several times with hot deionized water to remove the impurities, and then dried in an oven at 105 ^{0}C for 24 h, and was crushed into smaller pieces and then was placed in a vertical stainless steel reactor and heated in a furnace at a rate of 10 °C/min from room temperature to 450 °C. The black residue was cooled and sieved to get BP carbon with an average particle size of 0.125 mm and finally stored in air glass container. The materials were mixed in a 1:1 wt ratio with concentrated H_3PO_4 and allowed to soak for 24 h at room temperature. The samples were placed in an oven and heated to 105ºC where they were held for 24 h. After this, the samples were allowed to cool and back to room temperature. Then, the samples were washed with distilled water and soaked in1% NaOH solution to remove any remaining acid. The samples were then washed with distilled water until pH of the activated
carbon reached 6 and then dried at 105°C for 24 h and sieved to the particle size 0.120 to 0.125 mm .

2.2 Batch adsorption experiments

Batch experiments were conducted in order to study the effect of important parameters such as pH, contact time and the initial ion concentration on the removal of Pb(II) using by BP. For the batch adsorption experiments, 25 ml solution of Pb (II) of initial concentration 50 mgL^{-1} was contacted with 12 mg BP. The contents were placed in a stirrer and gently agitated at 150 rpm. The solution was filtered, and the residual Pb(II) ion concentration was analyzed. The effect of the initial pH onto the BP was studied across a pH range of 2.0-11.0. The effect of the initial concentration and contact time on the uptake of the Pb(II) ions were conducted by varying the ion concentration from 20.0 to 200.0 mgL^{-1} and different contact times (0.0-120.0 min), respectively. The percent of Pb(II) removal(R%) and the amount of adsorbed Pb(II) at equilibrium, q_e, were calculated as follows:

$$R\% = [\frac{C_i - C_e}{C_i}] \times 100 \quad (1)$$

$$q_e = \frac{(C_i - C_e)V}{m} \quad (2)$$

where C_e and C_i are the equilibrium and initial concentrations of Pb(II) (mgL^{-1}), respectively; q_e is equilibrium Pb(II) concentration on adsorbent (mgg^{-1}); V is the volume of Pb(II) solution (L); m is the mass of BP used (g).

3. Results and Discussion

3.1 Effect of initial pH

Solution pH is a significant control parameter affecting the biosorption process. Batch experiments were conducted at different initial pH values ranging from 2.0 to 11.0. Pb (II) solutions (50 mg L^{-1}) were brought into contact with the biosorbent (0.012 mg) at 25 ± 1°C for 60 min. The effect of pH on the removal efficiency of Pb (II) ions is presented in Fig. 1. The results indicate that the increase in pH of the solutions from 2.0 up to the range 5.0, causes a rapid increase in the removal efficiency from aqueous solutions for the investigated metal ion. With a further increase in pH to 6, the amount of metal ion removed by BP will reach equilibrium state. Heavy metal cations seemed to be mostly unsorbed at low pH values. Minimal adsorption at high solution acidity could be explained by a high concentration and mobility of H^+ ions. That is why, in comparison to lead ions, hydrogen ions were adsorbed first on the sorption sites. An increase in metal ion desorption capacity with an increase in H^+ ion concentration indicated that the adsorption process was probably carried out via an ion exchange mechanism [10]. At decreased acid concentration, metal ions in solution entered into competition with H^+ ions for the sorption sites, according not only to the mass transfer law but also to their chemical and physical properties [10].

3.2 The effect of initial metal ions concentration

The effect of initial metal concentration on the adsorption efficiency of BP is shown in Fig. 2. Adsorption experiments were carried out at different initial Pb(II) concentrations ranging from 20 to 200 mg L^{-1}in metal ion solution. It was observed as a general trend that there is a decrease of the removal percentage with increase in initial concentration. The maximum removal of Pb (II) was attained at 25 ºC, pH 5.0, 150 rpm and adsorbent dose of 0.48 $g.L^{-1}$ in 20 mg L^{-1}.On changing the initial concentration of Pb(II) solution from 20 to 200 $mg.L^{-1}$, the amount adsorbed increased from 32.55 $mg \cdot g^{-1}$ (97.65 % removal) to 193.00 $mg \cdot g^{-1}$ (57.90 % removal).

3.3 Effect of contact time

To determine the dependence of Pb (II) sorption on time, 0.012 g of BP was exposed to a 25 ml metal solution of Pb(II) ion with initial concentration 20.0 $mg.L^{-1}$,at 25 ± 1°C and pH 5.0, in the batch process. The residual metal concentration in aqueous solution was determined after a contact time of 0-120 min (Fig. 3). Metal uptake, as a function of contact time, was noticed to occur in 2 phases. The first phase was extremely rapid in the case of all investigated metal, regardless of the influence of metal nature. The maximum adsorption efficiency was observed in the first 20 min of sorbent-sorbate contact, which was followed by a slow phase of metal removal spread over a longer period until equilibrium was reached (Fig. 3).The sorption equilibrium was attained after 60 min of contact time, when 99.92 of Pb(II) ions were removed.

3.4 Langmuir and Freundlich adsorption isotherms

The sorption data was subjected to Langmuir and Freundlich adsorption isotherms. The equilibrium data for single metal solutions was correlated with the Langmuir isotherm according
the following equation [11,12]:

$$q_e = \frac{q_{max} b C_e}{1 + b C_e} \quad (3)$$

The Langmuir equation can be rearranged in a linear equation form and rewritten as follows:

$$\frac{C_e}{q_e} = \frac{C_e}{q_{max}} + \frac{1}{q_{max} b} \quad (4)$$

where q_e is the amount of adsorbed material at equilibrium (mg g^{-1}), C_e is the equilibrium concentration (mg L^{-1}), b is the energy or net enthalpy of adsorption constant (L mg^{-1}), and q_{max}
is the Langmuir constant related to maximum adsorption capacity. When C_e /q_e was plotted against C_e, straight lines with slope of $1/q_{max}$ were obtained. Constants of the model, b and q_{max}
were calculated and these values are given in Table 1.
The adsorption capacity was found to increase with rising temperature, which reveals the endothermic nature of the ongoing process.
Another mathematical model used to fit the data obtained in this study was the Freundlich isotherm [13-15]. This model is known for its good fit of data over a wide range of

concentrations. It gives an equation that includes the heterogeneity of the surface of the ion exchanger and the exponential distribution of active sites and their energies. The Freundlich equation is given by:

$$\log q_e = \frac{1}{n}\log C_e + \log K_f \quad (5)$$

where q_e is the amount of adsorbed metal at equilibrium (mg g^{-1}), C_e is the equilibrium concentration of the adsorbate (mg L^{-1}) and K_f and n are Freundlich constants related to adsorption capacity and adsorption intensity, respectively.

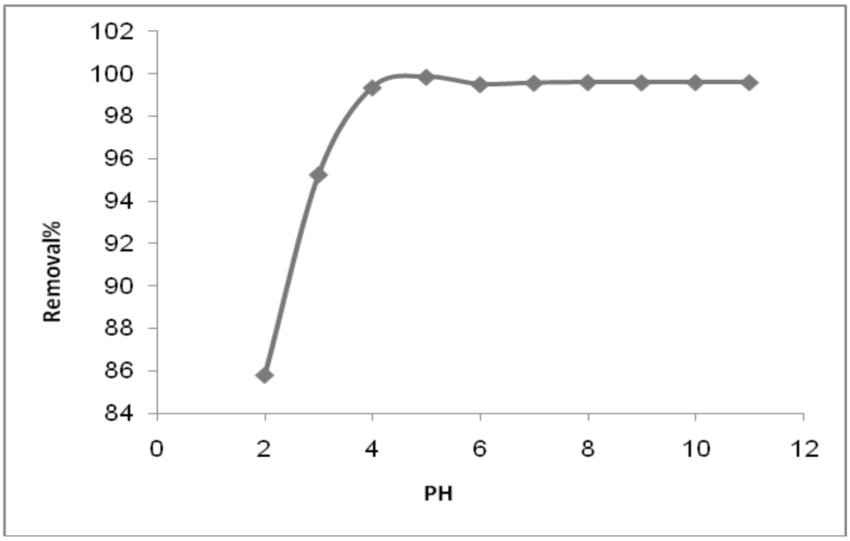

Fig. 1. Effect of pH on removal of Pb(II) ions from solutions using by BP. Contact time: 60 min, BP: (0.48 g L^{-1}), initial Pb(II) concentration: 50 mg L^{-1}, temperature: 25 ± 1°C

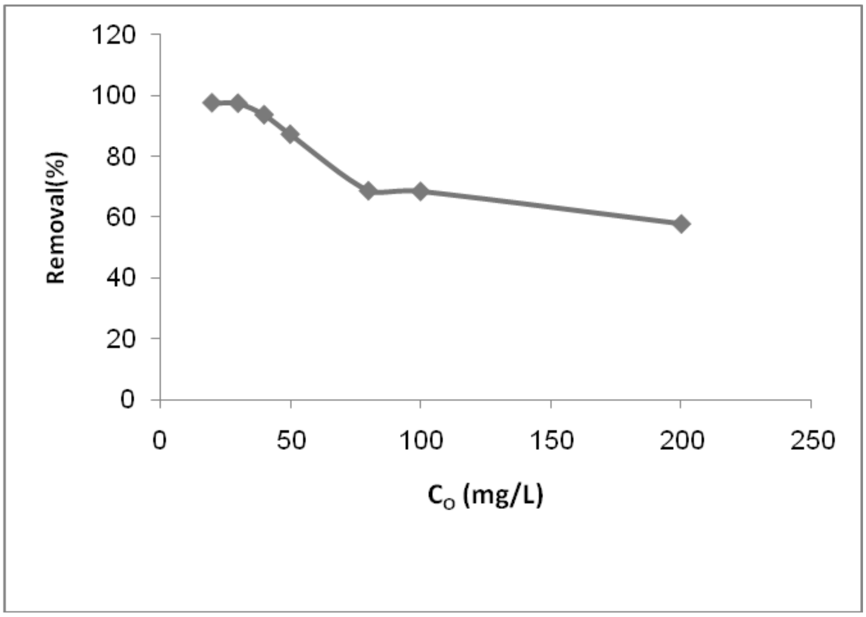

Fig. 2. Effect of initial metal concentration on removal of Pb (II) ions from solutions using by BP. Contact time: 60 min, BP: (0.48 g L^{-1}), pH: 5, temperature: 25 ± 1°C

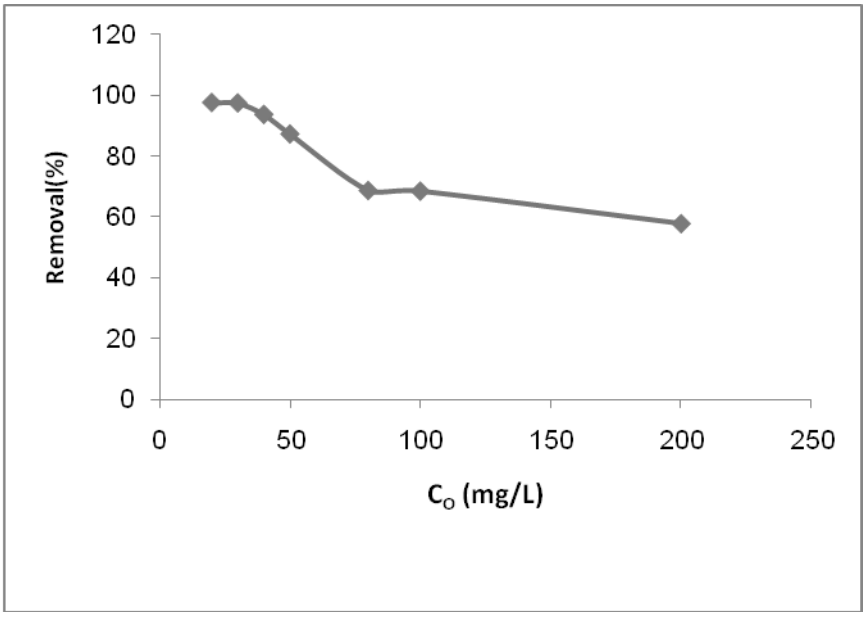

Fig. 2. Effect of initial metal concentration on removal of Pb (II) ions from solutions using by BP. Contact time: 60 min, BP: (0.48 g L^{-1}), pH: 5, temperature: 25 ± 1°C

Table 1. Langmuir parameters for adsorption of Pb(II) ion on BP at different temperatures

t(°C)	**25**	**35**	**45**
R^2	0.8157	0.9855	0.9933
b(L.mg^{-1})	0.68	0.83	1.92
q_{max}(mg.g^{-1})	322.58	400.00	400.00

Table 2.Freundlich parameters for adsorption of Pb(II) ion on BP at different temperatures

t(°C)	**25**	**35**	**45**
$\mathbf{R^2}$	0.9489	0.9895	0.7553
K_f($\left(\frac{mg}{g}\right)L/mg^{1/n}$)	102.84	153.39	212.91
1/n (L.g^{-1})	0.337	0.382	0.392

The plot of log q_e against log C_e was plotted for the adsorption data and straight lines with slope of 1/n were obtained, constant of the model, K_f was calculated and these values are given in Table 2.
The good correlation coefficients show that the Langmuir model is suitable to predict the adsorption equilibrium state of (Pb(II).

4 Conclusions

The feasibility of using a new adsorbent derived from Banana peel for the rapid removal of Pb(II) from aqueous solutions was studied. The following conclusions can be drawn from the present study:

•Batch adsorption studies show that approximately 99.85% of the Pb(II) are removed at pH 5.0. •Efficient and rapid adsorption takes place within only 20 min contact time.
•The equilibrium isotherm analysis indicates that the experimental adsorption data of Pb(II) onto BP follows the Langmuir isotherm.
•Low cost of this adsorbent with its rapid adsorptive capability offers a promising technique for partial treatment of industrial wastewaters.

References

[1] G. Cimino., A. Passerini and G. Toscano. (2000). Removal of toxic cations and Cr(VI) from aqueous solution by hazelnut shell. Water Res. 34. 2955-2962.

[2] F. Eba., R. Kouya., J. Ndong Nlo., Y.G. Bibalou and M. Oyo. (2011). Lead removal in aqueous solution by activated carbons prepared from Colas edulis shell (Alocaceae). Penthaclethra macrophylas husk (Mimosaceae) and Aucoumea klaineana sawdust (Burseraceae). African Journal of Environmental Science and Technology. 5.3.197-204.

[3] M.F. Burriel., F. Lucena Conde., S. Arribas Jimeno and J. Hernández Méndez. (1989). Química Analítica Cualitativa. Paraninfo Ed. Madrid.

[4] J.M. Moore and S. Ramamorthy., (1994). Heavy metals in natural waters.Springer Verlag. New-York.

[5] Z. Shujing., H. Haobo and X. Yongjie. (2008). Kinetic and isothermal studies of lead ions adsorption onto bentonite. Applied Clay Science. 40. 171-178.

[6] S. Gueu., B. Yao., K. Adouby and G. Ado. (2006). Heavy metals removal in aqueous solution by activated carbons prepared from coconut shell and seed shell of the palm tree. Journal of Applied Sciences. 6.13. 2789-2793.

[7] M. Serkar., V. Sakthi and S. Rengaraj. (2004). Kinetics and equilibrium adsorption study of lead (II) onto activated carbon prepared from coconut shell. Journal of Colloid and Interface Science. 279.2. 301-307.

[8] J. Avom., J. Mbadcam., J. Ketcha., M. Math and P. Germain. (2001). Adsorption isotherme de l'acide acétique par des charbons d'origine végétale. African Journal of Environmental Science and Technology. 2. 2. 1-7.

[9] K.M. Kifuani., W.M. Mukana., V. Noki., E.A. Musibono., P. Nzuzi., P. Pungi and B. Kunyima. (2004). Adsorption de bleu de methylene en solution aqueuse sur charbon actif obtenu à partir des sciures végétales préparation et caractérisation du charbon actif. Revue Congolaise des Sciences Nucléaires. 20.1-2. 215-224.

[10] D.L. Mitic-Stojanovic. (2011). Biosorptive removal of Pb^{2+}. Cd^{2+} and Zn ionsfrom water by Lagenaria vulgaris shell. Water SA . 37.3. 303-312.

[11] I. Langmuir. (1918). The adsorption of gases on plane surfaces of glass. micra and platinum. Journal of the American Chemical Society. 40. 1361-1402.

[12] M. Ghasemi., Mu. Naushad., N. Ghasemi and Y. Khosravi-Fard. (2014). A novel agricultural waste based adsorbent for the removal of b(II) from aqueous solution: Kinetics. equilibrium and thermodynamic studies. Journal of Industrial and Engineering Chemistry. 20 .454–461.

[13] N.O. Alti., H. Özbelge and T. Dogu. (1998). Use of general pur pose adsorption isotherms for heavy metal-clay mineral interactions. Journal of Colloid and Interface Science. 198.130-140.

[14] A. Ahmadpour., M. Zabihi., M. Tahmasbi and T. Rohani Bastami. (2010). Effect of adsorbents and chemical treatments on the removal of strontium from aqueous solutions. Journal of Hazardous Materials. 182.552–556.

[15] M. Ghasemi., Mu. Naushad., N. Ghasemi and Y. Khosravi-Fard. (2014). Adsorption of Pb(II) from aqueous solution using new adsorbents prepared from agricultural waste: Adsorption isotherm and kinetic studies. Journal of Industrial and Engineering Chemistry. 20. 2193–2199.