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Short Communication

The removal of Pb (II) from aqueous solution using a bio-adsorbent constructed from sugarcane bagasse and banana peels

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ABSTRACT

Water pollution is a serious threat to our environment as it can cause degradation of the quality of water. Heavy metal is one of the major pollutants contributing to water contamination. Amongst the heavy metals, lead (Pb II) is one of most common heavy metals discharged from the industries into water system. The exposure to Pb (II) can lead to negative health effects on humans even at low concentrations if it is not removed from the water. Conventional method for Pb (II) removal has some limitations. Therefore, an alternative method of using an inexpensive bio-adsorbent made from agricultural waste was explored. The aim of this paper is to determine the ability of a bio-adsorbent made from the combination of banana peels and sugarcane bagasse powder in removing Pb (II) ion from water. The results showed that the bio-adsorbent of mixed sugarcane bagasse and banana peel powder produces the highest adsorption with 6.27 mg/L of Pb (II) ions. Furthermore, biomass as low as 1.0 g can yield the optimum removal percentage of Pb (II) ions. The bio-adsorbent of mixed sugarcane bagasse and banana peels can serve as a low-cost alternative to remove Pb (II) from wastewater.

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INTRODUCTION

Uncontrolled anthropogenic activities lead to the unleashing of heavy metals in water thereby threatening the aquatic eco-system [1]. Drinking water polluted by heavy metals can pose serious consequences to human health because the heavy metals bio-accumulate easily [2]. Amongst the heavy metals, Pb (II) has received the most attention because the metal is widely used for lead-acid battery manufacturing, cable sheathing and processing [3]. This causes the number of cases, whereby the industrial effluent with the concentration of Pb ions exceeds the permissible limits, to increase [4]. The contamination of Pb in drinking water has been reported to cause mortality of children in India [5], and in some instances to cause pathological damages to organs, tissues and the central nervous system [6, 7]. The other adverse effect of Pb contamination includes soil and water quality degradation [8]. Thus, an efficient removal technique of Pb needs to be applied in a way to reduce the contamination level on the water resources.

Several physico-chemical techniques including lime coagulation, chemical precipitation, ion exchange, reverse osmosis and solvent extraction have been regularly used to remove Pb from wastewater [9-11]. However, high operational cost and toxic residual waste generated from the process cause these techniques to be unsustainable [12, 13]. In light of this, the bio-adsorption method using agricultural by-product offers an interesting alternative in removing Pb (II) from the environment [7, 14, 15]. Bio-adsorption using fruits peels, rick husk and soya bean hulls is a sustainable process because these agricultural byproducts are easily and continuously available. Thus, it provides a low cost and economical way to counter the Pb (II) pollution [16, 17]. Furthermore, the constituents of most of the agricultural by products like hemicellulose, pectin, lignin and hydroxyl group bind to Pb (II) ions efficiently, and these components are not toxic to the environment [18, 19].

The efficiency of a bio-adsorbent in absorbing Pb (II) varies depending on the types of agricultural by-products sources like sugarcane bagasse, rice husk, coconut husk, fruit peels and oil palm shell. Different bio-adsorbents have specific functional groups like polyphenols and amino acids that interact with the metal ions to support the adsorption mechanisms [17, 20, 21]. Abiotic factors like Pb (II) concentration and pre-treatment of bio-adsorbent can affect the outcome of the Pb removal process [22, 23]. This paper reports on the comparative assessment of using non-alkaline and alkaline-treated banana peels and sugarcane bagasse as a bio-adsorbent to remove Pb (II) from water.

MATERIALS AND METHODS

Adsorbent preparation

Two different types of agricultural waste, banana peels and sugarcane bagasse were dried inside a drying oven for 6 days at the temperature of 40 °C. The agricultural waste was ground into powder form. The powder was then treated with 0.5 N of sodium hydroxide (NaOH) for 20 minutes, followed by washing in distilled water to eliminate the NaOH completely. The powder was dried in a drying oven at 40 °C until completely dried [23].

Bio-adsorption process

A series of conical flasks containing 50 mL of 10 mg/L of Pb (II) solutions were prepared. Then, 0.5 g of bio-adsorbents (banana peels + sugarcane bagasse) was added into the conical flask. The mixture was shaken in rotary shaker for 60 min at room temperature. The same process was repeated using banana peels and sugarcane bagasse separately. After the shaking process, the suspension generated was filtered using a filter paper and the filtrate was analysed to determine the residue Pb (II) using atomic absorption spectroscopy (AAS).

After determining which of the three is the best bio-adsorbent, it was again used at different biomass (0.1 g, 0.5 g, 0.7 g, 1.0 g and 2.0 g) to repeat the bio-adsorption experiment. The adsorption capacity resulting from the bio-adsorption process was calculated using the formula of Al-Qahtani, [7]

$$Qe = \frac{(Po - Pe)}{W} \times V$$

where Po and Pe are the initial and final concentrations of the Pb (II) ions in the solution before and after bio-adsorption process for a period of time (mg/L), respectively, while V (mL) represents the volume of the solution used and W (g) is the amount of adsorbent used for each experiment.

Furthermore, the removal percentage (%) of Pb (II) was calculated as specified in the formula below:

$$metal\ removal\ (\%) = \frac{(Po - Pe)}{Po} \times 100$$

where removal percentage represents the ratio of the difference in metal concentration before and after the adsorption process.

Statistical analysis

Data obtained from the bio-adsorption was analyzed using analysis of variance (ANOVA) with 95% confidence level. Results were reported as mean ± standard deviation ($n = 3$).

RESULTS

Figure 1 shows the residue of Pb (II) concentration in the filtrate at the end of the bio-adsorption process using banana peels (BP), sugarcane bagasse (SB) and the mixture of banana peels and sugarcane bagasse (MBS). Bio-adsorption using

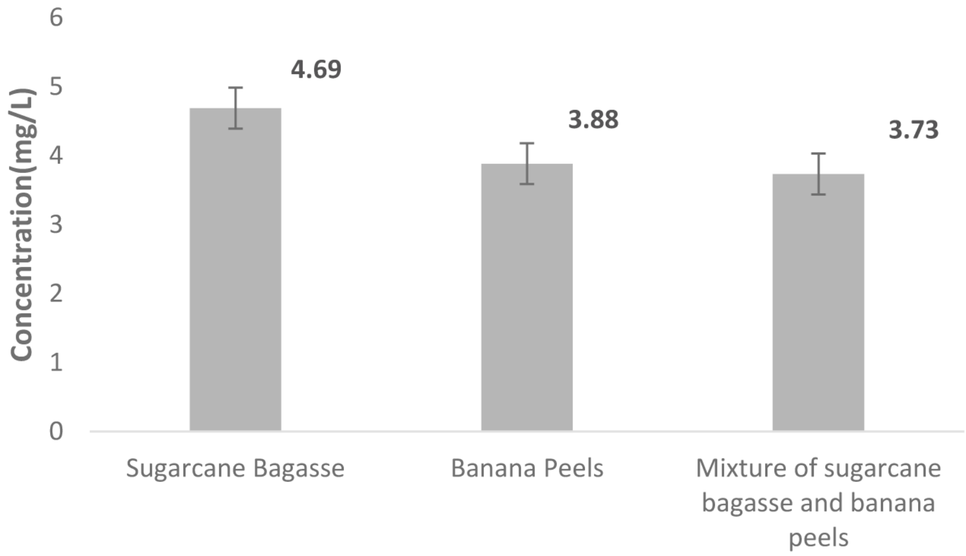

Figure 1. The mean concentration of Pb (II) residue (mg/L) after bio-adsorption process.

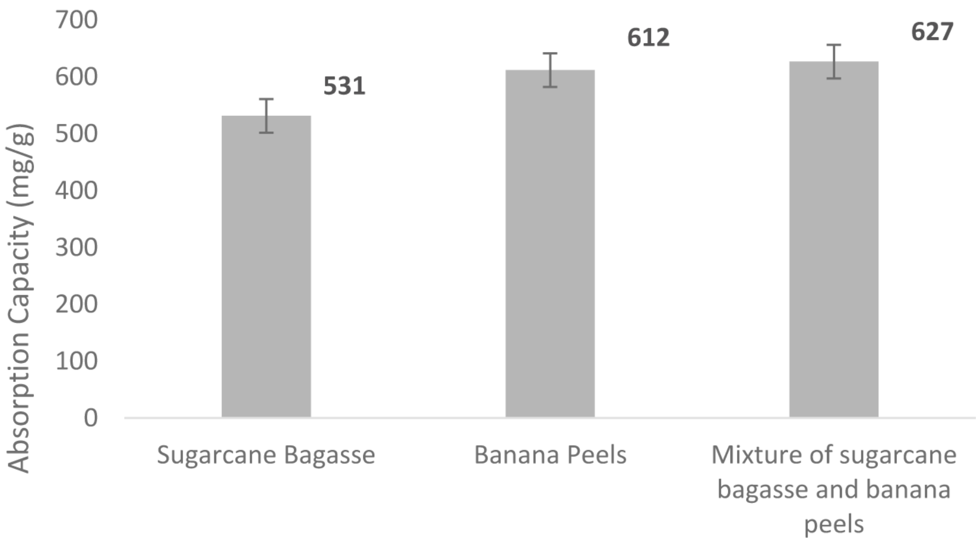

Figure 2. Bio-adsorption capacity (mg/g) of the different types of bio-adsorbents.

the mixture of banana peels and sugarcane bagasse was able to bio-adsorb most of the Pb (II) from the solution showing the lowest ($p<0.05$) residue Pb (II) in the filtrate. This is followed by banana peels and sugarcane bagasse.

Bio-adsorption capacity was calculated for each of the bio-adsorbents and the results are presented in Figure 2. The mixture of banana peels and sugarcane bagasse has the highest capacity to remove Pb (II), followed by the banana peels and lastly the sugarcane bagasse.

Results from Figure 1 and Figure 2 show that MBS was the most efficient bio-adsorbent tested. Furthermore, it was tested whether the MBS performs differently at different biomass (g). Table 1 shows that an increase in the biomass (g) from 0.1 g to 1.0 g of MBS results in the increase in the percentage of Pb (II) removal from the

Table 1. Efficiency of Pb (II) removal using different biomass (g) of the mix banana peels and sugarcane bagasse.

Biomass of bio-adsorbent (g)	Mean concentration of residue Pb (II) (mg/L)	Pb (II) removal (%)
0.1	4.9	50.7
0.5	4.4	56.3
0.7	3.8	62.2
1.0	2.9	71.0
2.0	5.2	48.0

water. However, when the biomass was increased to 2.0 g of MBS, the percentage of Pb (II) removal did not increase but dropped to similar efficiency as 0.1 g of MBS.

DISCUSSION

All three bio-adsorbents in this study were shown to adsorb Pb (II). However, the percentage of Pb (II) removal from the water using BP, SB and MBS were much lower than those reported in other studies using pokeweed [24], mango seed [25], *Pleurotus ostreatus* [26], and mixed fruit waste [27]. One of the main factors that control the outcome of the percentage of removal is contact time [28]. In most of the reported studies, the contact time between the bio-adsorbent and Pb (II) was 24 hours or more. In the current study, the Pb (II) removal percentage was calculated employing a contact time of 60 minutes. Increasing the contract time will also increase the percentage of Pb (II) removal [17]. Experiment using the red algae (*Gracilaria changii*) also showed that increasing the contact time also increases the Pb (II) adsorption from aqueous solution [29].

Despite the comparatively lower percentage of Pb (II) removal reported in the current study due to the short contact time, the adsorption capacity of all the three bio-adsorbents, namely SB, BP and MBS, was higher than that reported in the studies using other agricultural wastes [17]. One of the possibilities is the alkalization pre-treatment of the bio-adsorbent used in the current study. Alkalization process can increase the overall negative charge of the bio-adsorbent, allowing it to increase the uptake of Pb (II) ions [7].

The MBS bio-adsorbent was the most efficient in removing Pb (II) from the water, compared to using BP or SB individually. By mixing banana peels and sugarcane bagasse together, the adsorption sites within the bio-adsorbent increase. Within banana peels alone, the pectin and galacturonic acid present contain approximately 21% carboxyl site (-COOH) in which Pb (II) can be adsorbed [30]. Sugarcane bagasse consists only of cellulose component that allows Pb (II) ions to bind [2]. This explains why MBS can adsorb more Pb (II) than BS and SB.

Increasing the amount of the bio-adsorbent from 0.1 to 1.0 g can also increase the percentage of Pb (II) removal up to 70%. This is because the binding sites available to bind with Pb (II) increases in proportion to the amount of the bio-adsorbent [31]. However, once it passes the saturation point at 1.0 g, the percentage of Pb (II) removal starts to decrease. Although this trend was not commonly noted in literature, it can be postulated that the increased amount of the bio-adsorbent might result in its decomposition faster in the water due to higher bacterial populations [32]. Decomposition of organic bio-adsorbents releases the Pb (II) back into the water. Further study on the bacterial population during the bio-adsorption might reveal more insight into this scenario.

CONCLUSION

This study shows that the combination of sugarcane bagasse and banana peels (MBS) is the most efficient to remove Pb (II) from water (up to 70%). The adsorption of Pb (II) ions is influenced by two factors namely the type of bio-adsorbents and the amount of bio-adsorbent. Utilising both sugarcane bagasse and banana peels as bio-adsorbents serves as an alternative low-cost and eco-friendly approach to treat wastewater contaminated by Pb (II). Furthermore, re-using agricultural industrial waste as bio-adsorbent can reduce the problem of solid waste management and provide extra income to the agricultural sector owing to the commercialization of the agricultural wastes.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

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