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Adsorption of Pb^{2+} Ions in Aqueous Solution by Activated Carbon

Dang Ngoc Ly

*Faculty of Food Technology, Ho Chi Minh City University of Food Industry,
Ho Chi Minh City, 700000 Vietnam, Email: lydn@hufi.edu.vn*

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ABSTRACT

This study presents the synthesis of activated carbon material by simple thermal treatment of bamboo wood. The synthetic AC shows an amorphous and porous structure. The adsorption of lead ions on synthetic AC was effectuated. The obtained results show that the synthetic AC has a high ability for lead ions removal with high efficiency of 97% after 2 hours of adsorption experiment. The isotherm study showed that lead removal is suitable for both the Langmuir and Freundlich models with a high value of correlation coefficient (R^2 = 0.97). The maximum capacity of lead ions removal is high (Q_m = 24570 mg/g). Summing up, AC material synthesized from bamboo wood presents a potential material for lead ions removal from the aqueous solution.

Keywords: *Lead ions, Activated carbon, Adsorption, Heavy metal, Removal, Isotherms.*

1. Introduction

Heavy metal pollution due to industrial development is a serious problem and harmful to public health [1,2]. In particular, lead metal pollution in the form of lead II ions is quite common because its origin comes from several key production fields such as construction, battery production, and metallurgy. When exposed to certain levels, lead is toxic to animals as well as humans. It damages the nervous system and causes brain disorders. Exposure at high levels causes disorders of the blood, nervous system, and joints [3].

One of the ways to treat water contaminated with lead ions in particular and contaminated with metal ions, in general, is popularly applied, is the ion exchange method [4,5]. Ion exchange is the process of separating unwanted ions from an existing solution and replacing them with other ions. This method has advantages such as being environmentally friendly, does not use any chemicals to treat wastewater, and bringing standard output water quality before being discharged into the environment. However, the relatively high investment and operating costs are the disadvantages of this method.

Therefore, the use of a simple, efficient, and low-cost method can have wide applications. In recent years, activated carbon (AC) synthesized from various agricultural waste products has been studied and used as an effective lead ion adsorbent [6,7]. In this study, we present the low-cost activated carbon synthesized from bamboo wood, which is used for lead removal from the aqueous solution. The physical-chemical characterization of synthetic AC and its ability for lead adsorption are evaluated.

2. Materials and Methods

2.1. Synthesis of Activated carbon (AC) from bamboo wood

AC material is prepared by a simple thermal method. Fresh bamboo was cut into pieces of 5cm(wide)*10cm (long). The samples were dried naturally, then put directly in an oven at 1000°C for 5 hours at a heating rate of 10°C.

2.2. Experiment of Pb (II) ion adsorption

The experiment of Pb^{2+} ion adsorption from aqueous solution was effectuated following the previous study [6]. The solutions of Pb^{2+} ion were prepared by dissolving $Pb(NO_3)_2$ in distilled water. The adsorption experiments of Pb^{2+} ion were carried out by soaking 20 mg of AC material in 100 mL of lead solution. The mixtures were stirred at the speed of 50 rpm at room temperature for different periods of contacting-times. At the end of the experiments, the mixtures were filtered to obtain the liquid solutions. The remaining solutions were measured to determine the remaining lead amounts. The percentages of lead ions removal are identified by the following equation,

$$\text{Lead removal (\%)} = \frac{C_0 - C_f}{C_0} * 100\% \quad (1)$$

where C_0 is the initial concentration, and C_f is the final concentration.

2.3. Characterization

Several physical-chemical techniques were used for the characterization of synthetic activated carbon. The phase analysis of synthetic AC was identified by X-ray Diffraction (XRD). The morphology was observed by Scanning Electron Microscopy (SEM). The textural structure was evaluated by the BET method based on N_2 adsorption/desorption. The lead ion contents in solutions were identified by Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES).

3. Results and discussion

3.1. XRD analysis

The x-ray diffraction (XRD) pattern shows that the activated carbon (AC) material has an amorphous structure, represented by a wide diffraction halo, and does not appear any crystal peaks. This result is similar to the previous study [7],[8], confirming the success of the activated carbon material synthesis in this study.

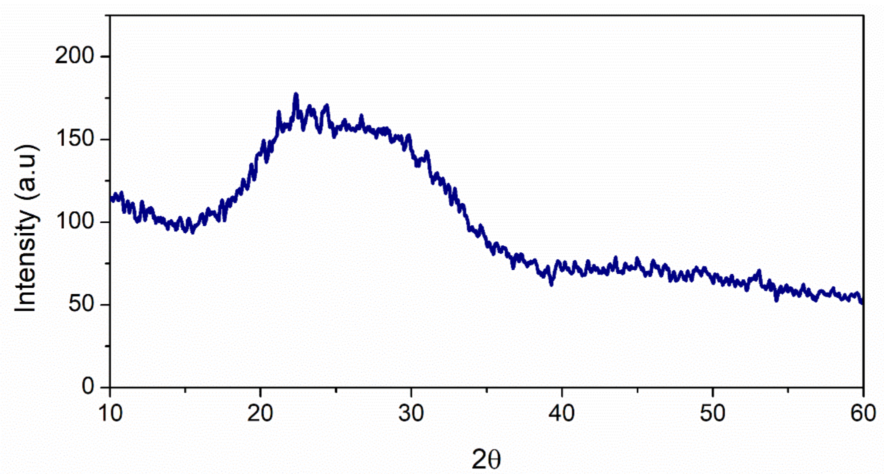

Fig.1. XRD diagram of synthetic activated carbon

3.2. SEM observation

The SEM image clearly shows the 3D porous structure of the activated carbon material, similar to the previous study [8]. However, the structure of AC material in this study clearly shows the interwoven layers, creating the porous structure of the material. Porosity is a very important property of activated carbon materials in creating a large specific surface area, as well as increasing the adsorption capacity of the material.

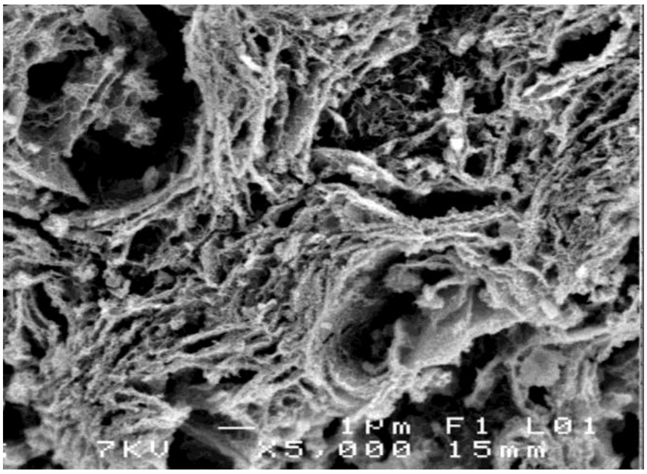

Fig.2. SEM observation of synthetic activated carbon

3.3. BET analysis

The textural characteristics for pore volume and surface area were evaluated by the BET method based on N_2 adsorption/desorption. Experiments were performed for 4 separate samples of activated carbon materials. The obtained data are shown in Table 1. The average calculated result for pore volume of 0.963 (cm^3/g), and specific surface area of 970.625 (m^2/g). These are quite high values for synthetic activated carbon compared to previous studies [7],[8].

Table 1. Textural data of synthetic AC

Samples	**Pore volume (cm^3/g)**	**BET specific surface area (m^2/g)**
1	0.93	960.2
2	0.97	970.5
3	0.96	980.5
4	0.99	971.3
Average values	0.963	970.625

3.4. Lead ion adsorption on synthetic AC in aqueous solution

3.4.1. Effect of pH on the Pb^{2+} ion removal

To select the optimal value of pH for Pb^{2+} ion removal, a series of experiments was carried out at Pb^{2+} concentration of 20 (mg/L); AC dose of 0.2g/100mL; and contacting time of 2h. The obtained data showed that the capacity of lead ion removal increased sequentially in the pH range from 1-5, then the lead ion removal decreased gradually in the pH range from 5-10. At a pH value of 5, the lead removal is 97%, confirming the efficiency of synthetic activated carbon in this study for lead ion removal. From obtained analysis, the optimal value of pH for lead ion adsorption by activated carbon material is 5.

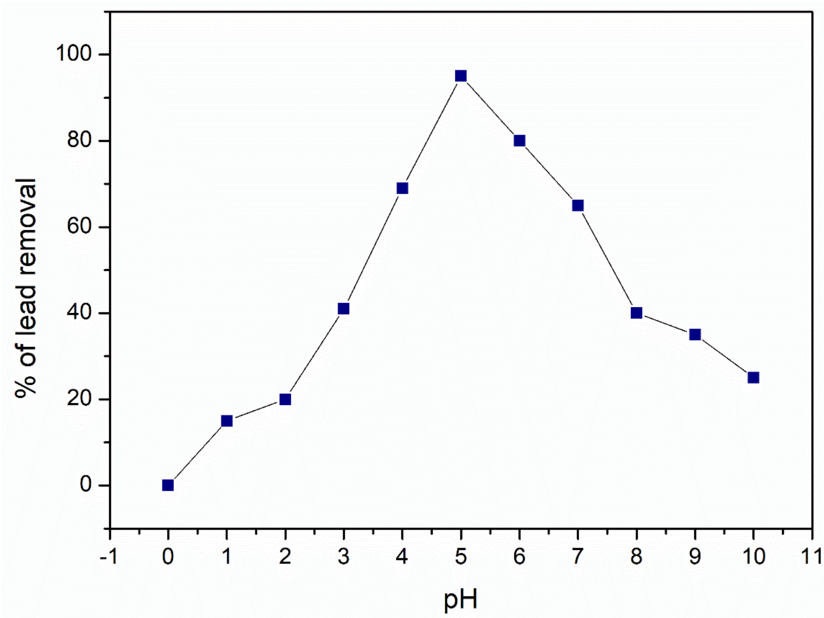

Fig.3. Effect of pH on Pb^{2+} ion removal

3.4.2. Effect of contacting time on lead removal at pH = 5

The behavior of leas removal on synthetic activated carbon (AC) is shown in Fig. 4. Adsorption experiments were effectuated at lead ion concentration of 20 (mg/L); AC dose of 0.2 g/100 Ml; contacting time from 0 to 100 minutes. After 10 minutes of the experiment, the lead removal increased rapidly from 0 to 29.3%. Then, the lead removal reached 84% after 40 minutes. From 40 minutes to 100 minutes, the lead removal increased slightly, confirming the saturation point of adsorption. The obtained results show the efficiency of synthetic AC for lead ions removal from aqueous solution in a short time and the time for adsorption equilibrium of 40 minutes.

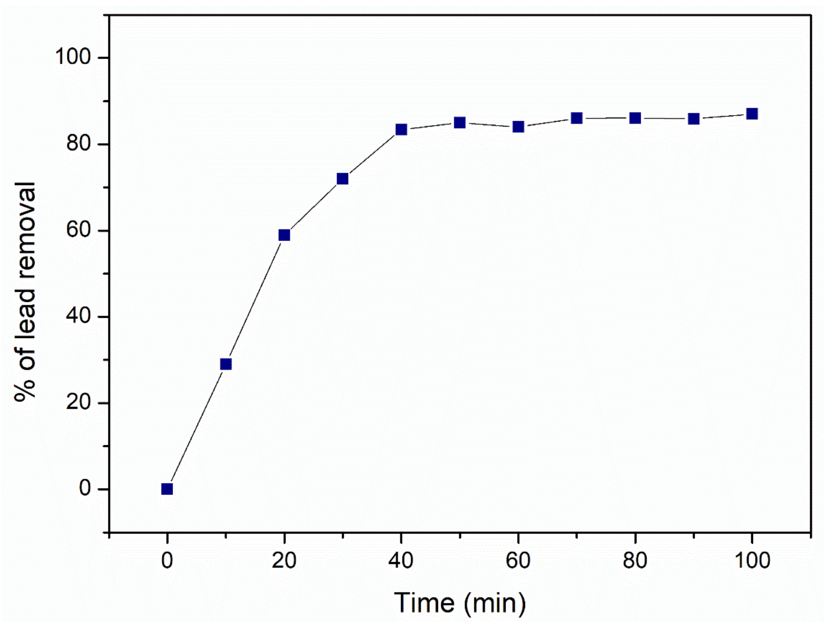

Fig.4. Effect of contact time on lead removal at pH = 5

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3.5. Isotherm study

Based on the time of adsorption equilibrium, the isotherm models of lead ions removal were evaluated with a series of adsorption experiments. The samples of AC material (0.2 mg) were immersed in 100 mL of lead solutions at several concentrations of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 mg/L, and at pH of 5.0 for 40 minutes. The experimental data were fitted for the isotherm models as mentioned below:

Langmuir model:

$$\frac{C_e}{Q_e} = \frac{C_e}{Q_m} + \frac{1}{K_L.Q_m} \qquad (2)$$

Freundlich model:

$$\mathrm{Ln}Q_e = \mathrm{Ln}K_F + \frac{1}{n}.\mathrm{Ln}C_e \qquad (3)$$

The Q_e was determined by the equation:

$$Q_e = \frac{(C_0 - C_e).V}{m} \qquad (4)$$

where C_e is the concentration at equilibrium, Q_e is the adsorption capacity at equilibrium, Q_m is the maximum-adsorption capacity, K_L and K_F are Langmuir and Freundlich constants, respectively, and n is the Freundlich coefficient.

The calculated values for Langmuir and Freundlich models are shown in Table 2. The isotherm models were established and presented in Figs.5 and 6. From the isotherm models, the experimental coefficients were determined and summarized in Table 3. Both the Langmuir and Freundlich models are suitable for the description of lead ions adsorption on synthetic AC with an equal value of R^2 coefficient of 0.97. From the Langmuir isotherm, the Q_m of lead adsorption on synthetic AC was 24570 (mg/g). The high value of Q_m highlighted the efficiency of synthetic AC in this study for lead ions removal compared to other studies [7-8].

Table 2. The calculated values for the isotherm model

C_o (mg/L)	C_e (mg/L)	LnC_e	Q_e (mg/g)	LnQ_e	C_e/Q_e (g/L)
5	0.6	-0.51082562	2200	7.696	0.00027273
10	1.4	0.336472237	4300	8.366	0.00032558
15	2.9	1.064710737	6050	8.708	0.00047934
20	3.32	1.199964783	8340	9.029	0.00039808
25	4.56	1.517322624	10220	9.232	0.00044618
30	6.7	1.902107526	11650	9.363	0.00057511
35	7.5	2.014903021	13750	9.529	0.00054545
40	10.3	2.332143895	14850	9.606	0.0006936
45	13.1	2.57261223	15950	9.677	0.00082132
50	15.7	2.753660712	17150	9.750	0.00091545

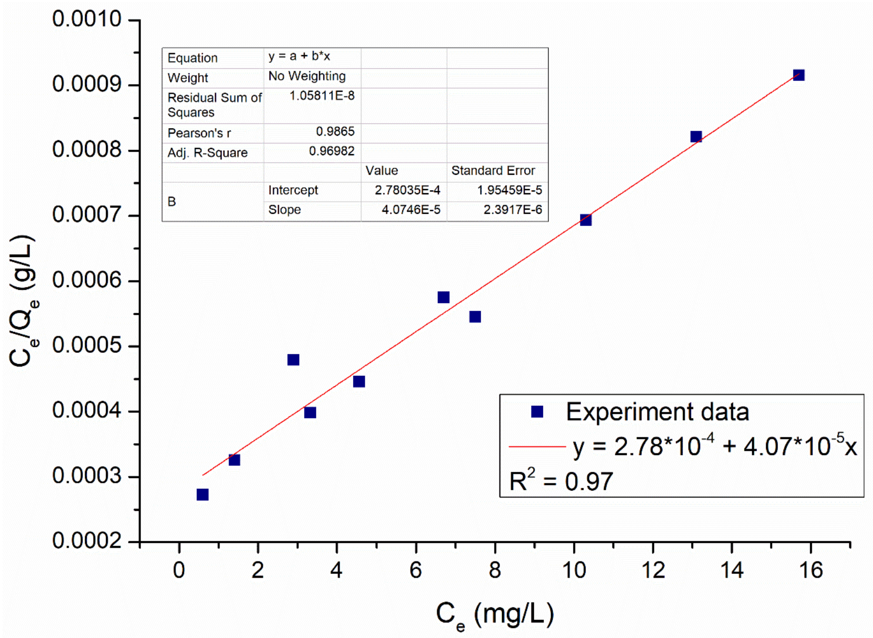

Fig.5. Langmuir model for lead ions adsorption on synthetic AC

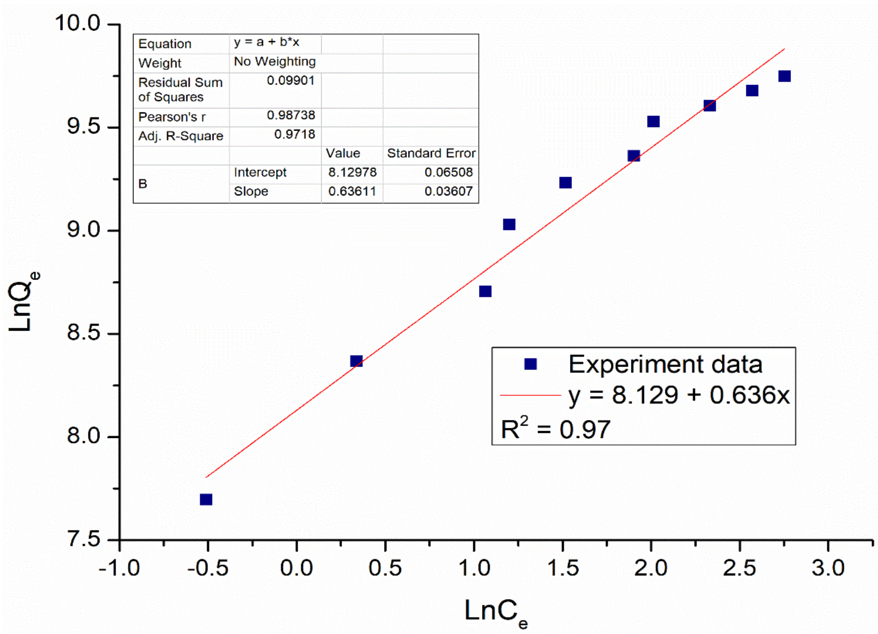

Fig.6. Freundlich model for lead ions adsorption on synthetic AC

Table 3. Experimental coefficients in the Langmuir and Freundlich models

Langmuir			Freundlich		
Q_m	K_L	R^2	n	K_F	R^2
24570	0.146	0.97	1.57	3391	0.97

4. Conclusions

Activated carbon was successfully synthesized from bamboo wood by simple thermal treatment. The synthetic material shows an amorphous structure with high porosity. The synthetic AC was used for lead removal from the aqueous solution. The result confirmed that the synthetic AC has high efficiency for lead adsorption. The adsorption capacity of AC for lead ion can reach 97% after 2 hours of contacting time. The isotherm study shows that the removal of lead ions on the synthetic AC is suitable for both the Langmuir and Freundlich models. The maximum value of lead adsorption is high (24570 mg/g), confirming the efficiency of synthetic AC for lead ions removal from the aqueous solution.

Declarations

Source of Funding

This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The author declares no competing financial, professional, or personal interests.

Ethical Approval

Based on institutional guidelines.

Consent for publication

The author declares that he/she consented to the publication of this research work.

Availability of data and material

The author is willing to share the data and material according to relevant needs.

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