REMOVAL OF LEAD IONS FROM WASTEWATER WITH ECONOMICAL ADSORBENTS: A PRELIMINARY FINDING

[1]Megat Ahmad Kamal Megat Hanafiah, [2]Shariff Che Ibrahim,[2]Muhd Zu Azhan Yahya
[1]Faculty of Applied Sciences, Universiti Teknologi MARA, Cawangan Pahang, 26400, Jengka, Pahang
[2]Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor

Abstract: The removal of lead from synthetic wastewater with economical materials particularly *Hevea brasiliensis* (HB) leaf, *Imperata cylindrica* (IC) leaf and *Sterculia spp* (SS) leaf was investigated by the batch mode method. The influence of pH and particle size on the removal of lead was determined. The removal percentages by adsorption onto HB, SS and IC showed high values for lead ions. The extent of lead removal increased with decrease in the size of adsorbents and increase in the pH of the solution. Lead ions were removed best (75%) by SS and IC at pH 7 by using adsorbent size of 500 μm. Highest removal of lead by HB was recorded by using the size of 500 μm, at pH 5. Due to their demonstrated ability for lead uptake and low production cost, these natural wastes are attractive adsorbents for the removal of lead from waste streams.

Keywords: Adsorption, Natural adsorbents, Batch mode, Percentage removal, Low-cost adsorbents

INTRODUCTION

Water is the most important substance in our lives, and it makes nearly 70% of the earth surface. Pure water is a colorless, tasteless and odorless compound containing hydrogen and oxygen with the chemical formula of H_2O. It is a universal solvent; and as a result, it dissolves many natural and man-made substances. The dissolved and suspended materials in water are termed impurities or pollutants and they gain entry into water as a result of the hydrologic system. An example of pollutant is heavy metals, and they are ubiquitous in the environment. Generally the term heavy metal has been taken to mean all metals and metalloid other than alkali and alkaline earth elements. The tremendous increase in the use of heavy metals over the past few decades has inevitably resulted in an increase flux of metallic substances in the aquatic environment. Heavy metals are of special concern because they are non-biodegradable and therefore persistent. The presence of heavy metals in the environment can be detrimental to a variety of living species including humans. Heavy metals can be distinguished from other toxic pollutants since they can be accumulated in living tissues, causing various diseases and disorders. Pollution caused by heavy metals has been a worldwide phenomenon.

Among many heavy metals, lead is one of the well-known toxic heavy metals. Unlike organic compounds, lead cannot be degraded or destroyed. It is primarily introduced into the atmosphere by the use of lead-containing gasoline and then introduced into the food chain by deposition on crop plants and soil dust inhalation. There are many other ways in which humans are exposed to lead: through deteriorating paint, household dust, bare soil, air, drinking water, food, ceramics, home remedies, hair dyes and other cosmetics. Much of this lead is of microscopic size, invisible to the naked eye. The tolerance limits for the discharge of lead into inland waters are 0.10 mg/l (Standard A) and 0.5 mg/l (Standard B) according to the Malaysian Standards. Since the presence of lead in the environment has become a major threat to plant, animal and human life due to its bioaccumulating tendency and toxicity, lead must be removed from municipal and industrial effluents.

In advanced countries, removal of heavy metals in wastewater is normally achieved by advanced technologies such as precipitation-filtration, ion exchange, membrane separation, electrolytic methods and adsorption on activated carbon. Although the treatment cost for precipitation-filtration is relatively cheap, the treatment procedure is complicated. Adsorption processes that involve ion exchange and membrane separation are simple, yet their chelating and ion exchange resins are expensive. Other than that, those treatment processes involve high-energy requirements, production of toxic sludge that also require disposal and may also be insufficient to meet regulatory requirements. Therefore, it is worthwhile to develop the economical adsorbents of heavy metals, which can be applied in developing countries. Sorption processes using agricultural waste products are becoming the new alternative for wastewater treatment because they are cheap, simple, sludge free and involve small initial cost and land investment [1]. The use of agricultural by-products for the removal of toxic and valuable metals from wastewater has continued to attract considerable attention in recent years.

In general, an adsorbent can be assumed as low cost if it requires little processing, is abundant in nature, or is a byproduct or waste materials from another industry. Natural materials that are available in large quantities or certain waste products from industrial or agricultural operations may have potential as inexpensive adsorbents. Materials that have been investigated include rice straw, sugarcane bagasse, soybean and cottonseed hulls [2], chitosan [3], bone powder and Nile rose plant [4], fly larva shells [5], peanut shell [6], Pinus pinaster bark [7], sunflower stalks [8], apple wastes [9] and tree fern [10]. A review of low cost adsorbents for water and wastewater treatment has been presented by Bailey et al. [11]. Plant wastes particularly HB, SS and IC are very common in Malaysia due to their high availability. In this present work, we report the work on the use of selected natural wastes as adsorbents for the removal of a divalent metal ion, Pb(II) from aqueous solution. The effect of varying adsorbents size and pH on the ability of natural adsorbents in removing lead ions from solution was investigated.

MATERIALS AND METHODS

Preparation of samples

Three types of natural wastes given as HB, SS and IC were collected from rubber estates in Jengka, Pahang. These natural adsorbents were washed with double distilled water to remove dirt and laid on trays. The adsorbents were dried in an oven at 105 ^{0}C for a period of 2 days, then ground with Cuisinart Mini-Mate Plus Chopper and screened through a sieve stack to obtain the geometric mean particle size of 1000 and 500 μm. The adsorbents were stored in airtight plastic containers and ready to use.

Batch mode adsorption studies

The synthetic wastewater sample, which contains Pb(II) was prepared from lead nitrate solution. The chemical was supplied by Fisher Chemical, ACS Certified. A stock solution of lead (1000 ± 2ppm) was prepared and suitably diluted to 50 mg/l. Batch mode adsorption studies were carried out to determine the adsorption of Pb(II) on the natural adsorbents. Tests were performed in 250 ml conical flasks by agitating 1 g of adsorbents with 100 ml of lead solution for 2 hours in a shaking water bath at 200 rpm and at 30 °C. The pH of the solutions was adjusted to the required value (range: 3-7) by adding either 0.1 M HCl or 0.1 M NaOH solution. Adsorbate and adsorbent were separated by filtering through a 0.45 μm membrane filter. The heavy metal concentration in the supernatant was analyzed by atomic absorption spectrophotometer (Perkin-Elmer Analyst 400). Blanks containing adsorbents but without heavy metal were used to detect the presence of Pb(II) from natural adsorbents and served as controls. The percentage removal of heavy metal was calculated using the following relationship:

$$\text{Percentage removal} = 100(C_i - C_f)/ C_i$$

where C_i and C_f are the initial and final concentrations (in mg/l) of lead, respectively. The average values of duplicate runs were obtained and analyzed.

RESULTS AND DISCUSSIONS

The pH level is one of the most important parameters on biosorption of metal ions from aqueous solutions. The effect of pH on the amount of lead adsorbed was studied because wastewater from metal industries has various pH values. Generally, it is considered that wastewater from metal industries is acidic solution. Therefore, this effect on the removal of lead was investigated over the pH range 3 – 7. The initial pH values investigated were lower than 7.0 since insoluble lead hydroxide starts precipitating from the solutions at higher pH values, making true sorption studies impossible. For HB with 500 μm sizes, it can be seen that the percent adsorption of lead at pH 3 is 73.8% and increased to 77.6% at pH 5, as shown in Figure 1. The highest removal percentage of lead by 1000 μm size occurred at pH 7 (73.6%), and the lowest occurred at pH 3 (67.6%). For HB, the lead adsorption was slightly affected by the change in pH of the solution and the size of adsorbent. Analyses on the blanks found no trace of lead originated from the adsorbents, and therefore it can be concluded that the source of lead in the wastewater sample was purely from lead nitrate solution.

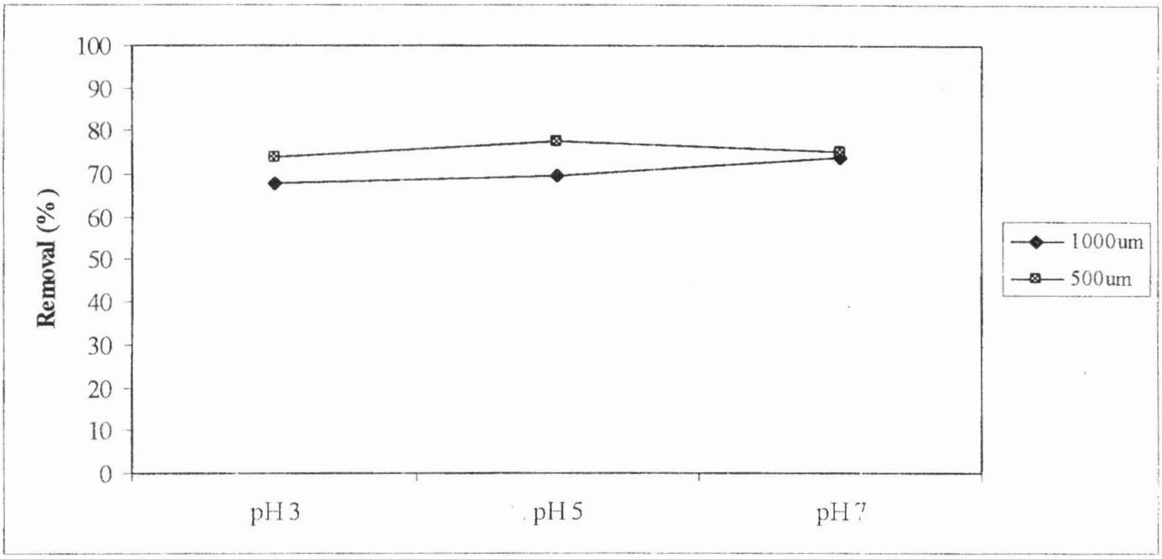

Figure 1: Removal of Lead by HB at 50 mg/l

The effect of pH and size of adsorbent on the lead removal by SS is shown in Figure 2. The highest removal percentage of lead was achieved by 500 μm size at pH 7 (78.4%), and the lowest removal was 66.9% at pH 3 by 1000 μm size. The removal rate of lead by 1000 μm was almost constant at pH above 5.

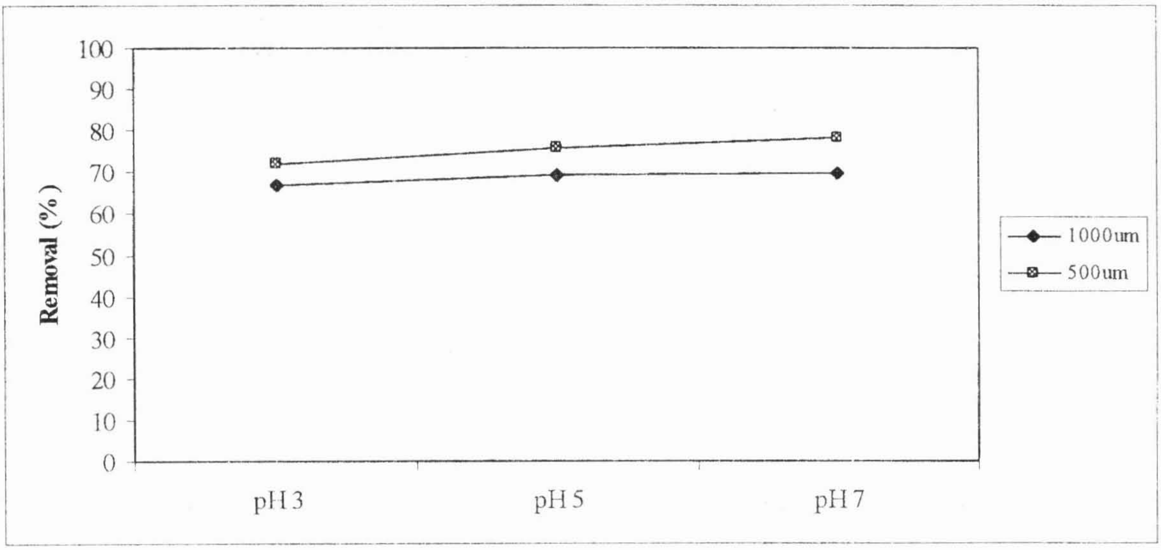

Figure 2: Removal of Lead by SS at 50 mg/l

A more obvious effect of pH and the size of adsorbent could be seen by IC, as shown in Figure 3. At pH 3 with the adsorbent size of 1000 μm, only 36.9% lead removal was recorded and the maximum value of adsorption was 56.3% at pH 5. The amount of lead adsorbed increases with the decrease in particle size of the adsorbent. By using 500 μm sizes, the percent adsorption increased from 73% to 76.7% at pH 5 and 7, respectively. This accords well with the findings of other investigators [12,13].

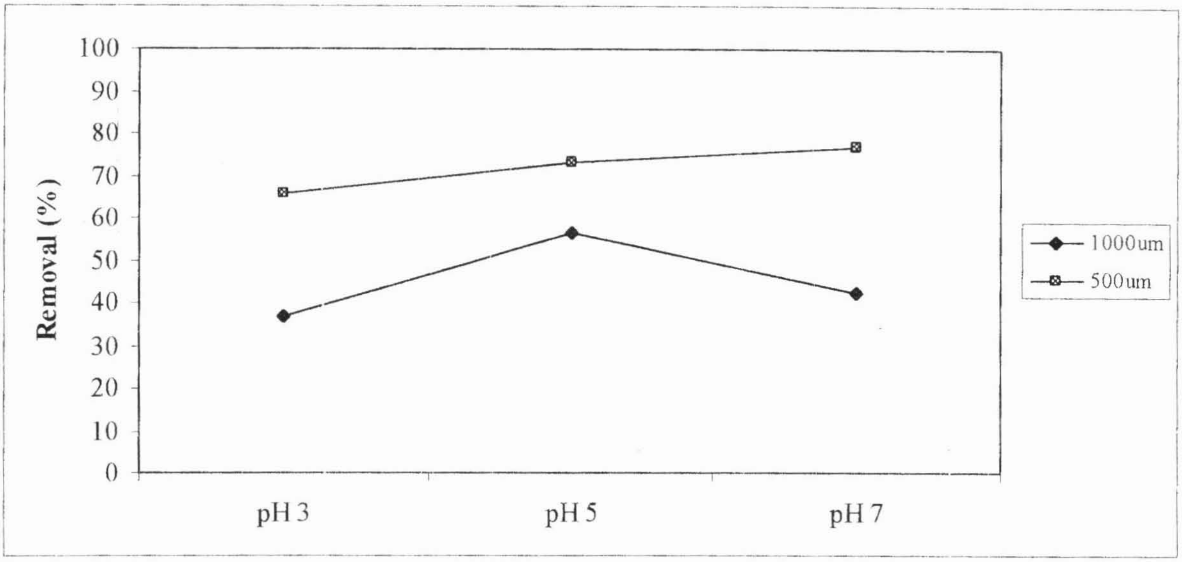

Figure 3: Removal of Lead by IC at 50 mg/l

From the above figures, it is noticed that SS and IC showed a higher removal rate of lead at pH above 5 by using the adsorbent size of 500 μm. According to Namasivayam et al., as the pH of the system decreased, the number of negatively charged adsorbent sites decreased and the number of positively charged surface sites increased, which did not favor the adsorption of positively charged metal cations [14]. In addition, the overall trend observed in pH-dependent binding suggests that the metal binding could occur through an ion-exchange type mechanism. This trend in pH-dependency suggests that by reducing the pH, the bound metal ions could be desorbed and the spent biomass regenerated. These trends have also been observed by other works [15,16]. Mckenzie proposed the following equations, which explain the possible adsorption mechanism [17]:

$$SO^- + M^{2+} \rightarrow SOM^+$$

$$SO^- + MOH^+ \rightarrow SOMOH$$

$$SOH + M^{2+} \rightarrow SOM^+ + H^+$$

$$SOH + MOH^+ \rightarrow SOMOH + H^+$$

where SO^- denotes negatively charged surface, SOH denotes neutral surface and M denotes Pb.

The adsorption of lead by these natural adsorbents increases with decreasing particle size. This suggests the adsorption to be a surface phenomenon, since the surface area available for adsorption increases with decreasing particle size.

CONCLUSION

The present study concludes that HB, SS and IC could be employed as low cost adsorbents for the removal of lead from wastewater in developing countries since these natural wastes can be easily and commercially synthesized.

ACKNOWLEDGEMENT

The authors are grateful to Fischer Scientific Sdn. Bhd. for providing the chemicals used in this study. The authors wish to thank the management of the Department of Applied Chemistry, UiTM, Shah Alam for technical assistance.

REFERENCES

1. Quek SY, Wase DAJ, Foster CF. 1998. The use of sago waste for the sorption of lead and copper. Water SA. 24(3), 251 – 256

2. Snoeyink VL, Summers RS. 1999. Adsorption of organic compounds in R.D. Letterman (ed.), Water Quality and Treatment: A handbook of community water supplies, 5th ed., Mc-Graw Hill, New York.

3. Juang RS, Shao HJ. 2002. A simplified equilibrium model for sorption of heavy metals ions from aqueous solutions on chitosan, Water Research. 36, 2999 – 3008

4. Abdel-Halim SH, Shehata AMA, El-Shahat MF. 2003. Removal of lead ions from industrial wastewater by different types of natural materials, Water Research. 37, 1678 – 1683

5. Gyliene O, Rekertas R, Salkouskas M. 2002. Removal of free and complexed heavy-metals ions by sorbents produced from fly (*Musca domestica*) larva shells, Water Research. 36, 4128 – 4136

6. Chamarthy S, Seo CW. Marshall WE. 2001. Adsorption of selected toxic metals by modified peanut shell, J. of Chemical Technology and Biotechnology. 76, 593 – 597

7. Vazquez G, Antorrena G, Gonzalez J, Doval MO. 1998. Adsorption of heavy metal ions by chemically modified Pinus pinaster bark, Bioresource Technology. 48 (3), 131 – 140

8. Sun G, Shi W. 1998. Sunflower stalks as adsorbents for the removal of metal ions from wastewater. Ind Eng Chem Res. 69, 309 – 320

9. Lee SH, Yang JW. 1997. Removal of copper in aqueous solution by apple wastes. Sep Sci Technol. 32(8), 1371 – 1387

10. Ho YS. 2003. Removal of copper ions from aqueous solution by tree fern, Water Research. 37, 2323 – 2330.

11. Bailey SE, Olin TJ, Bricks RM, Adrian DD. 1999. A review of potentially low-cost sorbents for heavy metals, Water Research. 33, 2469 – 2479

12. Katsumata H, Kaneco S, Inomata K, Itoh K, Funasaka K, Masuyama K, Suzuki T, Ohta K. 2003. Removal of heavy metals in rinsing wastewater from plating factory by adsorption with economical viable materials, Journal of Environmental Management. 69, 187 – 1991

13. Garg VK, Gupta R, Yadav AB, Kumar R. 2003. Dye removal from aqueous solution by adsorption on treated sawdust, Bioresour. Technol. 89, 121 – 124

14. Namasivayam C, Kadiverlu, K. 1998. Coir pith, an agricultural waste by-product, for the treatment of dyeing wastewater, Bioresour. Technol. 64, 77 – 79

15. Gardea-Torresdey JL, Tang L, Salvador JM. 1996. Copper adsorption by esterified and unesterified fractions of *Sphagnum* peat moss and its different humic substances. J Hazard Mater. 48, 191 – 206

16. Gardea-Torresdey JL, Gonzalez JH, Tiemann KJ, Rodrignuez O, Gamez G. 1998. Phytofiltration of hazardous cadmium, chromium, lead and zinc ions by biomass of *Medicago sativa* (alfalfa). J Hazard Mater. 57, 29 – 39

17. McKenzie R. M. 1980. The adsorption of lead and other heavy metals on oxides of manganese and iron, Aust. J. Soil Res. 18, 61 – 73