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Removal of Lead (II) Ions in Water Using Banana Fiber

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ABSTRACT

The removal of lead (II) ions in water is important as lead is a hazardous heavy metal and poses threat to human health. The conventional processes used to treat lead in water are usually expensive, not environmental friendly and produced harmful byproducts. The use of natural sorbent is cheap and has high sorption capacity. Thus, the aim of this paper was to use three different parts of banana fiber as sorbent to remove lead (II) ions from water. The banana stalk sorbent showed the highest lead (II) removal compared to banana stem sorbent and banana leaves sorbent. Higher initial concentration and higher pH favours lead (II) removal using banana fiber.

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INTRODUCTION

Lead is a heavy metal with a lot of hazardous effect towards human health. The consumption of lead by infants led to contemporary presence of visual impairments. Adults that inhaled or consumed lead are affected by all-cause mortality, cardiovascular disease, infertility and neurological disorders (Riva *et al*., 2012). Lead can be found in manufactured products, such as coloured pencils, paint, petrol, and it is also present in the environment, contaminating soils and waterways (Ayrault *et al*., 2012; Batista *et al*., 2013). Lead which is found in wastewater is usually from industries, such as metal smelting (Batista *et al.*, 2013) and battery manufacturing industries (Chen *et al*., 2009; Lee *et al*., 2012).

Conventional treatment processes of lead in wastewater are chemical precipitation (González-Muñoz *et al*., 2006), electrocoagulation (Merzouk *et al*., 2009; Meunier *et al*., 2009), nanofiltration (Bouranene *et al*., 2008; Ortega *et al*., 2008), ion exchange (Rahman *et al*.), and adsorption using activated carbon (Cechinel *et al*., 2014). These processes are usually expensive, not environmental friendly and at the same time produce by-products that are hazardous (Gautam *et al*., 2014). Therefore, the use of natural sorbent is an alternative solution for lead ions removal. A good sorbent usually demonstrates the following characteristics: low in cost, efficient, high surface area, and high ion exchange capabilities (Hamidpour *et al*., 2010).

Natural sorbents are sorbents that originated from plant or animal residues and minerals (Wahi *et al*., 2013). The natural sorbents mostly can absorb lead, but with differing capability. The search for a viable natural sorbent has to take into account the availability of the material, its price and sorption capacity (Kaya *et al*., 2014). The use of peanut shell achieved about 65% Pb(II) ion removal at pH 3.5-5.5 and temperature 20°C (Taşar *et al*., 2014). The equilibrium adsorption capacity for this sorbent is 33.7 mg/g (Taşar *et al.*, 2014). Another study using hyacinth root in a fixed bed column produced equilibrium capacity of Pb(II) sorption as 24.9 mg/g (Mitra *et al*., 2014). Thus the search for viable natural sorbent is never ending as the possibility is abundant, depending on the place of origin. In Malaysia, its tropical climate provides an array of choice in terms of natural sorbents – however the sorbent needs to be examined further to determine its optimum sorption capacity and the sorbate that it can adsorbed.

Methodology:

A. Preparation of Sorbents:

The banana fibers were taken from three different parts of banana plant – the stem, the stalk and the leaves. All the parts were cut and dried at ambient temperature for three days before dried in oven at 50°C for 24 hours. The dried banana parts were then grinded and sieved to the desired sizes (< 500 µm). The prepared sorbents were then kept in air tight bottles prior to use.

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B. Chemicals:

The chemicals used in this experiment are analytical grade lead(II) nitrate, $Pb(NO_3)_2$ from Acros Organics (US), nitric acid, HNO_3 from Merck (Germany) and sodium hydroxide, NaOH from Systerm (Malaysia). Stock solution of lead(II) nitrate (1000 mg/L) was prepared for use. The nitric acid and sodium hydroxide was prepared at a concentration of 0.1 M to adjust the pH of solution.

C. Analysis of Sorbent:

The sorbent was analysed using Fourier Transform Infra Red (FT-IR) to analyse the functional groups of the sorbent. The FT-IR spectra was recorded using Shimadzu ASC 7000 Autosampler in the range of 400 – 4000 cm^{-1} with a resolution of 4 cm^{-1}.

D. Batch Adsorption Tests:

All three types of sorbents were tested in 200 mL for desired lead(II) nitrate solution at room temperature of 25 ± 2°C with adsorbent dose of 0.025g/L. All three sorbents were tested against contact time to study the kinetics of the adsorption. Then, the sorbent with the highest ion removal capacaity was studied for the effect of solution pH and initial ion concentration.

RESULTS & DISCUSSIONS

A. Sorbent Analysis:

The three sorbents were analysed using FT-IR to determine the functional groups of the sorbents. Figure 1 shows the IR spectrum from all three banana fibers. The absorbance at around 3338 cm^{-1} indicates stretching vibrations of hydroxyl group. The small peak at 2914 cm^{-1} is assigned to symmetric stretching of CH_2 group present in polysaccharides. Several peaks between 1600 to 1250 cm^{-1} are due to C-C, C=C, OH, CO, CH_n, CH and C-O-C vibrations. The overlapping peaks are generally observed for cellulose, hemicellulose and lignin (Becker *et al.*, 2013). Peaks between 553 to 432 cm^{-1} are the angular deformations of C-H group in aromatic linkages.

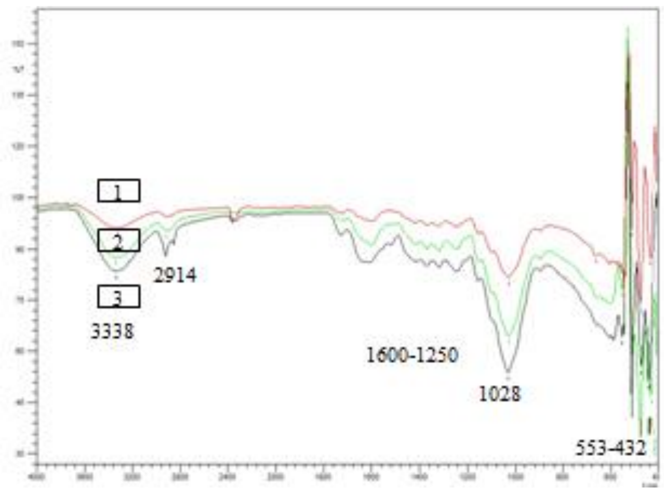

Fig. 1: FT-IR spectrum of: (1)banana stalk fiber, (2) banana stem fiber, (3) banana leaves fiber.

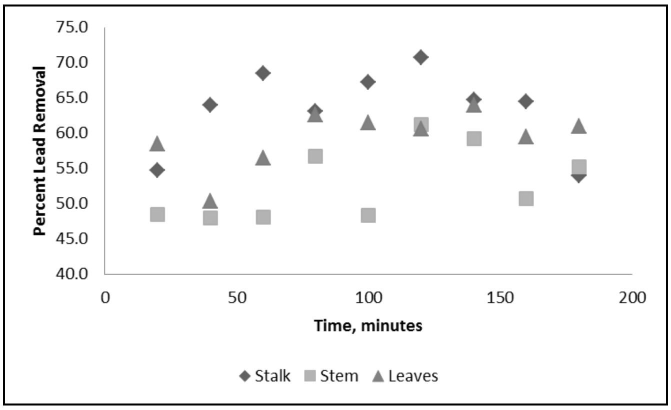

Fig. 2: Effect of contact time on removal of lead(II) using banana stem, stalk and leaves fibers.

Batch Adsorption Tests:

1) Contact Time:

The three sorbents were tested using initial concentration of 1000 ppm of lead(II) ions at 20 to 180 minutes to determine the sorbent with the highest lead(II) removal. Figure 2 shows the percent lead(II) removal using three different types of sorbents.

From the three sorbents, banana stalk fiber showed the highest lead removal at all times, followed by banana stem fiber and banana leaves fiber. The highest lead(II) removal by banana stalk fiber was found to be approximately 70%, at 120 minutes. The removal of lead(II) increased with the increase of contact time. At the contact time chosen, up to 180 minutes, the removal has not yet reached equilibrium. The lead(II) removal usually increases with time until it reaches equilibrium, where the removal will become constant (Martins *et al*., 2013; Wang *et al*., 2013). The results presented have not yet achieved the constant removal, thus suggesting that the process is not yet in equilibrium.

However, based on this result, it can be seen that the sorbent of banana stalk fiber showed more potential to be used as sorbent for lead(II) removal. Therefore, the sorbent of banana stalk fiber was further used to determine the effect of solution pH and initial concentration on lead removal.

2) Effect of Initial Concentration:

The effect of initial concentration was done using banana stem fiber at pH 7 and initial concentration of 200 – 1000 ppm. The result is illustrated in Figure 3 below. The figure 3 shows that the higher initial concentration favours the removal of lead(II) ions. The higher initial concentration gives a higher driving force for adsorption (Özer *et al*., 2006). This data is supported by other works using different types of metal ions on natural sorbents. The sorption of Cr(IV) using bast fiber (Gupta *et al*., 2013) and sorption of Co(II) and Ni(II) using almond shells (Kılıç *et al*., 2013) also showed similar trend.

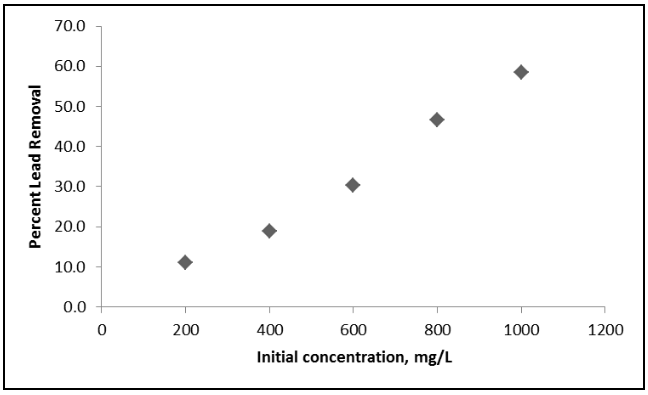

Fig. 3: Effect of initial concentration on removal of lead (II) using sorbent of banana stalk fiber.

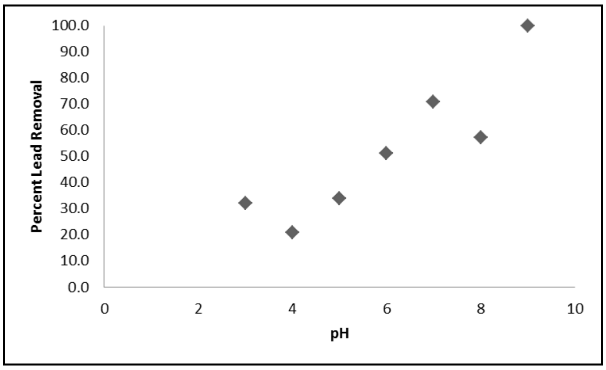

Fig. 4: Effect of solution pH on lead(II) removal using sorbent of banana stalk fiber.

3) Effect of pH:

The effect of pH was performed using sorbent of banana stem fiber at 1000 ppm. The tested pH values were from 3 to 9. The result is shown in Fig. 4 below. As the pH increases, the lead(II) removal percentage also increases. The increase in pH favours the removal of lead(II) ions. Solution pH plays an important role in sorption process. The solution pH is a controlling factor in metal removal from water, as it affects the ionisation and speciation of heavy metals (Nurchi and Villaescusa, 2012).

Conclusion:

The potential of banana fibers to be used as sorbent for lead (II) removal was studied. Three types of sorbents was taken from different part of banana plant – the stem, bark and leaves. From the three, banana stem fiber was found to have the highest lead (II) removal at ~70% after 120 minutes. Further investigation at the same time on banana stem fiber shows that higher pH and higher initial concentration favours the removal of lead(II) in water.

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