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Research article

ADSORPTION OF LEAD IN AQUEOUS SOLUTION BY A MIXTURE OF ACTIVATED CHARCOAL AND PEANUT SHELL

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Abstract
The presence of heavy metals in waste water is known to cause severe damage to aquatic life in which these heavy metals kill microorganism during biological treatment of waste water with a consequent time delay of the treatment process. Hence this research aims to apply low-cost adsorbents for simultaneous adsorption of lead from an aqueous solution. In this research, charcoals and peanut shells were used as low-cost adsorbents, which are abundant in nature, or are a by-product or waste material from another industry. The experiments were conducted using batch adsorption method. The effect of contact time, initial metal concentration, dose and pH on the simultaneous adsorption of lead were studied. The experimental results concluded that the better adsorption efficiency was obtained within 30 minutes of contact time. Furthermore, the adsorption of lead is higher when using a mixture of charcoal and peanut shell as adsorbent compared to the single adsorbent of charcoal. The maximum removal of lead on the charcoal and peanut shell was achieved when pH is 4 which is about 98.57 %. The surface morphology of charcoal and peanut shell before and after the adsorption process was observed under Field Emission Scanning Electron Microscopy (FESEM).

Keywords: Heavy metals, lead, adsorbents, charcoal & peanut shell

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Introduction

Heavy metals such as lead can often be found in industrial wastewater and their discharge to the environment poses a serious threat due to their toxicity to aquatic and terrestrial life which includes humans. Therefore, environmental engineers and scientist have investigated the method by treat heavy metal-bearing wastewater effectively and economically. Enhanced industrialization by the various uses of lead which has caused the release of large quantities of the by-product of this material into air, soils and surface waters. Lead is used as an industrial raw material in manufacturing of storage batteries, television tube, printing, paints, pigments, photographic materials, fuels, matches and explosives. The manufacturing process of these materials produces lead-bearing wastewaters, which have to be treated and disposed of before have being release into the environment. One of the largest consumers of lead is the storage battery industry followed by the petroleum industry in producing gasoline additives.

Lead contamination in wastewater may often have various adverse effects on both aquatic and terrestrial life. Lead is an ubiquitous in the environment and its presence in varying concentrations can be found in adverse locations. The Royal Society of Canada (1986) reported that human exposure to lead has harmful effects on kidney, central nervous and reproductive systems [1]. Air, food and water generally do not usually contain large amounts of lead. However excessive contamination of these natural sources by industrial activities can result in continuous toxic levels of exposure and consequently clinical poisoning [2]. Another pertinent health problem of lead is bioaccumulation or magnification, which may elevate its concentration to toxic level [3]. There are many techniques for the removal of heavy metals from wastewater such as chemical precipitation, ion exchange, adsorption, electrolytic recovery, electro dialysis, solvent extraction, reverse osmosis, membrane separation, ultrafiltration, ozonation. Foam floatation, vapor recovery, gamma irradiation, freeze crystallization, and photochemical methods [3][4]. The application of chemical precipitation to dilute low concentration solution can be difficult unless the addition of flocculating agents such lime, caustic and sodium carbonate. However a bulky sludge is produced, and the disposal constitutes a problem [5]. Ion exchange and activated carbon adsorption are quite expensive and require recharge of resin or spent activated carbon as well as the disposal of substantial volume of used regeneration solution. Other methods mentioned require elaborated and considerably high operation costs.

Adsorption process is a fundamental process in the physicochemical treatment of municipal wastewater, a treatment which can be economically meet today's higher effluent standard and water reuse requirements. Activated carbon is the most effective adsorbent for this application. The adsorption process is enhanced by *in-situ* partial regeneration effected by biological growth on the surface of the carbon. Advantages over biological treatment systems which include the lower and area requirements, lower sensitivity to diurnal flow and concentration variations and toxic substances, potential for significant heavy metal removal, greater flexibility in design and operation and superior removal of organic wastes [6]. Activated charcoal used as adsorbent is a porous carbonaceous material prepared by carbonizing and activating the organic substances of mainly biological origin. The peanut shell also have a potential alternatives to be used as low cost adsorbent for the adsorption of heavy metal from aqueous solution since they are abundant in nature ,inexpensive, require little processing and are effective materials. These waste materials have little or no economic value and often present a disposal problem. The aim of this study are to determine the percentage adsorption of Pb(II) ions from an aqueous solution using low-cost adsorbents namely charcoal and peanut shells based on the parameter of contact time, pH, initial metal concentration, and dose.

Experimental

Reagents

All chemicals used for the experiments (hydrochloric acid, sodium hydroxide, nitric acid, sulfuric acid, lead nitrate) were analytical grade. Deionized water was used to prepare solution.

Preparation of adsorbent material

The charcoal and peanut shell was collected from the local supermarket and will be putted in the oven at 105 ^{o}C for 24 hours. The dry samples was grinded separately with the electrical grinder until become a small powder. Afterthat dry samples was crushed and sieved to obtain 300-600 µm particle size and stored in the desiccator until used [7].

Preparation of synthetic wastewater

1.6 g of $Pb(NO_3)_2$ was dissolved in 1000 ml distilled water to prepare 1000 mg/L Pb stock solution. The desired Pb(II) concentration was prepared from the stock solution by making fresh dilution for the sorption experiment.

Adsorption experiment

Effect of initial metal concentration

Solution of different metal ion concentration of $Pb(NO_3)_2$ ranging from 10, 20, 40, 60, 80, 100 ppm was took in different beakers. Then, 1 g of dry charcoals and peanut shells was mixed together and added into each beakers and leave for 1 hour with successive mechanical stirring at 400 rpm. The solution was filtered by using vacuum pump suction and the supernatant was analyzed by using Atomic Absorption Spectrophotometer (AAS) to measure the absorbance of Pb(II) [8].

Effect of pH

25 ppm of 1000 mg/L Pb stock solution was took in 100 ml volumetric flask and made up to the mark with distilled water to obtain 25 mg/L of lead concentration prepared. The pH of the aqueous solution was varied from pH 2-8 by adjusted using 0.01 M HCl and 0.01 M NaOH. Then, the samples of charcoal and peanut shell was mixed together and added into the Pb(II) solution. The mixture was stirred by using electrical grinder at 300 rpm for 1 hour. The separation of adsorbent solution was carried out by suction filtration to collect the supernatant and then was analyzed by using AAS.

Effect of dosage of adsorbent

25 ppm of Pb(II) concentration prepared was took and placed in 5 beakers. The dosage of adsorbent, charcoal and peanut shell was varied from 1.0, 2.0, 3.0, 4.0 and 5.0 g each and was added to the Pb(II) solution. The mixture was subjected to the hot plate stirred at 300 rpm for 1 hour. After that, the filtrate was analyzed by using AAS.

Effect of contact time

25 ppm of Pb(II) concentration was took and added with 1 g of charcoal and 1g of peanut shell. The solution was stirred at 300 rpm at various duration ranging from 30, 60, 90, 120, 150, 180, 210, 240, 270 and 300 minutes. Then, the mixture was filtered using suction filtration. The filtrate will be centrifuge and the supernatant will be analyst by using AAS .

Result and discussion

Effect of pH

Charcoal can generate a good amount of negative charge ion .The present of a large quantity of surface negative charge and high charge density also reported by Liang *et al*.,2006 [9]. The pH of the solution is one of the most important factor in the study of the adsorption of metal ion on solids. The state of metal ions in solution strongly depends on the pH. The acidity and basicity of the various solutions can influence the composition and the properties of the adsorbent surface. Therefore, in order to determine the optimum pH for metal adsorption, the adsorption was studied at various pH.

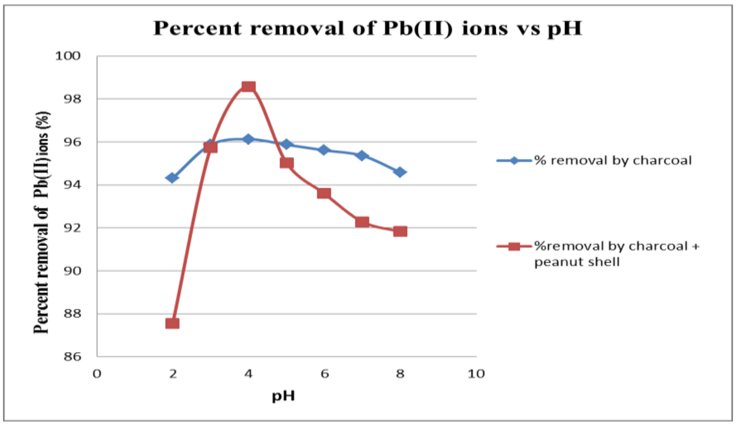


Figure 1: Effect of pH on the removal of lead by mixture of charcoal and peanut shell.

The adsorption was carried out by using single adsorbent of charcoal and mixing adsorbent of charcoal and peanut shell in order to see the performance of adsorption of Pb(II) ions. The performance is increasing by mixing both adsorbent compare to the single charcoal as adsorbent at optimum pH which is at pH 4.
Figure 1 shows graph had maximum adsorption at pH 4 and the adsorption is higher for the mixed adsorbent of charcoal and peanut shell in which shows the % removal of Pb(II) ions about 98.57% instead of using single adsorbent of charcoal which had the % removal about 96.13% . It shows that by mixing both adsorbent can enhance the performance of adsorption of Pb(II) ions. This may be due to the variety size of the pores on the difference adsorbent of activated charcoal and peanut shell since activated charcoal have a circular porous structure and peanut shell have longitudinal porous structure. With that more Pb(II) ions have been trapped into the pore of the adsorbent thus increase the adsorption capacity of the Pb(II) ions.

At pH 2, the adsorption of Pb(II) ions is low for both graph and increase at pH 3 until achieved maximum adsorption at pH 4 and then decreasing until pH 8. This is because at pH < 3, higher concentration of H^+ ions compete with Pb(II) ions for the surface of adsorbent which would hinder Pb(II) ions from reaching the bonding sites of the sorbet caused by the repulsive forces. At pH > 6, the Pb(II) ions get precipitated due to hydroxide anions forming lead hydroxide precipitate. This hydroxylated form of metal can also compete with the metals ions at the actives sites of the adsorbent thereby decreasing the adsorption [10].

Effect of adsorbent dosage

Based on figure 2, the adsorption of Pb (II) ions is observed increase linearly as the amount of adsorbent is increased gradually from 1 g to 3 g and constant from 3 g to 5 g. The maximum adsorption is obtained at the adsorbent dose 3 g with 97.73 % removal of Pb(II) ions where a further increase in the quantity of the adsorbent had no more effect to the adsorption rate. Therefore, the study indicated that 3 g of the adsorbent is sufficient to adsorb the maximum Pb(II) ions. For the 1 g to 3 g of adsorbent, the adsorption is increase due to the availability of more adsorbing sites at high doses.

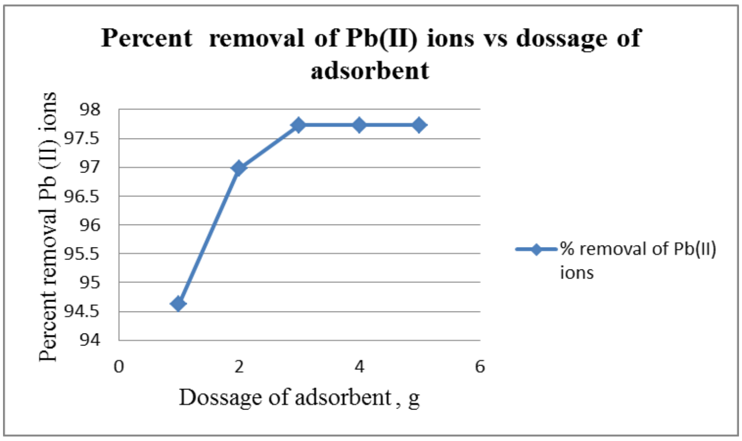


Figure 2: Effect of dosage of adsorbent on the removal of lead by mixing of charcoal and peanut shell.

It have been suggested that electrostatic interactions between the adsorbent can be a significant factor in a relationship between adsorbent and metal sorption. In this connection, at a given metal concentration, the higher adsorbent dosage in suspension, the higher will be the metal ration ant the metal retained by sorbent unit. Unless the adsorbent reaches unsaturation [11].

Effect of metal concentration

The adsorption of Pb(II) ions by the adsorbent of mixing charcoal and peanut shell increased linearly with increasing Pb(II) ions concentrations from 20 ppm to 100 ppm in figure 3. It shows the % removal of Pb(II) ions about 91.62 % to 98.32 % from 20 ppm to 100 ppm respectively. The rapid increase in the uptake of Pb(II) ions can be attributed to the interactions between the metals ions and the active sites of the adsorbent. This is because the higher the concentration of Pb(II) ions, the higher the amount of Pb(II) ions present in the solution. Thus, the more adsorption of the metal ions occur on the adsorption site of the adsorbent. Otherwise, at higher metal ions concentration / adsorbent ratio, metal ions adsorption involve higher energy sites. As the metal ions / adsorbent ratio increase resulting in the decreasing adsorption efficiency [10].

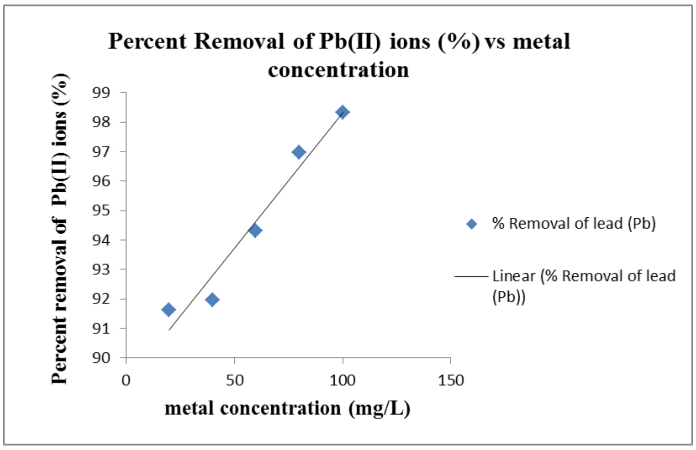


Figure 3: Effect of metal concentrations

Effect of contact time

The effect of contact time on the uptake of Pb(II) ions by the mixing adsorbent of activated charcoal and peanut shell has shown in figure 4. This was achieved by varying the contact time from 30 minutes to 300 minutes. The adsorption of Pb(II) ions becomes constant when it reach equilibrium.

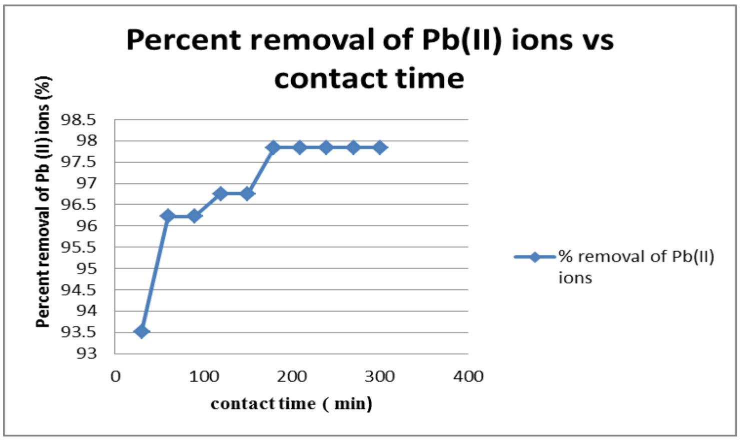


Figure 4: Effect of contact time

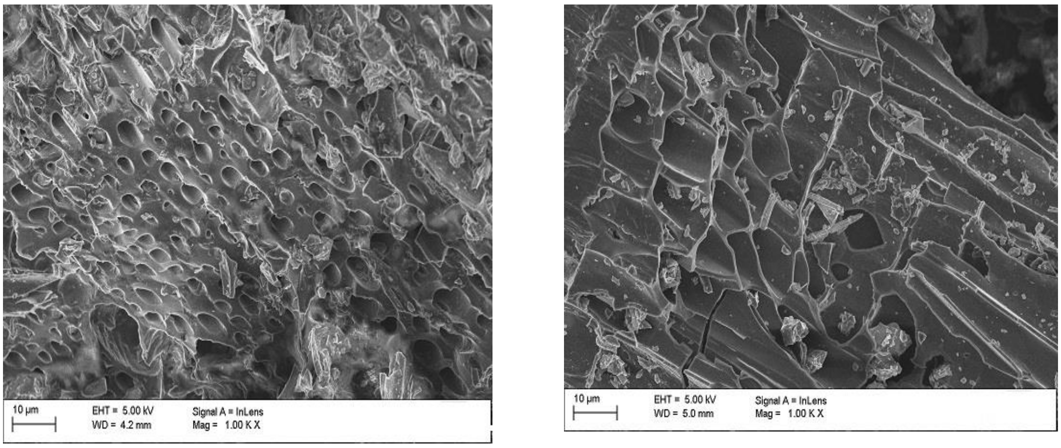
The adsorption was increase at specific time and becomes constant when reach equilibrium. The adsorption of lead into charcoal and peanut shell as the adsorbent occurred in two stages an initial rapid uptake due to surface adsorption onto the charcoal and peanut shell and almost constant uptake due to diffusion of lead ions onto the surface of adsorbent have reach equilibrium. The rapid uptake from 30 minutes to 60 minutes is about 93.52 % to 96.22 % removal of lead ions. It was shows some specifications of the interaction between metal ion and the site of organic matter responsible of ions uptake. The fast initial uptake was due to the accumulation of metal ions on surface of adsorbent which is a rapid step. This is also may be attributed to the highly porous structure of adsorbent and the particles size, which provide large surface area for the sorption of metals on the binding sites. More time was consumed on diffusion of ion to binding sites [12].

The adsorption process also can be considered faster because of the largest amount of lead ions attached to the adsorbent within 30 minutes. The adsorption almost constant from 60 minutes to 90 minutes with 96.22 %

removal of lead ions . After that, the adsorption increase back from 90 minutes to 120 minutes with 96.76 % removal of lead ions. Then, it was constant from 120 minutes to 150 minutes and almost constant until 300 minutes with highest 97.84 % removal of lead ions. At that time, it was showed the sufficient to achieved equilibrium and the adsorption did not change with further increase in contact time. The constant stage probably due to the less abundant availability of active sites thus, the sorption becomes less efficient in the constant stage [13].

Morphology of charcoal

Figure 5 shows comparison of the morphology of charcoal powder before and after adsorption. The charcoal revealed that the surface was highly porous in nature and this will increased the surface area for metal adsorption. The structure of charcoal exhibit irregular netlike structure, which implies the formation of complete three dimensional porous inner structure consisting rough surface area.



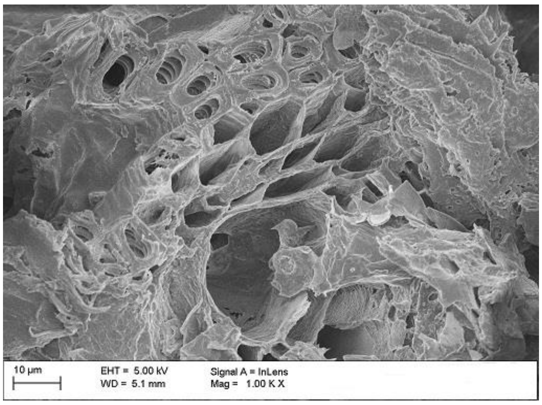
(a) (b)

Figure 5: FESEM micgrographs of charcoal (a) before adsorption (b) after adsorption process.

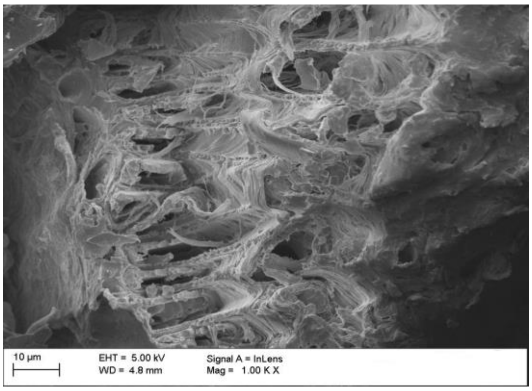
Most of the pores show a round or elliptic shape and pore diameters about 10µm. The micrograph of charcoal surface before adsorb Pb(II) ions is dissimilar to the surface of charcoal after adsorb Pb(II) ions. Apart from that, there are small particles was adhering on the surface was seen on the structure of charcoal after adsorption of Pb (II) ions. Based on the surface morphology result of charcoal, it is suggested that the charcoal can be used as low cost adsorbent for liquid- solid adsorption process due to the important of mesopores to many liquid adsorption process [14].

Morphology of peanut shell

The FESEM figure of peanut shell before and after adsorption of Pb(II) ions are shown in figure 6. It shows the irregular structure with rough texture and large number of cavity or pores. This will provide the surface for adsorption of Pb (II) ions. Peanut shell have prolonged slit and slightly longitudinal shape instead of rounded shape for the charcoal. As we can seen in the figure 6 (b), the pores structure is quite shallow and not clearly be seen. This is due to the metal loaded in the pores after adsorption of Pb(II) ions while in the figure 6 (a) the pores is clearly seen since there are no adsorption occurs [14].



(a)



(b)

Figure 6: FESEM micgrographs of peanut shell (a) before adsorption (b) after adsorption process.

Conclusions

Charcoal and peanut shell can be utilized as biological resources with immerse potential for adsorption of lead in aqueous solution. The efficiency of charcoal and peanut shell for the removal of metal ions depend on batch sorption of contact time, metal concentration, adsorbent dosage and pH. The fastest adsorption at 31 minutes and almost constant after 180 to 300 minutes. At the certain time , the adsorption become constant because the low availability of adsorbent to trap heavy metals since no more sites available. Removal efficiency of lead obtained at pH 4 with % removal of lead ions of 98.57 %. Furthermore, the charcoal and peanut shell can cause the environment problem but they can turns to be a good, inexpensive sources of readily available for adsorbent.

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