eProceedings Chemistry 4 (2019) 158-165

eISSN 2550-1453 http://eproceedings.chemistry.utm.my/

Removal of Lead from Aqueous Solution Using Banana Peel as An Adsorbent

Nor Shahirah Ismail and Zaiton Abdul Majid*

Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
**Corresponding Author: zaitonmajid@utm.my*

Article history:
Received 27 June 2019
Accepted 26 July 2019

GRAPHICAL ABSTRACT

Banana peel (left) and banana peel powder (right)

ABSTRACT

This research was conducted to examine the use of banana peel as an adsorbent for the removal of lead from aqueous solution. The banana peel was washed with distilled water and dried under sunlight. The banana peels was blended and dried in oven at 105 ºC to remove excess moisture. The powdered banana peel was characterized before and after adsorption by using Fourier Transform Infrared (FTIR) to determine the functional group present in banana peels. The functional groups observed are O-H stretching, CH stretching, C=C group and C-O group. Powder X-ray Diffraction (XRD) analysis was also conducted to determine the crystalline phase in banana peels. Batch adsorption test using a shaker at 200 rpm for 140 minutes, was performed to evaluate the sorption characteristics of powdered banana peels towards lead. The effects of contact time, pH and adsorbent dosage on the sorption of lead by powdered banana peel were evaluated. The highest percentage removal of lead ion from aqueous solution by banana peel powder was observed at pH 5 with adsorbent dosage of 1.4 g. The adsorption isotherm also was tested with Langmuir adsorption and Freundlich adsorption isotherm and the kinetic study was conducted by using pseudo-first order and pseudo-second-order kinetic models. The adsorption results are well fitted to the Langmuir isotherm model with q_{max} was 1.364 mg g^{-1} and follow pseudo-second order kinetic model. The study shows that banana peel can be effectively used as potential adsorbent for the adsorption of lead from aqueous solution.

Keywords: Adsorption, banana peels, adsorption isotherms, kinetics study

© 2019 Dept. of Chemistry, UTM. All rights reserved

1. INTRODUCTION

Excessive heavy metal released to wastewaters from various industrial activities is a global environmental problem [1]. The contaminant of heavy metal comes in two ways which are indirect or direct causes. The unplanned urbanization, metal finishing and mining, rapid industrialization and textile manufacturing are contributors for contaminate water quality. The most common heavy metals pollutants are arsenic, cadmium, chromium, nickel, lead, copper and mercury [2].

Various treatment technologies or process are available differently that make to overcome and minimize water pollution [3]. Treatment technology or process for removal of heavy metal form wastewater which are chemical precipitation, ion exchange, adsorption, membrane filtration, electrochemical methods and coagulation [4]. Adsorption is an effective method for removal of heavy metal in wastewater. In adsorption, activated carbon is a most common that use as an adsorbent. Activated carbon has been widely used in many applications. However, the high cost for effectiveness in the activation process limits it use in the wastewater treatment process [5].

Nowadays banana peel was used as adsorbent in water treatment. Banana peel is considered as a preliminary agricultural waste which causes more problem occur because banana is one of the highest consumed fruit in the world and useless peels. This problem has been overcome by utilizing banana peel to be used as an adsorbent to remove heavy metals from water. Banana peels represent lignin, pectin, cellulose, hemicelluloses, in its biomass that containing functional groups like hydroxyl, amine and carboxyl [6].

This research was focused on the preparation and characterization of banana peel as an adsorbent and applying it in the adsorption of lead from aqueous solution. In this research, there are some parameters that will be consider for sorption study likes effect of pH, effect of contact time and effect of adsorbent dosage. The maximum adsorption capacity of banana peel was evaluated by using Langmuir adsorption isotherm and intensity of adsorption will evaluate by Freundlich adsorption isotherm. Kinetic study was conducted by using pseudo-first order and pseudo-second-order model.

2. EXPERIMENTAL

2.1. Preparation of adsorbent

Banana peel ('Pisang Berangan') was selected and washed using tap water to remove ash. Then, it was washed by distilled water to remove contaminants. Banana peel was cut into small piece. Then wash again with distilled water. The banana peel was dried under sunlight for 2 days. Then, it was grinded with blender. After that, it was dried in the oven at 105ºC for 2 hours to remove excess moisture. The banana peel was blended again until it forms into powder. After that, the powder was sieved through 140 µm sieve.

2.2. Preparation of stock solution

The stock solution of lead was prepared by dissolving 1.6 g of lead(II) nitrate in 100 mL of deionized water. Then, it was transferred into 1000 mL volumetric flask. The volume was made up to mark and shake the lead solution. Concentration lead solution was 1000 mg/L. Then, lead solution was diluted into 5 mg/L as initial concentration.

2.3. Batch sorption study

The lead(II) adsorption was conducted by batch adsorption test. This experiment was conducted to study the efficient adsorption by using various factors which are the effect of contact time, pH and adsorbent dosage.

Percentage removal efficiency was calculated using the following equations respectively [7].

$$\text{Removal efficiency (\%)} = \frac{C_0 - C_c}{C_0}\, x\, 100 \qquad (1)$$

Where, q_c is amount of lead adsorbed on adsorbent; C_0 is the initial of concentration metal ion in solution; C_c is the metal concentration in solution at equilibrium; V is volume of solution in litre and m is the mass of adsorbent in grams.

2.4. Adsorption isotherm studies

The study of adsorption isotherm is usually to describe the adsorption capacity of the adsorbent [8]. In this study, the equilibrium data obtained for lead(II) removal using banana peel was tested with Langmuir adsorption and Freundlich Adsorption Isotherm.

The Langmuir adsorption model is adsorption onto solids based on the assumption that adsorption occurs on localized part without interaction between adsorbate molecules and the maximum adsorption will occurs when the surface is covered by a monolayer of adsorbate [5]. Freundlich adsorption isotherm equations were used for adsorption behavior of lead by banana peel [7].

2.5 Adsorption kinetics study

The kinetics study is required to find out the mechanism and rate determining step of a chemical reaction. Kinetic study conducted by using pseudo-first-order and pseudo-second-order kinetic models [9].

3. RESULTS AND DISCUSSION

3.1. Fourier transform infrared (FTIR)

FTIR spectroscopy method was used to show the functional groups present on the surface of the peels were measured within the range 400 – 4000 cm^{-1}. Figure 1 and Figure 2 shows FTIR spectra of the banana peel before adsorption (BP1) and after adsorption (BP2) respectively.

For the BP1, adsorption band of four functional groups are observed. The strong peak at the frequency 3431.12 cm^{-1} due to O-H stretching indicated presence of free hydroxyl group of polymeric compounds such as lignin or pectin that containing the functional groups of alcohols, phenols and carboxylic acid and adsorbed water molecule on the surface. The peak at frequency 2928 cm^{-1} is due to CH stretching vibrations of CH, CH_2, CH_3 groups. The FTIR peak located at 1634.38 cm^{-1} is indexed to C=C groups which is presence of alkene compound. The intense peak at frequency 1384.54 cm^{-1} was obtained presence of C-O carboxyl groups attributed to lignin band.

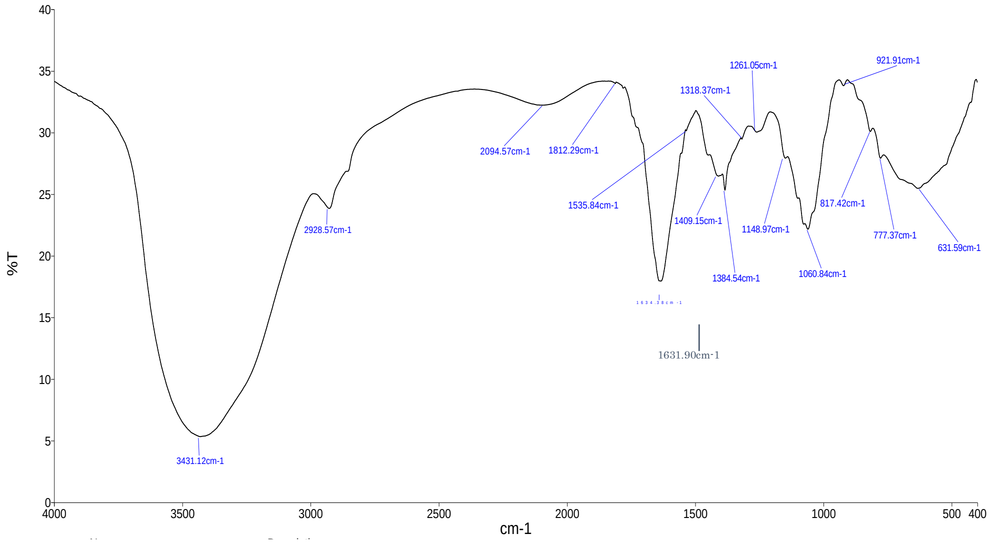

Figure 1. FTIR spectra of the banana peel before adsorption

In the spectrum of BP2, the frequency 3411.68 cm^{-1} represents the O-H group. Then, at peak 2922.26 cm^{-1} and 2853.5 cm^{-1} consist of CH stretching bands. The frequency 1732.70 cm^{-1} presence of C=O stretching vibrations of carboxylic acids or esters. For the peak at frequency 1631.90 cm^{-1} due to the C=C groups.

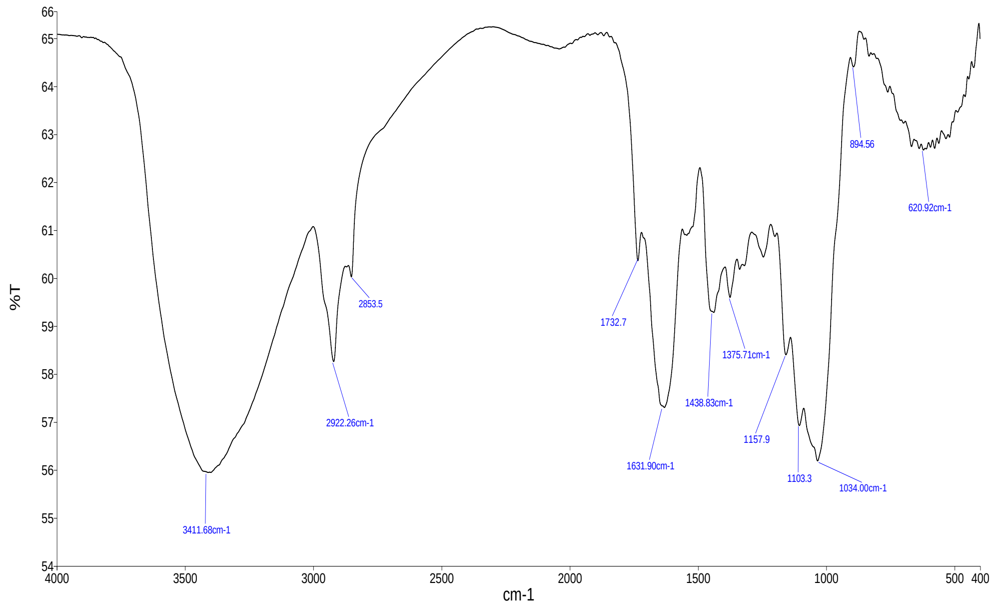

Figure 2. FTIR spectra of the banana peel after adsorption

3.2 Powder X-Ray Diffraction (XRD) analysis

The structure of banana peel was characterized using XRD analysis as presented in Figure 3. The diffraction spectra were recorded with a scan rate of ϴ/2ϴ. The angle range (2ϴ) was investigated between 0° and 80°.

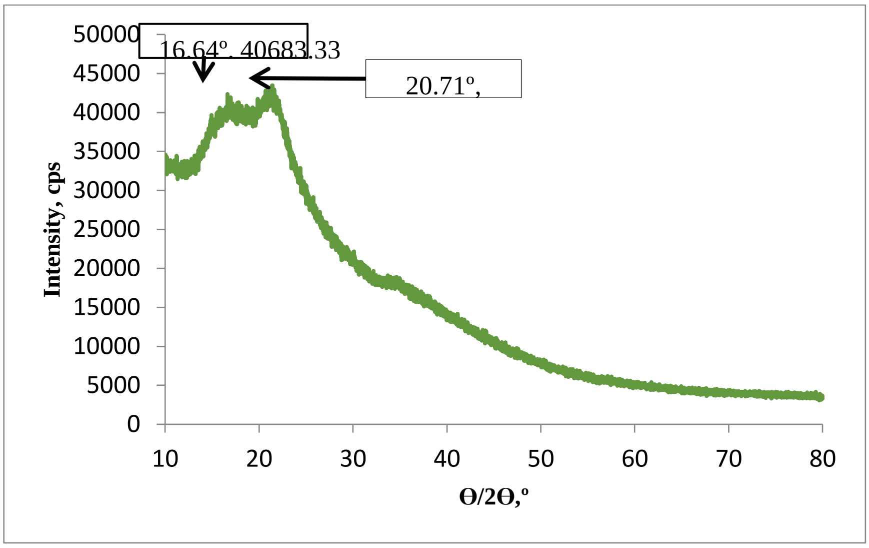

Figure 3. X-Ray diffraction spectra of banana peel

The XRD analysis commonly indicates crystalline parts and amorphous parts. Banana peel sample show two diffused peaks which are broad peak at 16.64° and sharp peak at 20.71° which indicates a mixture of crystalline and amorphous phases.

3.3 Effect of contact time

The effect of contact time on adsorption of lead(II) by banana peel as adsorbent was observed using different contact time in the range 20-140 minutes at constant pH, adsorbent dose and shaking speed. These results are important, as equilibrium time is one of the important parameters for selecting a wastewater treatment system. The results are illustrated in Figure 4.

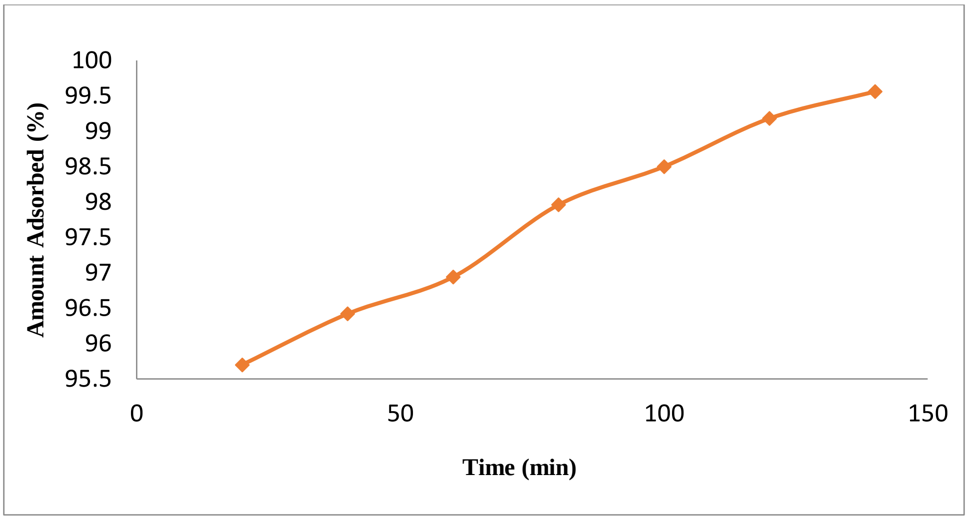

Figure 4. Effect of time on lead adsorption by banana peel

From the result obtained in Figure 4, adsorption of lead was increased with increasing of contact time. The result showed that maximum adsorption of lead was occurred at 140 minutes which is 99.6%. The initial faster adsorption rate removal metal ion may due to the availability of the uncovered surface area of the adsorbents. It proves that the metal ions took 140 minutes to fully adsorb onto banana peel.

3.4 Effect of pH

The effect of pH is one of the most important factors affecting adsorption process for binding of lead. This is because the adsorption of solute from wastewater is affected by the pH of the solution, which affects the surface charge of the adsorbent and degree of ionization. The effect of pH on the amount of lead(II) metal ions was carried out on pH range from 2-12 on the adsorption of lead was done at temperature 25 º C with constant shaking speed and time which are 200 rpm and 140 minutes respectively.

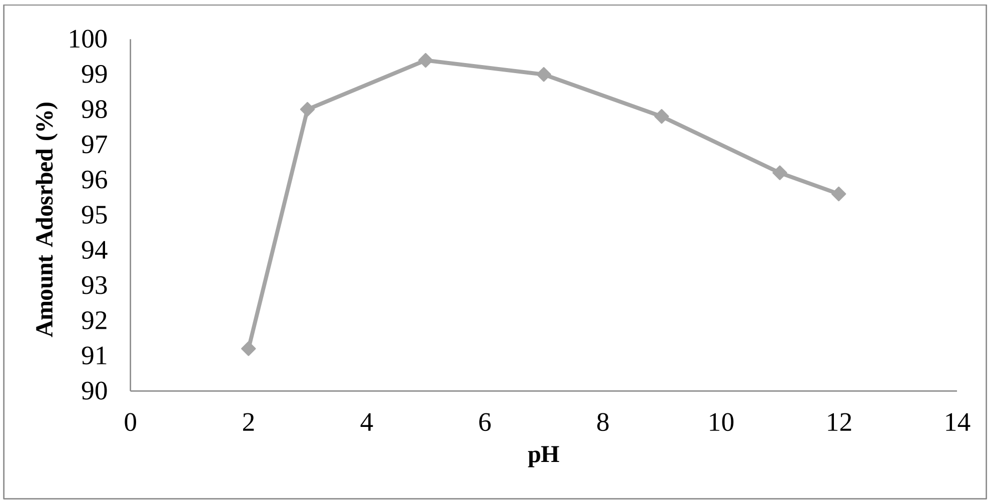

Figure 5. Effect of pH on lead adsorption by banana peel

As shown in Figure 5, maximum adsorption of lead has taken place at pH 5. Acidic conditions are required for metals increases affinity of banana peels to metal ions. Below optimum pH, adsorption decrease. At lower pH, H^+ competes with metals in the solution for the exchange sites. At higher pH, an adsorption site does not activate. The minimum adsorption at pH 2 may be due to the high mobility and high concentration of H^+. Due to this H^+ ions are adsorbed in more amount than the comparison of metal ions. Therefore, pH 5 was selected for further adsorption study.

3.5 Effect of adsorbent dosage

Effect of adsorbent dosage on adsorption of lead was studied as it determines the capacity of adsorbent for a given initial concentration of lead. In this study, 5 mg/L of lead solution with varying amount of adsorbent from 0.2 g to 1.4 g of banana peel is used to observe the effect of different amount of adsorbent on the adsorption of lead.

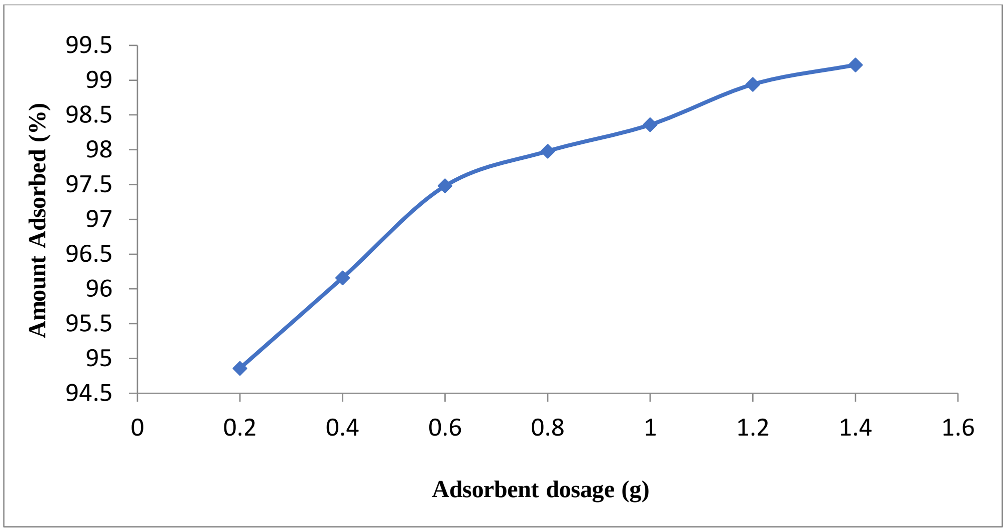

Figure 6 Effect of adsorbent dose on lead adsorption by banana peel

From the Figure 6, it can be seen that the percentage removal of lead increases when the adsorbent dose of banana peel increased from 0.2 to 1.4 g, the percentage removal of lead ion increased from 94.9% to 99.2% respectively. The increase in adsorbent amount will increases the number of available active sites for the removal of metal ions.

3.7 Adsorption Isotherms

The Langmuir adsorption isotherm assumes that the adsorption occurs with monolayer adsorption on homogeneous surface. The isotherm constants can be evaluated from the intercept and the slope the linear plot of the experimental data $1/q_e$ against $1/C_e$ as shown in Table 1. The linear form of Langmuir adsorption isotherm is given as below:

$$\frac{1}{q_e} = \frac{1}{q_{max}} + \frac{1}{a q_{max} C_e} \tag{2}$$

When $1/q_e$ against $1/C_e$ is plotted, a straight line graph is obtained with:

$$\text{Slope} = \frac{1}{a\, q_{max}} \tag{3}$$

$$\text{Intercept} = \frac{1}{q_{max}} \tag{4}$$

Freundlich isotherm model presumes that the adsorption of metal ions take place on heterogeneous surface with multilayer adsorption. Freundlich model is one of the most widely used isotherms for the description of adsorption equilibrium. The isotherm constant can be evaluated from the slope and the intercept of the linear plot of the experimental data log q_e against log Ce. The linear form of Freundlich adsorption isotherm is:

$$\log q_e = \log K_F + \left(\frac{1}{n \log C_e}\right) \tag{5}$$

When log q_e against log C_e is plotted, a straight line graph is obtained with:

$$\text{Slope} = \frac{1}{n} \tag{6}$$

$$\text{Intercept} = \log K_F \tag{7}$$

Table 1 Langmuir and Freundlich isotherm model parameters for the removal of lead(II) ion onto banana peel

Isotherm	Parameters	Value
Langmuir	q_{max} (mg g^{-1})	1.364
	α (dm^3 mg^{-1})	3.473
	R^2	0.9109
Freudhlich	n	1.047
	K_F	3.246
	R^2	0.9262

3.8 Adsorption kinetic

Kinetic study was carried out to examine adsorption capacity of adsorbent and to evaluate the rate constant. Adsorption kinetic describes the rate of solute uptake by adsorbent with increasing contact time of 20, 40, 60, 80, 100, 120 and 140 minutes. In this study, pseudo-first-order and pseudo-second-order was applied. The linear form of pseudo-first-order model is given as below:

$$\log\ (q_e - q_t) = \log q_e - \frac{k_1}{2.303} t \quad (8)$$

where, q_e and q_t are the amount of Pb(II) adsorbed (mg g^{-1}) on adsorbent at equilibrium and at time *t*, respectively and K_1 is the rate constant of pseudo first order adsorption (min^{-1}). The rate constant k_1 can be calculated from the slope of the linear plots.

The linear form of pseudo-second-order model is given as below:

$$\frac{t}{q_t} = \frac{1}{k_2 {q_e}^2} + \frac{t}{q_e} \quad (9)$$

where k_2 (g/mg/min) is the rate constant of pseudo-second order kinetic equation and q_e and q_t are the amount of lead(II) adsorbed (mg g^{-1}) onto banana peel at equilibrium and at time *t* respectively. The rate constant k_2 and equilibrium adsorption capacity q_e were calculated from the slop and intercept linear plot of *t* (time) versus t/q_t.

Table 2. Pseudo-first-order and Pseudo-second-order diffusion values for lead(II) adsorption onto banana peel.

Kinetic models	Parameters	Value
Pseudo-first-order	q_e (mg g^{-1})	0.711
	k_1 (mg g^{-1})	0.0002
	R^2	0.9857
Pseudo-second-order	q_e (mg g^{-1})	0.502
	k_2 (mg g^{-1})	1.232
	R^2	0.999

4. CONCLUSION

The adsorption of banana peel onto lead(II) ion from aqueous was carried out under different parameter in batch adsorption study. The lead adsorption was increase at pH 5 and decrease when in basic solution. This tells that the metal is not very stable in basic solution. Therefore, the removal of this metal by banana peel can be done at pH 5. Besides that, banana peel can be used as effective adsorbent for the removal of lead metal by maintaining the maximum conditions of contact time, pH and adsorbent dosage. In this study, the best optimum condition for the removal of lead is at 140 minutes with pH 5, using small particle size that is less than 140 µm and shaking speed at 200 rpm. From the study, increase in adsorbent dosage causes an increase in the adsorption of lead. The adsorption study is well fitted with Langmuir isotherm's model and follow pseudo-second-order kinetic model. The objectives of this study have been achieved where the banana peel has been prepared and characterized as an adsorbent for the removal of lead from aqueous solution.

REFERENCES

[1] Kumar, U., Agricultural Products and By-Products as a Low Cost Adsorbent for Heavy Metal Removal from Water and Wastewater: A Review, *Scientific Research and Essays,* 1(2) (2006) 33-37.

[2] Tripathi, A., & Ranjan, M. R., Heavy Metal Removal from Wastewater using Low Cost Adsorbents, *J Bioremed Biodeg,* 6(1000315) (2015) 5.

[3] De Gisi, S., Lofrano, G., Grassi, M., & Notarnicola, M., Characteristics and Adsorption Capacities of Low-Cost Sorbents for Wastewater Treatment: A Review, *Sustainable Materials and Technologies,* 9 (2016) 10-40.

[4] Fu, F., & Wang, Q., Removal of Heavy Metal Ions from Wastewaters: A Review', *Journal of Environmental Management,* 92(3) (2011) 407- 418.

[5] Salam, O. E. A., Reiad, N. A., & ElShafei, M. M., A Study of the Removal Characteristics of Heavy Metals from Wastewater by low-cost adsorbents, *Journal of Advanced Research,* 2(4) (2011) 297-303.

[6] Anwar, J., Shafique, U., Salman, M., Dar, A., & Anwar, S., Removal of Pb (II) and Cd (II) from Water by Adsorption on Peels of Banana. *Bioresource Technology,* 101(6) (2010) 1752-1755

[7] Deshmukh, P., Khadse, G., Shinde, V., & Labhasetwar, P., Cadmium Removal from Aqueous Solutions Using Dried Banana Peels as An Adsorbent: Kinetics and Equilibrium Modeling, *J Bioremediat Biodegrad,* 8(395) (2017) 1-7.

[8] Shrestha, B., Kour, J., & Ghimire, K. N., Adsorptive Removal of Heavy Metals from Aqueous Solution with Environmental Friendly Material—Exhausted Tea Leaves, *Advances in Chemical Engineering and Science,* 6(04) (2016) 525.

[9] Ali, A., Saeed, K., & Mabood, F., Removal of Chromium (VI) from Aqueous Medium using Chemically Modified Banana Peels as Efficient Low-cost Adsorbent', *Alexandria Engineering Journal,* 55(3) (2016) 2933-2942.