Jurnal Teknologi

Full paper

Effect of Particle Size on Cadmium Removal by Banana Peels

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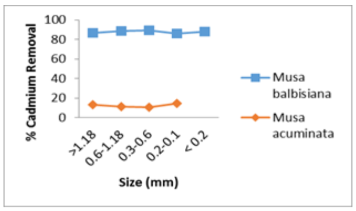
Article history

Received : 15 August 2014
Received in revised form :
15 October 2014
Accepted :15 November 2014

Graphical abstract



Abstract

Contamination of metals in aquatic environment is a worldwide problem because of its toxicity and capability to accumulate in biological chain, as well as persistence in the natural environment. Therefore various expensive technologies have been applied to treat metal-polluted water. In Malaysia there are abundance of banana species available which could provide cheap, low cost and environmental friendly bio-materials. Preliminary study was conducted on two species of banana i.e. *Musa balbisiana* (Nipah) and *Musa acuminata* (Kapas). The banana peels were washed, dried and grounded into various range of particle sizes (0.20–1.18 mm). The ability of the adsorbents were determined by agitation of 1.0 g banana peel and 100 ml of cadmium standard solution at the concentration of 100 mg/L. *Musa balbisiana* showed the highest removal of cadmium at 89.58% from the initial concentration compared to *Musa acuminate* with the particle size of 0.30-0.60 mm. Adsorption equilibrium data are well described by Langmuir isotherm model. The result also shows that different species have different capabilities to adsorb metal. Hence, their potential as bio-adsorbent could be further be examined for metal removal from wastewater.

Keywords: Adsorbent; banana peel; cadmium; *Musa balbisiana* (Nipah); *Musa acuminata* (Kapas)

1.0 INTRODUCTION

Rapid economic growth has resulted in increase production and usage of toxic chemicals such as trace elements in Malaysia [1]. A wide variety of metal species enters the water body through atmospheric deposition, cultivated fields, and industrial discharges, and these activities follow an upward curve in response to the world's ever growing population and its needs. Metals including both essential (copper, zinc and iron) and non-essential (cadmium, chromium, lead) elements have a significance effect in ecotoxicology, since they are highly persistent and have the potential to be toxic to living organisms [2].

Conventional methods commonly used for metal removal in water include chemical precipitation, ion exchange, reverse osmosis, membrane technologies and solvent extraction. However, the methods are often expensive and inadequate when the metal ions are present in high concentrations [3]. The development of new treatment method for removal of metal ions from wastewater which is cost effective and more efficient has spurred to overcome conventional methods.

Biosorption treatment technology has received much attention as it offered low cost biosorbent and non-hazardous biomaterials[4]. The processes of biosorption are relatively easy to operate and possess several inherent advantages, including low cost, operation over a wide range of conditions and the possible reuse of biosorbents [5]. Recently, waste materials from food and agricultural industry have raised attention due to their efficiency as natural sorbent involving removal of metal from wastewater. These materials can be considered as low cost adsorbents and require little processing and are abundant in nature [6].

Banana plants belong to the family Musaceae, they are cultivated primarily for their fruit and to a lesser extent for the production of fiber and as ornamental plants. Banana plants are normally tall and sturdy. For some species, the height can reach up to 8 m. Each stem can produce a bunch of green bananas which when ripened turn yellow. Banana fruits grow in hanging clusters, with nearly 20 fruits to a hand (tier) and 3–20 hands to a cluster. The fruit averages 125 g, of which 25% is dry matter and the remaining is water. Banana is one of the largest consumed fruit in the world with useless peels, therefore it creates one of the major agro-waste problems. Previous study showed that several tonnes of banana peels are produced daily in market places and household garbage that create environmental nuisance [7]. For this reason, it is essential to use the agricultural by-products and transform such materials to adsorbents.

Banana peel has been reported to act as a significant adsorbent for metals removal [8-9]. Nevertheless, none of the previous studies clarified which species of banana that have high efficiency as adsorbent. In Malaysia, there are several species of banana that can be found in the market such as *Musa balbisiana* (Nipah), *Musa acuminata* (Kapas), *Musa acuminata colla* (Berangan) and *Musa paradisaca L* (Cavendish) [10]. Therefore, this study aimed to determine capability of two selected species; *Musa balbisiana* and *Musa acuminata* to remove metals from wastewater.

2.0 EXPERIMENTAL

2.1 Preparation of Metal Ions Solution and Adsorbent

Cadmium stock solution (100 mg/L) was prepared by diluting 1000 mg/L standard solution of cadmium chloride (CdCl2) (1000 mg/L) with deionized water. Samples of banana peels were collected from local market at Taman Universiti, Johor Bahru. The matured banana with yellow peel were washed with deionized water to remove any contaminants and cut into small pieces. The cleaned peel were then oven dried at 105°C for 24 hours. After the drying process, they were grounded into powder and sieved with cut off size > 1.18, 0.6 – 1.18, 0.3 -0.6, 0.2-0.3 and 0.1-0.2. The grounded banana peel were then kept in an air tied bottle prior to experiment.

2.2 Batch Mode Adsorption Studies

Adsorption experiments were conducted by mixing 1.0 gram of adsorbent (banana peel) at different size with 100 ml aqueous solution of adsorbate (cadmium chloride) and placed on an orbital shaker at constant speed of 120 rpm for 24 hours. Samples were then filtered using a filter paper (Whatman type GF/C 0.7 µm). The metal concentration were then analysed using atomic absorption spectroscopy (AAS). Removal percentage of cadmium by the banana peel was calculated using the following equation:

$$\% R = (C_i – C_a)* 100/C_i \quad (1)$$

Where C_i is initial concentration (mg/L) and C_a is final concentration (mg/L)
Capability of adsorbent to adsorb the metal ion was calculated as follows:[4]

$$q = V (C_i – C_a) /S \quad (2)$$

where q = metal uptake capacity (mg/g), C_i = Initial concentration (mg/L), C_a = Final concentration(mg/L), S = dry weight of adsorbent (g) and V = volume of solution (L)

3.0 RESULTS AND DISCUSSION

Figure 3.1 illustrates the effect of particle size on Cd removal and comparison of adsorption capability between *Musa balbisiana* (Nipah) and *Musa acuminata* (Kapas). *Musa balbisiana* adsorbed more Cd compared to *Musa acuminata*. Cd removal increased from 86 to 89% by decreasing the particle size from 1.18 to 0.3 mm. The increase in adsorption percentage can be attributed to increase of surface areas with the decrease in particle size. Greater surface areas for bulk adsorption per uni t mass of the adsorbent and accessibility to larger pores have contributed to high adsorption capacity by smaller particles [11]. However, both *Musa balbisiana* and *Musa acuminata* obtained similar optimum adsorbent size for Cd which was 0.3-06 mm. Hence, smaller size adsorbents (< 0.3) may not cause any significant removal.

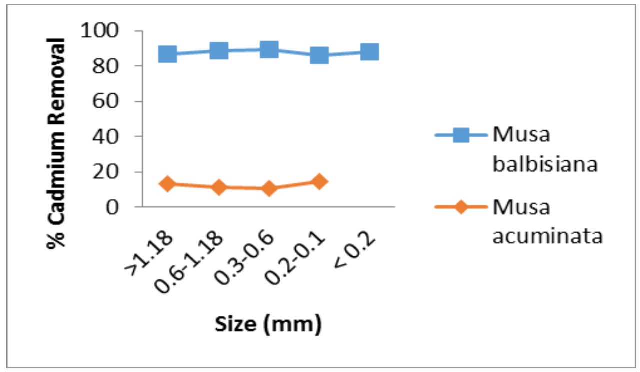


Figure 3.1 Effect of particle size on Cd removal and comparison between *Musa balbisiana* (Nipah) and *Musa acuminata* (Kapas)

The adsorption equilibrium can be expressed by using Langmuir model. The Langmuir isotherm assumes a monolayer adsorption on a surface of adsorbent and presented by the following Equation [12].

$$q_e = Q\, bC_e/ (1 + bC_e) \quad (3)$$

Equation (3) can be linearised as follows:

$$C_e/ q_e = 1 / (Q\, b) + C_e/Q \quad (4)$$

Where q_e and Q are the adsorption capacity at equilibrium and maximum (mg/g); C_e is the equilibrium concentration (mg/l); b is the adsorption coefficient. While, values of Q and K_L can be calculated from the slope and intercept of the plot. On the other hand, the Langmuir isotherm can be expressed by

$$R_L = 1 / (1 + bC_0) \quad (5)$$

C_o (mg/L) is the initial concentration. The value of RL indicates the shape of isotherm which is unfavourable (R_L > 1), linear (R_L =1), favourable (0 <R_L <1) or irreversible (R_L = 0).

Linear plot of C_e / q_e against C_e (Figure 3.2 and Figure 3.3) shows that adsorption follows the Langmuir model with correlation coefficients r^2 = 0.9999 for *Musa balbisiana* and r^2 = 0.9988 for *Musa acuminata*. This was suggested by the formation of monolayer coverage on the surface of adsorbent [13]. Maximum adsorption capacity, Q for complete monolayer coverage for *Musa balbisiana* and *Musa acuminata* are 0.13 and 0.25 mg/g respectively. Meanwhile, the values of R_L for both *Musa balbisiana* (0.04) and *Musa acuminata* (0.003) demonstrated that Cd adsorption by banana peel is favourable as the values are between 0 and 1 [14].

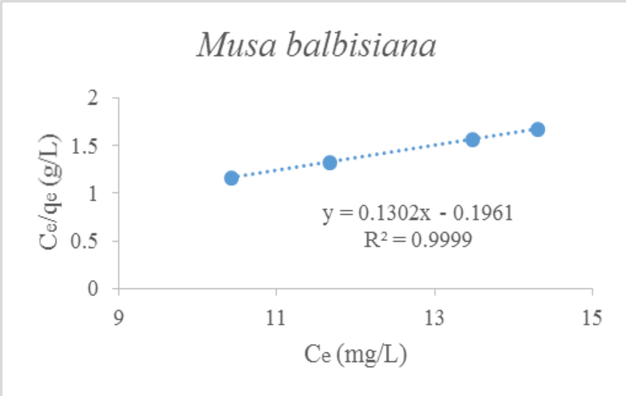


Figure 3.2 Langmuir isotherm for Cd adsorption by *Musa balbisiana*

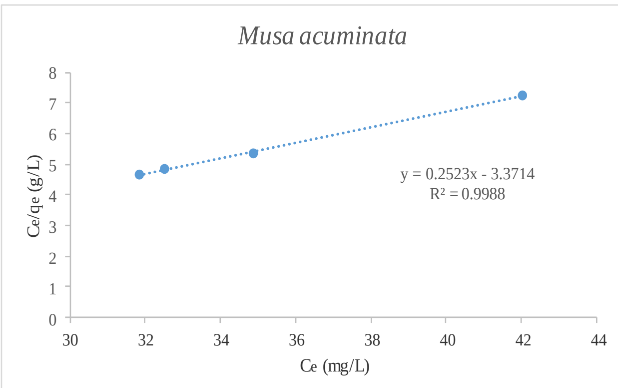


Figure 3.3 Langmuir isotherm for Cd adsorption by *Musa acuminata*

4.0 CONCLUSION

Banana peel was found to exhibit a good potential as adsorbent from removal of Cd from wastewater. Among the banana species, *Musa balbisiana* has shown higher removal percentage compared to *Musa acuminata*. Moreover, the experimental data of Cd adsorption onto banana peel fitted the Langmuir isotherm model and confirm the monolayer adsorption. Hence, the used of banana peel especially *Musa balbisiana* as bioadsorbent can be further investigated in order to get the optimum performance.

Acknowledgement

This work was supported by Exploratory Research Grant Scheme (Vote Number: 4L113) and Kementerian Pengajian Tinggi (MyBrain15).

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