

# REMOVAL OF LEAD (II) FROM AQUEOUS SOLUTION USING NATURAL AND ACTIVATED RICE HUSK

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## Abstract

*This paper presents the experimental results on the use of rice husk in the removal of lead (II) from the aqueous solution. In this study, rice husk is used in four different forms, namely, natural un-activated form (RH), rice husk ash acquired after carbonizing rice husk without pretreatment (RHA), rice husk pretreated with phosphoric acid (PRH) and acetic acid (ARH) separately and then followed by carbonization. Through batch adsorption studies the effect of various parameters such as pH of the aqueous medium, contact time of agitation, adsorbate concentration, and adsorbent dosage were examined. The results obtained show that the adsorption of the metal ion is pH, contact time, adsorbent dosage and adsorbate concentration dependent. The maximum percentage removal of lead (II) ions is 93.36%, 94.8%, 96.72% and 99.35% with adsorbents RH, RHA, PRH and ARH, respectively. It is found that RH, RHA and PRH followed Freundlich isotherm model whereas ARH followed Langmuir isotherm model. Further, both RH and RHA follow pseudo-second order kinetics.*

*Key Words: Adsorption, Lead, Natural Adsorbents, Rice husk, Isotherms, Reaction kinetics ...*

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## 1. INTRODUCTION

Amongst the present day's environmental issues, water scarcity and water pollution rank equal to climate change [1]. The industrial effluents have serious concern as they contain heavy metals like iron (Fe), lead (Pb), zinc (Zn), copper (Cu) etc., which are hazardous to human health. Heavy metals being non-biodegradable cause various diseases and disorders through bioaccumulation. Many methods have been developed to remove heavy metals from wastewater, such as adsorption, chemical oxidation / reduction, precipitation, ion exchange, electrochemical processes, membrane filtration and reverse osmosis. These methods tend to be expensive and often impracticable in remote regions where heavy metal contaminants originate from geogenic sources. On the contrary, adsorption technique has proved to be an efficient and cost effective among all the methods [2, 3]. Demirbas presented a review on heavy metal adsorption onto agro-based waste materials [4].

Lead as Pb (II) is released into the environment from various industrial processes: industries engaged in lead acid batteries, pulp and paper, petrochemicals, refineries, printing, pigments, photographic materials, explosive manufacturing, ceramics, glass, paint, oil, metal, phosphate fertilizer, electronics, wood production and also combustion of fossil fuel, forest fires, mining activity, automobile emissions, sewage wastewater, sea spray and many more [5]. Hashem [6] studied the

sorption of Pb (II) using okra wastes, Singh et al. [7] used maize bran in the adsorption of lead using maize bran, while El-Ashtoukhy et al. [8] employed pomegranate peel as a adsorbent in the removal of lead (II) and copper (II) from aqueous solution. Yoshita et al. [9] carried out the study on the removal of lead by spent tea leaf residue after instant tea extraction. Imamoglu and Tekir [10] have studied removal of copper (II) and lead (II) ions from aqueous solution by adsorption on activated carbon from a new precursor hazelnut husks. The thermodynamic study on the adsorption of Pb (II) and Zn (II) from aqueous solution by human hair was done by Ekop and Eddy [11]. Adie et al. [12] carried out the comparative analysis of the adsorption of Pb (II) and Cd (II) in wastewater using *Borrassus aethiopicum* and *Cocos nucifera*. The adsorption of lead from aqueous solution onto untreated orange barks was studied by Azouaou et al. [13]. Wahi et al. [14] studied the removal of mercury, lead and copper from aqueous solution by activated carbon of palm oil empty fruit bunch. Chairgulprasert et al. [15] studied phytoremediation of synthetic wastewater by adsorption of lead and zinc onto *Alpinia galangal Willd.* However, the studies on the use of activated rice husk in the removal of lead (II) are very few. Hence, the present study emphasizes on the use activated rice husk in the removal of lead (II) cations from aqueous solution. The study also include fitting of isotherms and reaction kinetics.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Materials

Lead nitrate was used for the preparation of stock Pb (II) solution in distilled water. To control the pH value during the experiment, hydrochloric acid and/or sodium hydroxide solutions were used, while phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) (88%), acetic acid (CH<sub>3</sub>COOH) (99.8%) were used for pretreatment. The equipments used for the study are: digital pH meter, Atomic Absorption Spectrophotometer (AAS), Scanning Electron Microscope (SEM), rotary shaker, muffle furnace, oven, sieves and weighing machine.

### 2.2 Preparation of Adsorbents

Locally available rice husk was washed with distilled water, dried in an oven at 105°C for 24 hours to remove the moisture content [16], ground and sieved to particle size of < 150 µm. The powdered rice husk was used in four forms: first one was used in its natural form and named as "Rice husk" (RH), second form named "Rice husk ash" (RHA) was obtained by carbonizing the powdered rice husk in muffle furnace at 800°C for half hour and then cooling in a dissicator, the third and fourth forms were activated respectively with phosphoric acid and acetic acid. The third was soaked for 36 hours in a solution of 0.1N phosphoric acid and 0.5N acetic acid separately at an impregnation percentage of 20%, then carbonized at 650°C for 90 minutes [17]. It was rinsed several times until the pH of the drained water was in the range of pH 6-7 followed by oven drying for 3 hours at 100°C to remove the moisture content. They were named as *Phosphoric acid treated rice husk* (PRH), and *Acetic acid treated rice husk* (ARH). The physical characteristics of all adsorbents were measured using standard procedures. The data are presented in Table 1.

Table 1: Characteristics of adsorbents

Adsorbent	pH	Bulk density (gm/cc)	Particle density (gm/cc)
RH	5.26	0.5604	1.0428
RHA	5.59	0.5011	1.0345
PRH	2.30	0.6105	1.0495
ARH	4.12	0.5890	1.0466

### 2.3 Adsorption experiments

Batch adsorption experiments were carried out at room temperature by shaking a series of beakers containing the desired dose of adsorbent in a known concentration of lead solution. Samples of lead solution were withdrawn at different time intervals, filtered and the filtrate was analyzed for the trace of heavy metal content. Experiments were carried out at optimum pH values. The initial pH of the solution was adjusted to the

desired value either by hydrochloric acid or sodium hydroxide solution. The percent removal of lead from solution was calculated using Eqs. (1).

$$\text{Percent removal} = \frac{(C_o - C_i)}{C_o} \times 100 \quad (1)$$

where C<sub>o</sub> is initial concentration of lead metal, C<sub>i</sub> is final concentration of lead metal. Isotherm studies were conducted by varying the initial concentration of lead solution from 10 to 50 mg/L. A known amount of different adsorbents was then added into solutions followed by agitation at 120 rpm.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Determination of Optimum pH

To study the effect of pH on adsorption of lead (II) ions, the batch equilibrium studies at pH values in the range of 3-7 were carried out. The results are furnished in Table 2 and the variation is presented in Fig 1. From Table 2 it can be observed that the percentage removal of lead is maximum in the pH range of 4-5 with RH and RHA. However, with PRH, the pH range is 5-6 and ARH it is in the range of 6-7. Therefore, the optimum pH range is chosen as 4-5 for RH and RHA, which is same as stated by Vieira et al. [3]. However, for PRH and ARH, the pH range of 5-6 was chosen. According to Issabayeva et al. [18] the speciation profiles of single lead species at a total concentration of 10 mg/L is in Pb<sup>2+</sup>. The main species in the pH range 3-5 were Pb<sup>2+</sup>, PbNO<sup>3+</sup> and aqueous Pb(NO<sub>3</sub>)<sub>2</sub>; their concentrations did not change until pH = 6. The formation of solid (precipitation) Pb(OH)<sub>2</sub> started at pH = 6.3 and that of other soluble hydroxides namely PbOH<sup>+</sup>, aq Pb(OH)<sub>2</sub>, and PbOH<sup>3-</sup> occurred after pH = 7. Therefore, a pH range of 3-7 was used during the analysis. The optimum value of pH depends on the adsorbents characteristics. Table 3 gives the optimum value of pH reported by various investigators with different adsorbents used in the removal of lead.

Table 2: Effect of pH on percentage removal of lead using different adsorbents

pH	Percentage removal of lead with adsorbent			
	RH	RHA	PRH	ARH
3	78.12	91.24	86.14	82
4	79.34	92.19	93.76	91.56
5	79.28	92.16	94.99	93.77
6	77.42	88.74	94.83	94.99
7	75	88.53	94.32	96.43

Table 3: Optimum pH value for different adsorbents

Adsorbent	pH range	Optimum pH	Authors
Okra waste	4-6	5	Hashem [6]
Maize bran	3.2-8	6.5	Singh et al. [7]
Pomegranate peel	4.5-9.4	5.6-7.6	El-Ashtoukhey et al. [8]
Hazelnut husks	-	6.7-7	Imamoglu et al. [10]
Orange barks	1-4.6		Azouaou et al. [13]
Activated carbon of palm oil empty fruit bunch	-	4.5	Wahi et al. [14]
Alpina galangal willd	2-7	6	Chairgulprasert et al. [15]
RH and RHA	3-7	4-5	Present study
PRH and ARH	3-7	5-6	

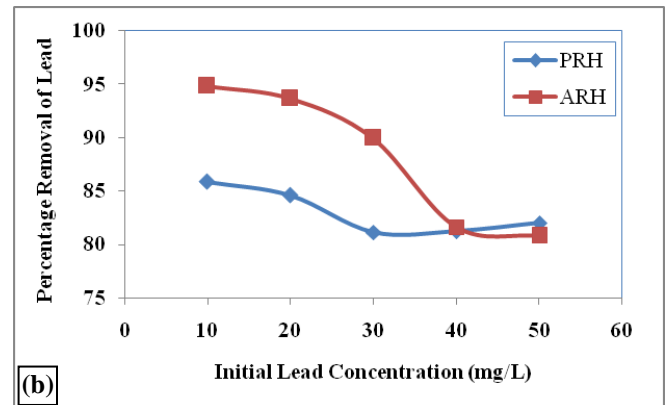


Fig. 2 Variation of adsorption efficiency with initial lead concentration using (a) RH and RHA and (b) PRH and ARH

The removal of lead is dependent on the initial lead concentration. Figs. 2 (a) and (b) show the effect of initial lead concentration on the percent removal of lead ions, respectively. From Fig. 2 (a) it is observed that, for RH the percentage removal increased drastically from 85.16% to 93.36% with an increase in initial lead concentration from 10 mg/L to 30 mg/L and thereafter it decreased sharply, while for RHA the percentage removal increase from 93.3% with an initial lead concentration of 10 mg/L to 94.8% at 20 mg/L. However, from Fig. 2 (b) it can be inferred that, the percentage removal of lead with adsorbent PRH decreases from 85.84% to 81.2% when initial lead concentration increased from 10 mg/L to 30 mg/L and thereafter the efficiency gradually increased. For ARH the percentage removal decreases steeply from 94.89% with initial concentration of lead at 10 mg/L to 80.7 % with initial concentration of lead at 50 mg/L. Similar results were also observed by Wong et al. [19] for tartaric acid treated rice husk. This is because, at low metal ion/adsorbent ratios, metal ion adsorption involves higher energy sites giving higher adsorption efficiency. On the other hand, as the metal ion/adsorbent ratio increases, the higher energy sites are saturated and adsorption begins on lower energy sites, resulting in decreases in the adsorption efficiency. The comparative study on the maximum percentage removal of lead at optimum adsorbate concentration investigated by various researchers is furnished in Table 4.

Table 4: Maximum percentage removal of lead at optimum adsorbate concentration

Adsorbent	Range of initial lead concentration (mg/L)	% removal of lead	Initial lead concentration of adsorbate (mg/L)	Authors
Okra waste	25-100	99	100	Hashem [6]
Maize bran	100-150	96.8	100	Singh et al.

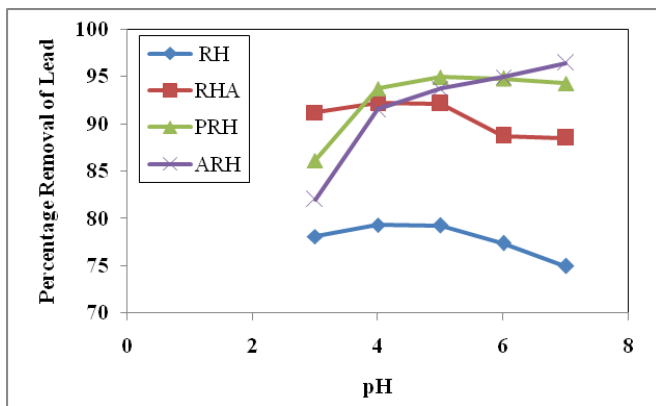
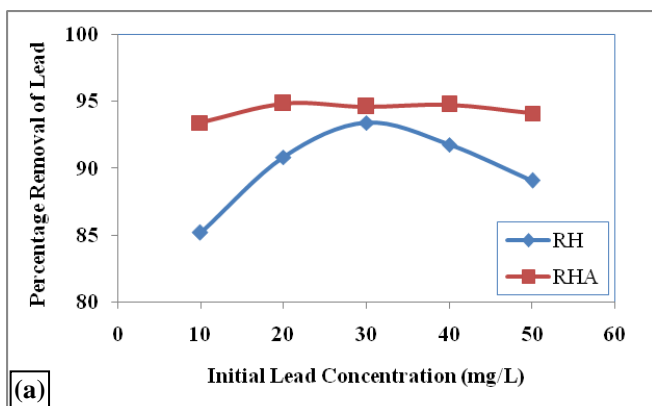


Fig. 1 Effect of pH on the percentage removal of lead with different adsorbents

### 3.2 Effect of varying lead concentration



(a)

				[7]
Pomegranate peel	10-50	95-100	10	El-Ashtoukhey et al. [8]
Hazelnut husks	5-200	97.2	5-30	Imamoglu et al. [10]
Alpina galangal willd		95.2	50	Chairgulprasert et al. [15]
Tartaric acid treated rice husk	400-800	90-100	400	Wong et al. [19]
RH	10-50	93.36	30	Present study
RHA	10-50	94.8	20	
PRH	10-50	85.84	10	
ARH	10-50	94.89	10	

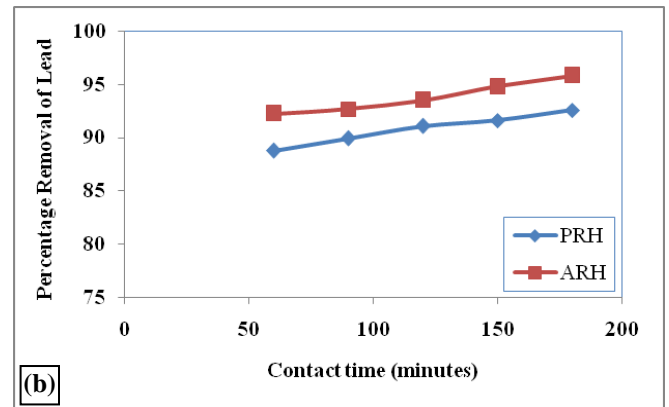


Fig. 3 Variation of adsorption efficiency with varying contact time using (a) RH and RHA (b) PRH and ARH

### 3.3 Effect of contact time

The variation between adsorption efficiency in terms of percentage removal of lead and contact time is shown in Fig. 3. From Fig. 3 (a) it is observed that for RH, the lead removal percentage is least of 74.64% at 60 minutes of contact time and highest of 76.69% at contact period of 120 minutes, while for RHA the percentage removal increased from 87.09% at 60 minutes contact time to 91.67% at 150 minutes of contact time. Similar value of equilibrium time was also observed by Jameel and Hussain [20] for RHA. From Fig. 3 (b) it is observed that the percentage removal of lead with PRH increased with an increase in contact time. At 60 minutes of reaction time, 88.79% of lead removal is observed, as the adsorption reaction was allowed for 180 minutes more lead removal efficiency of 92.2% is observed. For adsorbent ARH, it increased from 92.22% at 60 minutes contact time to 95.8% at 180 minutes contact time. However, equilibrium will be achieved beyond 180 minutes. Table 5 presents the optimum agitation time corresponding to maximum percentage removal of lead as reported by earlier investigator. In general, the optimum contact time is around 150 minutes.

### 3.4 Effect of adsorbent dosage

Fig. 4 illustrates the variation of adsorption efficiency with varying adsorbent dosage using different adsorbents, which shows that the adsorption efficiency increases with an increase in adsorbent dosage. As presented in Fig. 4 (a), RH the adsorption efficiency increases from 79.91% to 84.72% with adsorbent dosage from 1 gm to 2 gm, while for RHA it increased from 89.62% to 90.39% for adsorbent dosage from 1 gm to 2 gm. Fig. 4 (b) represents the effect of PRH and ARH adsorbent dosage on percentage removal of lead. It can be observed from Fig. 4 (b) that the percentage removal of lead with adsorbent PRH gradually increases from 1 gm to 3 gm and at 4 gm there is a sudden increase in percentage removal of lead by 96.72%. However, with ARH, there is increase in percentage removal of lead between 1 gm to 2 gm and beyond 2 gm the percentage removal of lead is minimal. For ARH, the results are 97.65% at 1 gm, 99.11% with 2 gm and highest at 99.35% with 4 gm. This is due to greater availability of surface area or active sites. The comparative study on the optimum dosage of adsorbents corresponding to maximum percentage removal is given in Table 6. The optimum dosage depends on type of adsorbent due to their varying surface area.

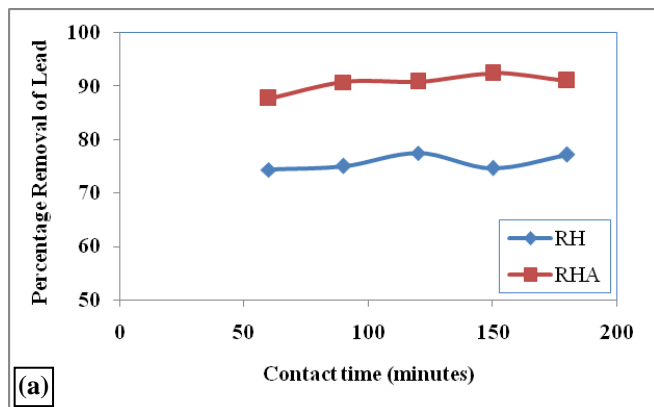


Table 5: Maximum percentage removal at optimum agitation time

Adsorbent	Range of agitation time (min)	% removal of lead	Optimum agitation time (min)	Author
Pomegranate peel	0-180	90-100	120	El-Ashtoukhey et al. [8]
Hazelnut husks	2-50	90-100	50-60	Imamoglu et al. [10]
Alpina galangal willd	30-180	95.2	150	Chairgulprasert et al. [15]
Tartaric acid treated rice	0-230	90-100	120	Wong et al. [19]

Adsorbent	Range of adsorbent dosage (gm)	% removal of lead	Optimum dosage of adsorbent (gm)	Author
Pomegranate peel	2.5-12.5	95	12.5	El-Ashtoukhey et al. [8]
Spent tea leaf	0.5-2	55.2	2	Yoshita et al. [9]
Hazelnut husks	0.05-0.5	97.2	0.3	Imamoglu et al. [10]
Activated <i>Borrassus aethiopiom</i> seed shells	0.5-2.5	99.75	2.5	Adie et al. [12]
Activated carbon of palm oil empty fruit bunch	0.2-1	100	0.2	Wahi et al. [14]
Alpina galangal willd	0.5-2	95.2	0.5	Chairgulprasert et al. [15]
RH	0.5-2	90.39	2	Present study
RHA	0.5-2	84.72	2	
PRH	1-4	96.72	4	
ARH	1-4	99.35	4	
husk				
Straws of rice	15-150	92.5	90-105	Siddiqui et al. [21]
Raw silkworm chrysalides	0-50 hours	4.68	25-50	Paulino et al. [22]
Acid washed silkworm chrysalides	0-25 hours	4.27	25	
Orange peel activated carbon	20-120	100	60-120	Bernard et al. [23]
RH	60-180	76.69	120	Present study
RHA	60-180	91.67	150	
PRH	60-180	92.2	180	
ARH	60-180	95.8	180	

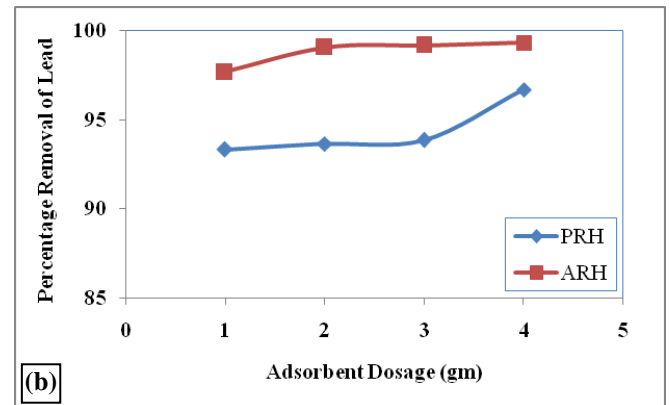
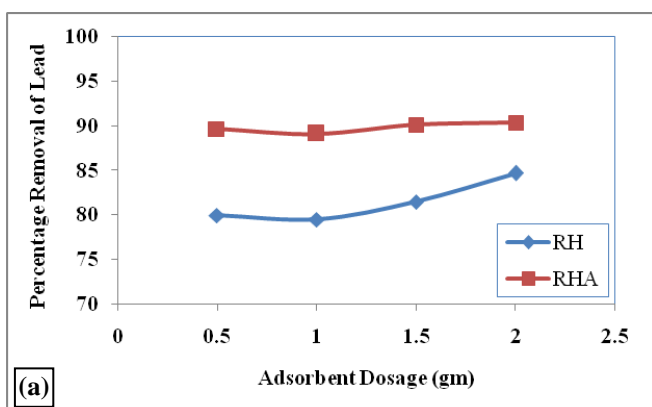


Fig. 4 Variation of adsorption efficiency with varying adsorbent dosage using (a) RH and RHA (b) PRH and ARH

Table 6: Maximum percentage removal at optimum dosage of adsorbent

### 3.5 Adsorption isotherms

The equilibrium data for adsorption are usually presented in the form of adsorption isotherms, which gives the equilibrium relationship between the concentration of the adsorbate held on the surface of an adsorbent and the concentration (or partial pressure) of the adsorbate in the fluid phase at a given temperature. The concentration of the adsorbate on the surface of the solid is expressed as the amount of the substance adsorbed per unit mass of the adsorbent. In case of solutions it is expressed as mass adsorbate per unit volume of solution or in mass units such as ppm (mg/L) [24]. Commonly used adsorption isotherms are Freundlich and Langmuir isotherms. In the present study, experimental data was fitted into the Freundlich and Langmuir isotherm models. Freundlich and Langmuir isotherm plots of lead adsorption using RH, RHA, PRH and ARH are as shown in Figs. 5 – 8, respectively. The coefficients of regression  $R^2$  with adsorbent RH are found to be respectively 0.875 and 0.832 for Freundlich and Langmuir isotherms. For RHA,  $R^2$  values are 0.943 and 0.876 for Freundlich and Langmuir isotherms. Similarly, with PRH,  $R^2$  values are 0.982 and 0.753 for Freundlich and Langmuir isotherms and with ARH,  $R^2$  values are found to be 0.954 and 0.976 for Freundlich and Langmuir isotherms, respectively. The regression coefficient for Freundlich isotherm is greater than Langmuir isotherm and thus Freundlich isotherm fits better with RH, RHA, and PRH than Langmuir isotherm. In the case of ARH, Langmuir isotherm is found to be the best fit isotherm. The comparative results on the fitted isotherms using Freundlich and Langmuir isotherm are presented in Table 7.



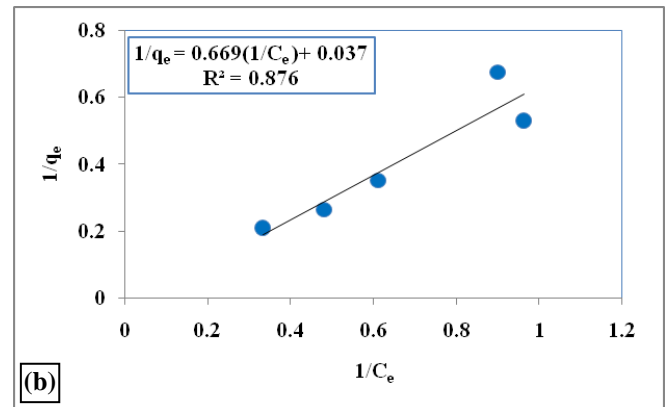
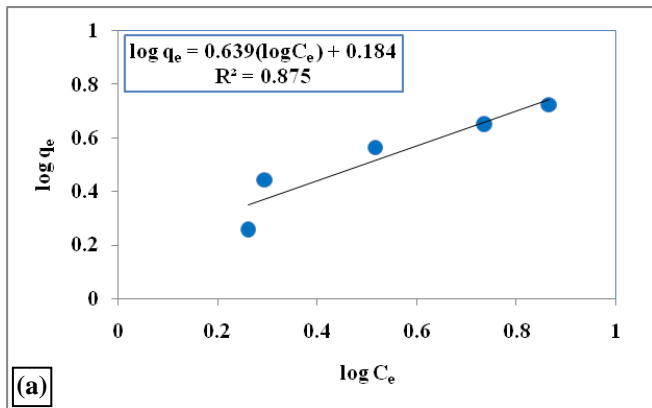


Fig. 6 (a) Freundlich and (b) Langmuir isotherm plot of lead adsorption by RHA

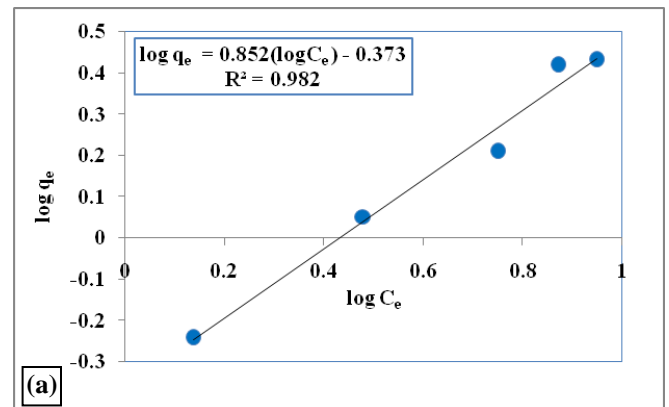
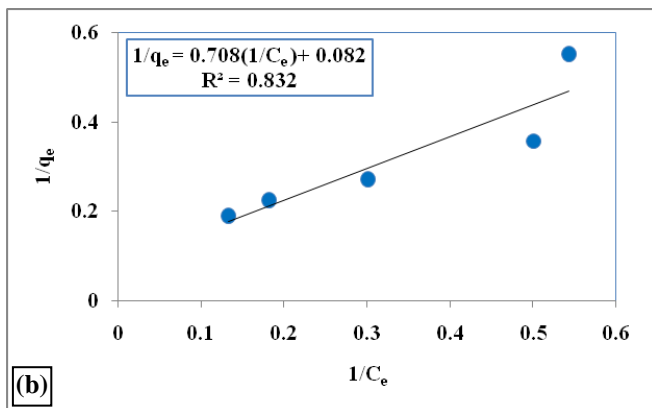


Fig. 5 (a) Freundlich and (b) Langmuir isotherm plot of lead adsorption by RH

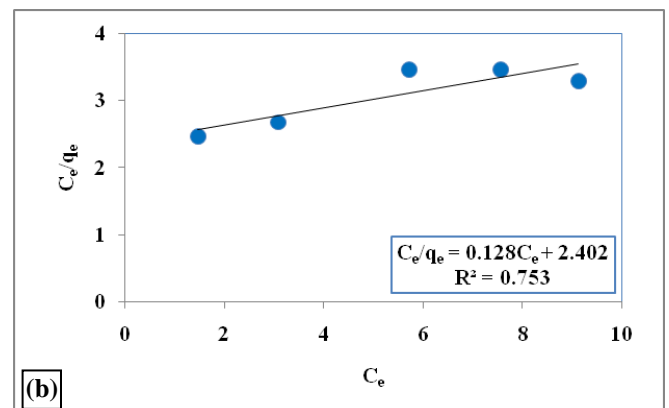
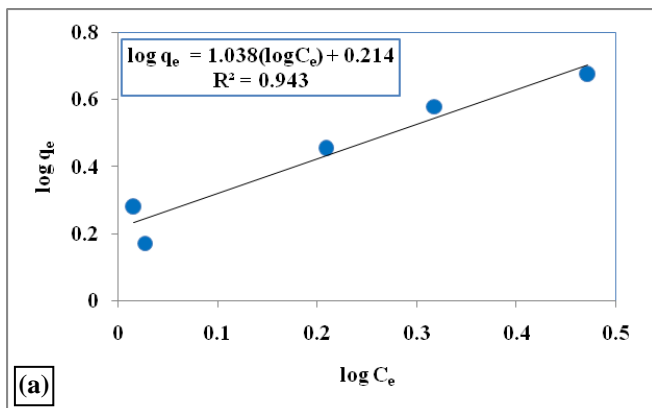


Fig. 7 (a) Freundlich and (b) Langmuir isotherm plot of lead adsorption by PRH

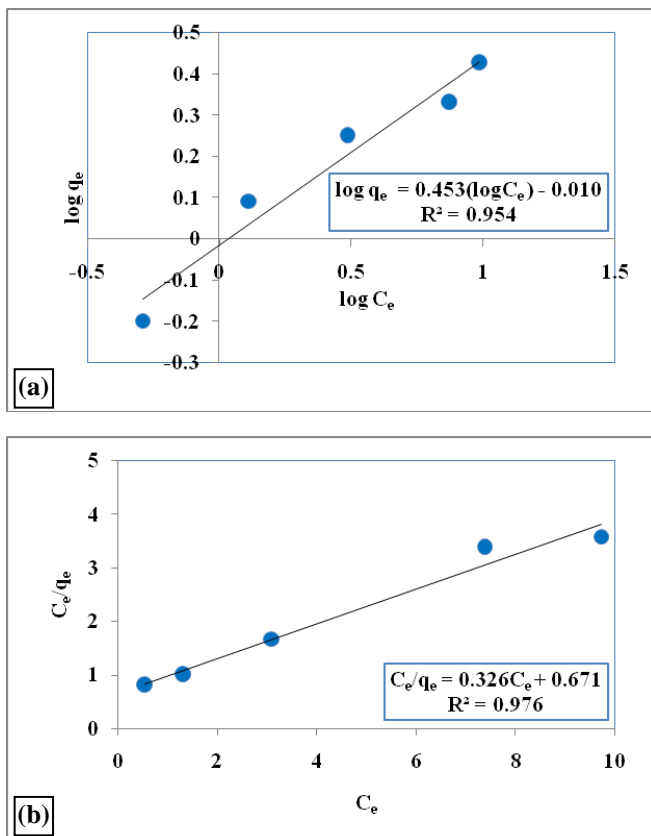


Fig. 8 (a) Freundlich and (b) Langmuir isotherm plot of lead adsorption by ARH

Table 7: Fitted isotherm parameters

Adsorbent	Freundlich isotherm			Langmuir isotherm		
	N	k	R <sup>2</sup>	Q <sub>m</sub>	b	R <sup>2</sup>
RH	1.564	1.527	0.875	1.412	8.636	0.832
RHA	0.963	1.636	0.943	1.492	-18.11	0.876
PRH	1.173	0.423	0.982	7.812	0.053	0.753
ARH	2.207	0.977	0.954	3.067	0.486	0.976

### 3.6 Reaction kinetics

Reaction kinetics also called chemical kinetics is used to know the rates of chemical processes and laws for the same. It includes the investigations on the influence of different chemical processes on speed of chemical reaction and yield information. It also helps in the development of mathematical models of a chemical reaction. Some of the laws used are zero-order, first-order, second-order etc. To analyze the adsorption kinetics of lead metal ions, the pseudo-first and pseudo-second order models were applied to data in the present study. The determinant coefficient (square of correlation coefficient) for the pseudo-second-order model was 0.998 for RH and 0.999 for RHA respectively, being significantly higher than that for the pseudo-first-order model presented in Table 8. It suggests that the lead adsorption process of the RH and RHA is fitted very well

to the pseudo-second order model than the pseudo-first order model. Fig. 9 and Fig. 10 show the kinetic plots for RH and RHA, respectively. In case of PRH and ARH, equilibrium was found achieve beyond 180 minutes and equilibrium point is unknown, hence, reaction kinetic study has been applied only to RH and RHA.

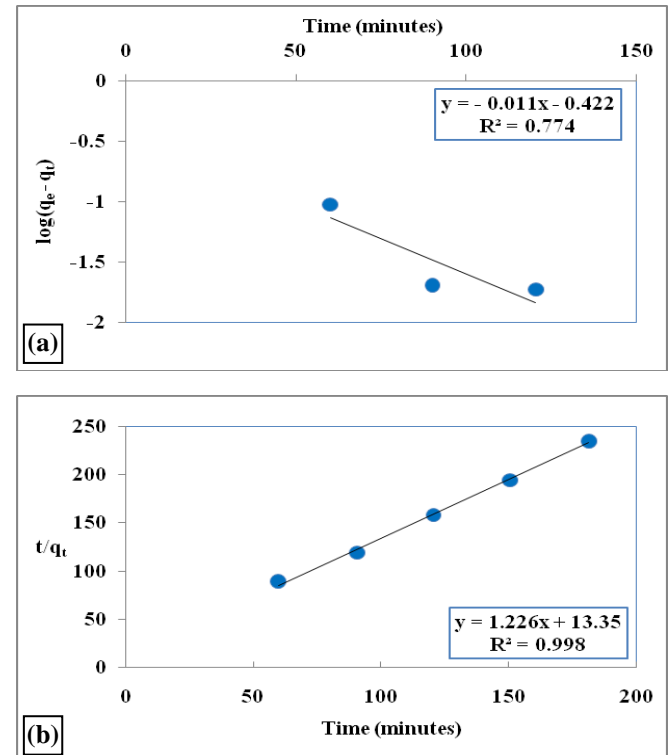
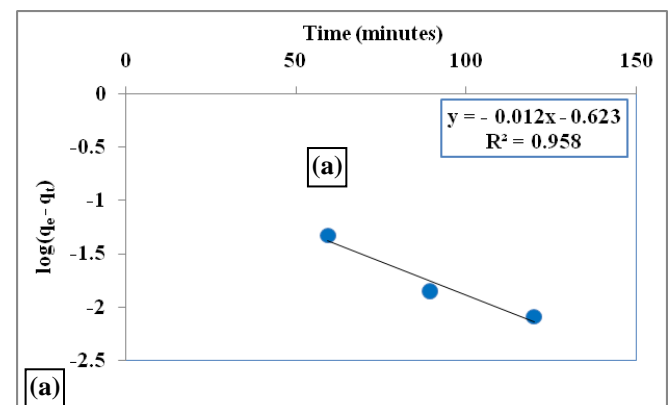


Fig. 9 (a) Pseudo-first order kinetic plot and (b) Pseudo-second order kinetic plot of RH



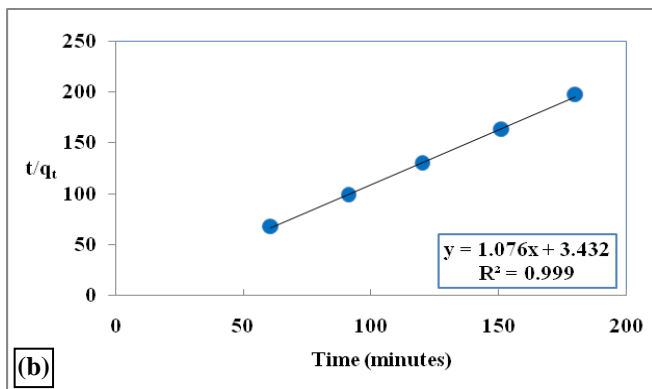


Fig. 10 (a) Pseudo-first order kinetic plot and (b) pseudo-second order kinetic plot for RHA

Table 8: Reaction Kinetics

Adsorbent	Pseudo-first-order				Pseudo-second-order			
	$Q_e$ (exp)	$Q_e$ (cal)	$K_1$	$R^2$	$Q_e$ (exp)	$Q_e$ (cal)	$K_2$	$R^2$
RH	0.766	0.378	0.025	0.774	0.766	0.815	0.049	0.998
RHA	0.916	0.238	0.0276	0.958	0.916	0.929	0.337	0.999

### 3.7 Surface morphology

According to Tarley and Arruda (2004), the material (adsorbent) morphology may facilitate the adsorption of metals in different parts of this material. Therefore, based on morphology, as well as the fact that the highest concentration of silica is present in the outer film of RH, this material presents a morphological profile with the potential to retain metal ions [6]. Fig. 11 shows a SEM micrograph of a sample of RH and RHA obtained, showing that RH is intact and has a smooth surface. Through calcination the organics are decomposed and the ash obtained may constitute of amorphous silica with high porosity having potential application as ligand in metals adsorbent, whereas RHA obtained, showing a very porous tracery surface morphology, with a high surface area. Similar results have been observed by Madrid et al. [25]. RHA is silica rich which serves as a good adsorbent. According to Vieira et al. [3], RH and RHA are predominantly mesoporous materials and the calcinations of RH caused an increase in the surface area, the presence of -OH, Si-O-Si and Si-H groups on the RHA surface were important for metal adsorption [6]. Hence, in this study, the maximum percentage removal of lead is higher with RHA than that with RH. Further,

through the carbonization of rice husk (RHA) the moisture content decreases, changes in the physical and chemical properties of rice husk improves adsorption efficiency of RHA.

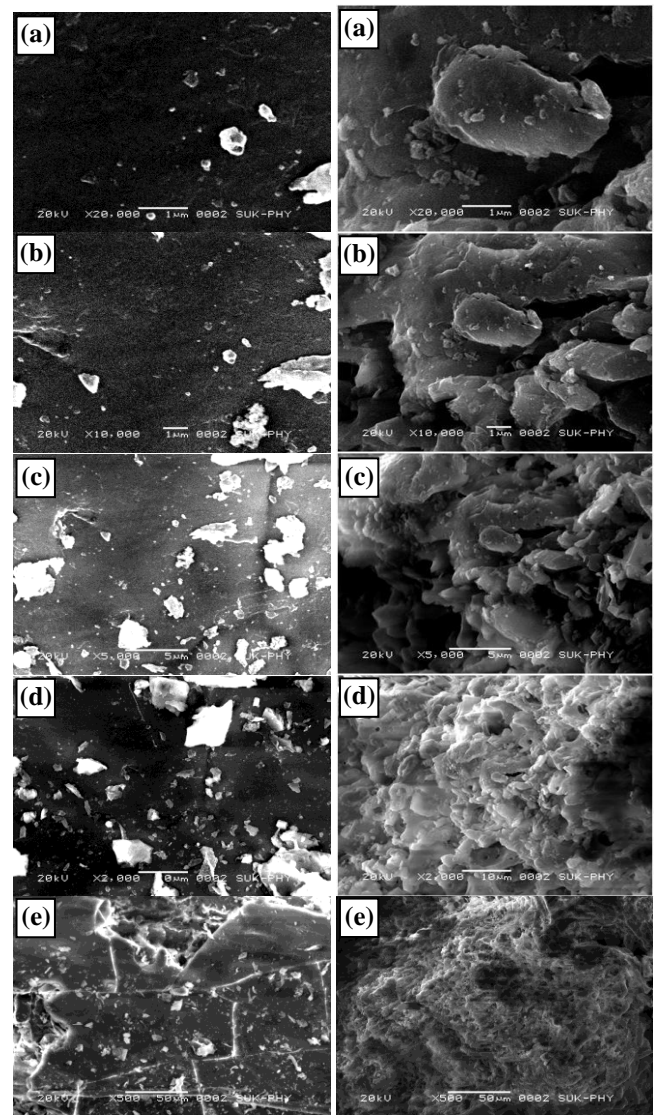


Fig. 11 Scanning electron micrographs (SEM) for RH (left picture) and RHA (right picture) at magnifications of (a) (50x), (b) (100x), (c) (500x), (d) (1000x) and (e) (5000x)

### 4. CONCLUSIONS

The experimental results on removal of lead (II) with un-activated and activated rice husk are presented in the paper. Through chemical activation of the adsorbent, the percentage removal efficiency of an adsorbent can be increased. Hence, activated rice husk shows greater efficiency than un-activated rice husk. Highest percentage lead removal with adsorbent RH found is 93.36 % at pH 4-5, initial concentration of lead 30 mg/L,



contact time of 60 minutes and adsorbent dosage of 1 gm. When RHA is used, the maximum percentage removal is found as 94.8 % at pH 4-5, initial concentration of lead 20 mg/L, contact time of 60 minutes, adsorbent dosage of 1 gm. However, with PRH, the highest percentage removal of lead is 96.72 % at pH 5-6, initial concentration of lead 10mg/L, contact time of 60 minutes and adsorbent dosage of 4 gm. Similarly, for ARH, the maximum lead removal is found to be 99.35% at pH 5-6, initial concentration of lead solution 10 mg/L, contact time of 60 minutes and adsorbent dosage of 4 gm. Rice husk, Rice husk ash and phosphoric acid treated rice husk followed Freundlich isotherm model whereas acetic acid treated rice husk followed Langmuir isotherm model. Rice husk and rice husk ash follow pseudo-second order kinetics. From this study, it is inferred that rice husk, an abundantly available agricultural waste can be used as a low cost adsorbent. The higher adsorption capacity is favored by higher number of active binding sites, improved ion exchange properties and enhancement of functional groups after chemical treatment.

## REFERENCES

- [1] Foo, K. Y., and Hameed, B. H. "Utilization of Rice Husk Ash as Novel Adsorbent: A Judicious Recycling of the Colloidal Agricultural Waste", *Adv. Colloid Interfac.*, vol. 152, pp. 39-47, 2009.
- [2] Liaoa, D., Zhengb, W., Li, X., Yangb, Q., Yueb, X., Guob, L., and Zengb, G., "Removal of Lead (II) from Aqueous Solutions using Carbonate Hydroxyapatite extracted from Egg Shell Waste", *Journal of Hazardous Material*, vol. 177, pp. 126-130, 2010.
- [3] Vieira, M. G. A., de Almeida Neto, A. F., Carlos da Silva, M. G., Nóbrega, C. C., and Melo Filho, A. A., "Characterization and Use of In Natura and Calcined Rice Husks for Biosorption of Heavy Metals Ions from Aqueous Effluents", *Brazilian Journal of Chemical Engineering*, Vol. 29 (3), pp. 619 - 633, 2012.
- [4] Demirbas, A., "Heavy Metal Adsorption onto Agro-Based Waste Materials: A review", *Journal of Hazardous Materials*, vol. 157, pp. 220-229, 2008.
- [5] Kumar, P. S., Vincent, C., Kirthika, K., and Kumar, K. S., "Kinetics and Equilibrium Studies of Lead (II) Ion Removal from Aqueous Solutions by Use of Nano-Silversol-Coated Activated Carbon", *Brazilian Journal of Chemical Engineering*, vol. 27 (2), pp. 339-346, 2010.
- [6] Hashem, M. A., "Adsorption of Lead Ions from Aqueous Solution by Okra Wastes", *International Journal of Physical Science*, vol. 2 (7), pp. 178-184, 2007.
- [7] Singh, K. K., Talat, M., and Hasan, S. H., "Removal of Lead from Aqueous Solutions by Agricultural Waste Maize Bran", *Bioresource Technology*, vol. 97, pp. 2124-2130, 2006.
- [8] El-Ashtoukhy, E.-S. Z., Amin, N. K., and Abdelwahab, O., "Removal of Lead (II) and Copper(II) from Aqueous Solution using Pomegranate Peel as a New Adsorbent", *Desalination*, vol. 223, pp. 162-173, 2008,.
- [9] Yoshita, A. Lu, J. L. Ye, J. H. and Liang, Y. R., "Sorption of Lead from Aqueous Solutions by Spent Tea Leaf", *African Journal of Biotechnology*, vol. 8, pp. 2212-2217, 2010.
- [10] Imamoglu, M., and Tekir, O., "Removal of Copper (II) and Lead (II) Ions from Aqueous Solutions by Adsorption on Activated Carbon from A New Precursor Hazelnut Husks", *Desalination*, vol. 228, pp. 108-113, 2008.
- [11] Ekop, A. S., and Eddy, N. O., "Thermodynamic Study on the Adsorption of Pb (II) and Zn (II) from Aqueous Solution by Human Hair", *E-Journal of Chemistry*, vol 7 (4), pp 1296-1303, 2010.
- [12] Adie, D. B., Okuofu, C. A., and Osakwe, C., "Comparative Analysis of the Adsorption of Heavy Metals in Wastewater using Borrassus Aethiopicum and Cocos Nucifera", *International Journal of Applied Science and Technology*, vol. 2 (7), pp. 314-322, 2012.
- [13] Azouaou, N., Sadaoui, Z., and Mokaddem, H., "Adsorption of Lead from Aqueous Solution onto Untreated Orange Barks: Equilibrium, Kinetics and Thermodynamics", *EDP Sciences*, 2014.
- [14] Wahi, R., Ngaini, Z., and Jok, V. U., "Removal of Mercury, Lead and Copper from Aqueous Solution by Activated Carbon of Palm Oil Empty Fruit Bunch", *World Applied Sciences Journal*, vol. 5, pp. 84-91, 2009.
- [15] Chairgulprasert, V., Japakeya, A., and Samaae, H., "Phytoremediation of Synthetic Wastewater by Adsorption of Lead and zinc onto *Alpinia galanga* Willd", *Songklanakarinn Journal of Science and Technology*, vol. 35 (2), pp. 227-233, 2013.
- [16] El-Said, A. G., Badawy, N. A., and Garamon, S. E., "Adsorption of Cadmium (II) and Mercury(II) onto Natural Adsorbent Rice Husk Ash (RHA) from Aqueous Solutions: Study in Single and Binary System", *Journal of American Science*, vol. 6 (12), pp. 400-409, 2010.
- [17] Thajeel, A. S., Raheem, A. Z., and Al-Faize, M. M., "Production of activated carbon from local raw materials using physical and chemical preparation method", *Journal of Chemical and Pharmaceutical Research*, vol. 5(4), pp. 251-259, 2013.
- [18] Issabayeva, G., Aroua, M. K., and Nik Meriam Nik Sulaiman, "Removal of Lead from Aqueous Solutions on Palm Shell Activated Carbon", *Bioresource Technology*, vol. 97, pp 2350-2355, 2006.

- [19] Wong, K. K., Lee, C. K., Low, K. S., and Haron, M. J., "Removal of Cu and Pb by Tartaric acid Modified Rice Husk from Aqueous Solutions", *Chemosphere*, vol. 50, pp. 23-28, 2003.
- [20] Jameel, A. A., and Hussain, A. Z., "Removal of Heavy Metals from wastewater using Activated Rice Husk Carbon as Adsorbent", *Indian Journal of Environmental Protection*, vol. 29 (3), pp. 263-265, 2009.
- [21] Siddiqui, B., Anwar, J., and Zaman, W., "Adsorption studies for the amputation of Lead from Squander Waters by using Straws of *Oryza Sativa* (Rice)", *Journal of Scientific Research*, vol. 39 (1), pp. 9-14, 2009.
- [22] Paulino, A. T., Minasse, F. A. S., Guilherme, M. R., Reis, A. V., Muniz, E. C., and Nozaki, J., "Novel Adsorbents based on Silkworm Chrysalides for Removal of Heavy Metals from Wastewaters", *Journal of Colloid Interface Science*, vol. 301, pp. 479-487, 2006.
- [23] Bernard, E., and Jimoh, A., "Adsorption of Pb, Fe, Cu and Zn from Industrial Electroplating Wastewater by Orange Peel Activated Carbon", *International Journal of Engineering and Applied Sciences*, Vol. 4 (2), pp. 95-103, 2013.
- [24] Gavhane, K. A., *Mass Transfer-II*, *Chemical Engineering*, Nirali Prakashan, 5<sup>th</sup> Edition, 2006.
- [25] Madrid, R., Nogueira, C. A., and Margarido, F., "Production and Characterisation of Amorphous Silica from Rice Husk Waste", *Fourth International Conference on Engineering for Waste and Biomass Valorisation*, Porto, Portugal, 2012.