

Removal of Pb(II) Ions in the Aqueous Solution by Using Activated Carbon Derived from Rice Husk

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Abstract

This paper deals with the feasibility of rice husk-based activated carbon as heavy metal sorbent for removing heavy metals [Pb(II)] from aqueous solution. The selected sample, rice husk (Yadanar Toe) was collected from rice mill in Hinthada Township, Ayeyarwady Region. Three types of rice husk-based activated carbon were prepared via simple carbonization and chemical activation process. The experimental yield percent of activated carbon working at the fixed temperature of 500°C for four hours were 22.1%, 27.6% and 18.5% for simple carbonization, acid treated and base treated respectively. The activated carbon was characterized by Scanning Electron Microscopic Analysis (SEM). For the removal of Pb (II) ions, the optimum contact times were found to be 30 min for R.H.A.C (A.T), 60 min for R.H.A.C (B.T) and R.H.A.C. Percent removals of lead were found to be 95.85%, 91.75% and 87.56% for R.H.A.C (A.T), R.H.A.C (B.T) and R.H.A.C respectively.

Keywords: Activated carbon, SEM, Pb(II), carbonization, rice husk, heavy metal, sorbent

Introduction

Rice husk is one of the major residues after rice production. Rice husk is the by-product of the rice milling industry. It is a good alternative for the production of cheap activated carbon as adsorbent. As rice husk is insoluble in water, having good chemical stability and structural strength due to high silica content so researchers are using it for treating heavy metal from ground water and surface water (Adbel et al., 2011). The major constituents of rice husk are cellulose, hemicelluloses, lignin and mineral components. The content of each constituent depends on rice variety, climatic conditions and the geographic localization. Due to its high cellulose and lignin content, rice husk can be utilized as the raw material to prepare activated carbon having highly porous structure in micropores range with high specific surface area.

Activated carbon, also called activated charcoal, activated coal, or carbon activates. Activated carbon (AC) is many known as a solid, porous, black carbonaceous material and tasteless. Marsh (1989) defined AC as a porous carbon material, usually chars, which have been subjected to reaction with gases during or after carbonization in order to increase porosity. AC is distinguished from elemental carbon by the removal of all non-carbon impurities and the oxidation of the carbon surface (Cooney et al., 1989).

Activated carbon is used in gas purification, decaffeination, gold purification, metal extraction, water purification, medicine, sewage treatment, air filters in gas masks and respirators, filters in compressed air and many other applications.

Heavy metal is a metal with high relative atomic mass. Generally, heavy metals have densities above 5 gcm⁻³. Because they cannot be degraded or destroyed, heavy metals are persistent in all parts of the environment. Human activity affects the natural geological and biological redistribution of heavy metals through pollution of the air, water and soil.

Heavy metals have been extensively used in various industrial processes, pharmaceutical manufacturing, and agriculture. These activities can cause wide spread

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environmental pollution of both soil and groundwater (Oboh et al., 2009). Heavy metal pollution can arise from many sources but most commonly arises from purification of metal, pigment manufacturer, storage battery industries and photographic industries. Lead is a poisonous metal that can damage nervous connection (especially in young children) and cause blood and brain disorders. The presence of lead in drinking water even at low concentration may cause such diseases as anemia, encephalopathy, hepatitis and nephritic syndrome.

Materials and Methods

Sample Preparation

Rice Husk (Yadanar Toe) was collected from rice mill in Hinthada Township, Ayeyarwady Region (August, 2014). Rice husk sample washed with distilled water, and then dried in the oven at 100°C for 24 hours. Cleaned and dried rice husk sample was stored in airtight plastic container.

SEM Analysis

Sample

Acid treated rice husk activated carbon RHAC (A.T), base treated rice husk activated carbon RHAC (B.T), and rice husk activated carbon RHAC.

Apparatus

Scanning Electron Microscope
(JOEL-JSM-5670, Japan)

Procedure

The morphological properties of activated carbon derived from rice husk were determined by using Scanning Electron Microscope (JOEL-JSM-5670, Japan) at Universities' Research Centre, University of Yangon. The operating voltage of 5 kV was applied. The procedure was followed according to the standard procedure presented in the catalogue. The SEM micrographs are shown in Figures 1, 2 and 3.

Removal of Lead from Aqueous Solution by Using Three Types of Activated Carbon

The batch experiments of sorption of lead from aqueous solution were studied by varying the initial lead concentration, adsorbent does and contact time.

Sample

Rice Husk Activated carbon, Acid Treated Rice Husk Activated Carbon, Base Treated Rice Husk Activated Carbon

Chemicals and Reagents

Lead (II) nitrate, sulphuric acid (0.1M) and sodium hydroxide (0.1M)

Determination of lead content in equilibrium solution

Chemicals and Reagents

Standard EDTA (0.05 M), Hexamine powder, xylenol orange indicator and dilute nitric acid

0.05 M EDTA Solution

18.613 g of disodium dihydrogen ethylenediaminetetraacetate dehydrate was dissolved in water and diluted to 1 liter in a volumetric flask with deionized water.

Xylenol Orange Indicator

0.5 g of xylenol orange was dissolved in 100 mL of distilled water.

Apparatus

Burette (50 mL), pipette (10 mL), volumetric flasks (1000 mL and 100 mL), measuring cylinder (25 mL) and conical flasks (250 mL).

Procedure

10 mL of the lead ion solution was pipette into a 250 mL conical flask, diluted with about 20 mL of distilled water, and 3 drops of the indicator solution were added. If the colour of the solution was red, dilute nitric acid was added, cautiously and with stirring, until the solution acquired a yellow colour. Powdered hexamine (hexamethylene tetramine) was added until the colour was intensely red. This step ensured that the solution has the correct pH (about 6) for the subsequent titration. The solution was titrated with standard EDTA until the colour changed to lemon yellow.

$$1 \text{ mL } 0.05\text{M EDTA} \equiv 10.3605 \text{ mg Pb}$$

Results and Discussion

Yield Percent of Rice Husk Activated Carbon

In this research, the experimental yield percent of activated carbon is working at the fixed temperature of 500° C for four hours (Table – 1).

Table (1) Yield percent of rice husk activated carbon

Type of Activated Carbon	Yield (%)
Simple carbonization	22.1
Chemical activation(H ₃ PO ₄)	27.6
Chemical activation(NaOH)	18.5

Scanning Electron Microscopic Analysis

Samples were analyzed using Scanning Electron Microscope (SEM) to study the morphological features of the three different rice husk activated carbons. Their scanning electron micrographs, were shown in Figure 1 (a, b and c) respectively. As compared to scanning electron micrographs of simple carbonization rice husk activated carbon, acid treated rice husk activated carbon and base treated rice husk activated carbon showed the evidence for the formation of pores. The porosity seen to be enhanced in acid treated rice husk activated carbon as shown in Figure 1 (a).

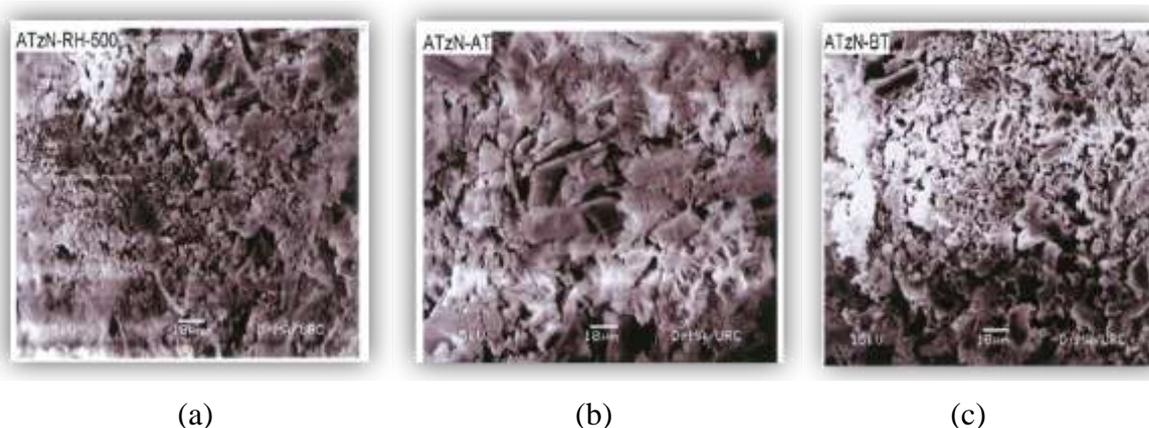


Figure (1) SEM micrographs of (a) RHAC (A.T), (b) RHAC (B.T), and (c) RHAC

Adsorption Capacity of Three Types of Activated Carbon and Removal Percentage of Pb Ion.

The adsorption behavior indicates that rice husk-based activated carbon has a potential as metal extraction agent Pb (II) from single aqueous solution (Arunrat & Sukjit, 2014). Since adsorption capacities of sorbents vary depending on the treatment on sorbent material and experimental conditions, it is advised that the reported sorption capacities should be taken as the values that can be maximum sorption capacities. Table (2) represents the adsorption capacities (or removal percentage) of rice husk-based activated carbon derived from rice husk in this study.

Generally, from the results of adsorption behavior for Pb (II) the metal ions adsorbed occupied a large number of pores at the beginning of adsorption process. As the contact time increased, the pores were filled and the rate of metal adsorption became slower gradually and reached a plateau. This behavior reflects the fact that the adsorption is surface phenomenon and that the surface are readily accessible to the metal ions in the solution (Qinggi et al., 2004). It also suggests the occurrence of a rapid external mass transfer followed by a slower internal diffusion process which could be the rate determining step.

Table (2) Adsorption capacity of three types of activated carbon and removal percentage of Pb ion.

Adsorbate	Sorbent material	Adsorption Capacity (mg/g)	Removal Percentage (%)
Pb(II)	R.H.A.C	4.69	87.57
	R.H.A.C (A.T)	4.89	95.85
	R.H.A.C (B.T)	4.79	91.75

Table (3) Adsorption parameter for Lead ions on three types of activated carbon to fit Langmuir Isotherms

C _o (mgL ⁻¹)	R.H.A.C (A.T)			R.H.A.C (B.T)			R.H.A.C		
	C _e (mgL ⁻¹)	q _e (mgg ⁻¹)	C _e /q _e (gL ⁻¹)	C _e (mgL ⁻¹)	q _e (mgg ⁻¹)	C _e /q _e (mL ⁻¹)	C _e (mgL ⁻¹)	q _e (mg g ⁻¹)	C _e /q _e (mL ⁻¹)
25	1.0360	2.4	0.432	2.061	2.3	0.896	3.108	1.2	1.413
50	3.1081	4.9	0.634	5.180	4.9	1.057	7.252	4.3	1.686
75	12.432	6.3	1.973	13.468	6.2	2.172	17.612	5.7	3.089
100	27.973	7.2	3.885	30.045	6.9	4.354	36.261	6.4	5.665

(Activated Carbon dose = 0.5 g, contact time = 60 min, pH =7)

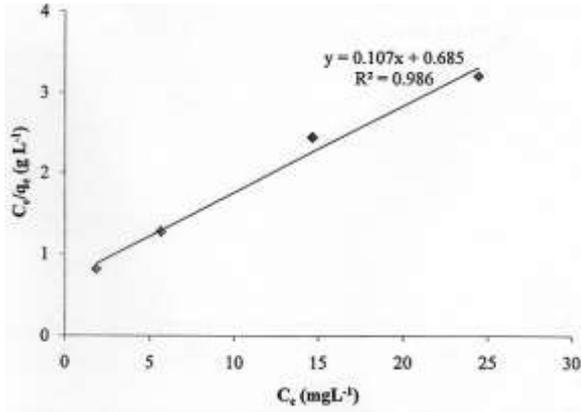


Figure (2) Langmuir isotherm for lead adsorption by R.H.A.C (A.T)

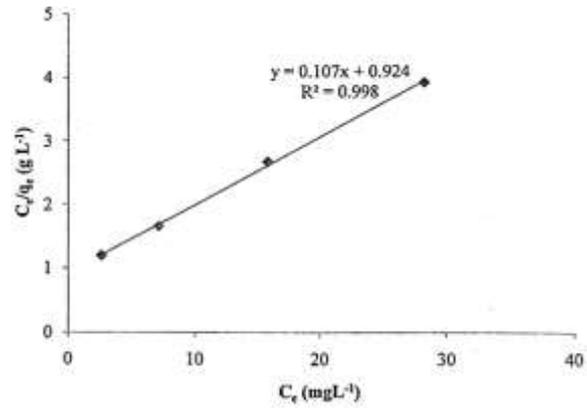


Figure (3) Langmuir isotherm for lead adsorption by R.H.A.C (B.T)

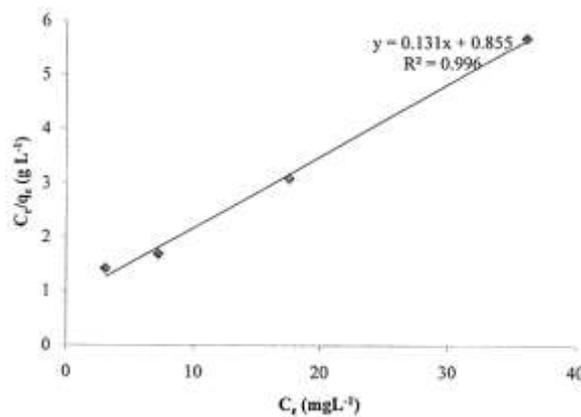


Figure (4) Langmuir isotherm for lead adsorption by R.H.A.C

Langmuir Adsorption Isotherm

Langmuir adsorption isotherm is based on the assumption that points of valency exist on the surface of the adsorbent and that; each of these sites is capable of adsorbing one molecule. Thus the adsorbed layer will be one molecule thick. Further it is assumed that all the adsorption sites have equal affinities for molecules of the adsorbent and that the presence of adsorbed molecules at one site will not affect the adsorption of molecules at an adjacent site. It is given by $q_e = \frac{q_{\max} \cdot b \cdot C_e}{1 + b C_e}$ (Yanchao et al., 2011). Where, q_e is the amount of metal ions adsorbed per specific amount of adsorbent (mg g^{-1}), C_e is the equilibrium concentration of metal ions (mg L^{-1}), q_{\max} is the amount of metal ions required to form a monolayer (maximum sorption capacity) (mg g^{-1}) and b is Langmuir constant related to the affinity of the binding sites (L mg^{-1}). The adsorption data for lead on three types of activated carbon are tabulated in Table (3). The linearised Langmuir isotherm allows the calculation of maximum adsorption capacities (q_{\max}) and Langmuir constant (b) and is equated by the following equations.

$$\frac{C_e}{q_e} = \frac{C_e}{q_{\max}} + \frac{1}{q_{\max} \cdot b}$$

The linear Langmuir plots of specific sorption (C_e/q_e) against the equilibrium concentration (C_e) for Pb^{2+} are shown in figures (2, 3 and 4) respectively. All systems provided good straight lines with $R^2 = 0.99$ indicating that the adsorptions conform to Langmuir isotherm.

Conclusion

The percent yields of rice husk-based activated carbon were found to be 22.1% (R.H.A.C), 27.6% (R.H.A.C (A.T)) and 18.5% (R.H.A.C (B.T)). These samples were analyzed using Scanning Electron Microscope (SEM) to study the morphological feature of R.H.A.C, R.H.A.C (A.T) and R.H.A.C (B.T). R.H.A.C (A.T) showed better evolution and development of pores as compared to others. Lead removal efficiencies by R.H.A.C, R.H.A.C (A.T) and R.H.A.C (B.T) were found to be 87.57%, 95.85% and 91.75% respectively at initial lead concentration of 50 mgL⁻¹ and sorbent dose 0.50g. Metal adsorption on the rice husk-based activated carbon were found to be well fitted to Langmuir ($R^2 = 0.99$). It can be concluded that rice husk-based activated carbon, more preferably acid treated rice husk activated carbon, may be considered as an effective sorbent for removal of heavy metals from industrial waste water.

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