Environmentally Friendly Biosorbent from *Moringa Oleifera* Leaves for Water Treatment

Eman N. Ali, Sabreen R. Alfarra, Mashita Mohd Yusoff, and Md Lutfor Rahman

***Abstract*—In this study *Moringa oleifera* leaves (biosorbent) is used for Cadmium (II) removal from water as a natural alternative for synthetic sorbents. Synthetic water was used to find optimum conditions for water treatment using biosorbent. The effect of biosorbent dosage and particle size, contact time, and pH effect were studied. Atomic Absorption Spectroscopy (AAS) was used to monitor the Cd (II) concentration before and after treatment with biosorbent. Fourier Transform Infrared Spectroscopy (FTIR) was used to monitor biosorbent structure changes before and after loading with Cd (II). Many parameters were studied such as: dosage of biosorbent (1 – 10 g/L), contact time (2 – 20 min), particle size (2 mm, 1 mm, 500 µm, 250 µm, and <250 µm), pH range (4-10), and Cd (II) concentrations (1, 3, 5, and 7 ppm). The statistical analysis of studied parameters showed that all parameters has an effect on Cd (II) removal with *p* values <0.05 except pH. FTIR result showed changes in the finger print area of biosorbent functional groups due to adsorption of Cd (II). As a conclusion, *Moringa oleifera* leaves can be used as an effective, low cost, and environmentally friendly biosorbent for the removal of Cd (II) from water.**

***Index Terms*—Biosorption, Cadmium (II), *Moringa oleifera*, water treatment.**

I. Introduction

Every day, there are thousands of chemicals discharged directly and indirectly into water bodies without further treatment for elimination of the included harmful compounds.

Heavy metals are without doubt well thought-out as the most hazardous and harmful metals even if they present as traces in water, since they accumulate in the tissue of living organism.

Cd (II) is one of the most toxic and hazardous heavy metal and it is responsible for causing kidney damage, renal disorder, high blood pressure, bone fraction, and destruction of red blood cells [1]. Major sources of Cd (II) in environment are electroplating, industries of pigments, plastic, and metal finishing industries.

Removal of Cd (II) from aqueous solutions can be accomplished by several techniques such as chemical precipitation, ion exchange, membrane separation and adsorption. Though, currently used methods contain several restrictions in the removal of Cd (II) from water [2]. Such methods showed to be not effective and not economically possible for the treatment of low heavy metal concentrations [3].

As a result, removal and eliminating of Cd (II) in the polluted water has become a vital mission and essential environmental goal to search for appropriate alternative solutions. Biosorption of Cd (II) by agricultural waste materials is one of these alternative treatment methods, because of its simplicity and availability [4], [5].

Many studies were conducted to develop an effective removal of heavy metals using biosorbents, such as microbial biomass [6], and agricultural waste materials such as: sugar cane bagasse fly ash and peat [7], rice husks and straws [8], soya bean, saw dust, walnut and cotton seeds hull, corn cobs, and banana peels [9].

Recently, researchers are paying attention on the removal of Cd (II) from aqueous solution using adsorbents derived from low-cost tree leaves such as loquat leaves (*Eriobotrya japonica*) [10], *Psidium guajava* leaves [11], *Maize* leaves [12], *Ulmus* leaves [13], *Scolymus hispanicus* [14], *Ulmus carpinifolia* and *Fraxinus excelsior* tree leaves [15], fig leaves [16], *Azadirachta indica* (Neem leaves) [17], *Olea europaea* (Olive leaves) [18], and *Prunus vium* leaves [19].

In this work, the effect of dosage of *Moringa oleifera* leaves, contact time, biosorbent particle size, and pH on Cd (II) removal from water was examined. The results of this study can be used to evaluate the efficacy of *Moringa oleifera* leaves for Cd (II) removal from water and may replace activated carbon in water treatment industry.

II. Materials and Methods

A. Biosorbent Preparation

Moringa oleifera leaves were collected from nearby area of Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia. Leaves were dried in sunlight for 1 day. After drying, leaves were grounded using electrical grinder, followed be sieving to different particle size (2 mm, 1 mm, 500 µm, 250 µm, and < 250 µm) then kept in plastic bags at room temperature to be used in the study.

B. Synthetic Water Preparation

A weight of 5 gm of kaolin, laboratory grade (k7375-500G

Manucript received June 6, 2014; revised July 20, 2014. This work was supported by Research & Innovation Department/ Universiti Malaysia Pahang / Malaysia, under grant #: RDU 140318.

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DOI: 10.7763/IJESD.2015.V6.582

Sigma- Aldrich) was dissolved with 500 ml of distilled water. Sodium bicarbonate solution with concentration of 100 mg/L was prepared by adding 100 mg of sodium bicarbonate (Hamburg Chemicals) to 1000 ml of distilled water; Adding 500 ml of the sodium bicarbonate solution to the kaolin. The suspension was stirred for about 1 hour at 200 rpm to achieve a uniform dispersion of kaolin particles. Then it was left for at least 24 hours for complete hydration of the kaolin [20]. The synthetic turbid water was used for biosorption test on Cd (II) removal from water by *Moringa oleifera* leaves. This stock was diluted a few times to get the turbidity needed for each particular test.

C. Biosorption Experiments

The jar test is a commonly used method to evaluate coagulation- flocculation processes [21]. Biosorption tests were carried out using the jar test equipment. Six beakers were filled with 500 ml of the synthetic water and known quantity of Cd (II) (0.5, 1.5, 2.5, and 3.5 ml of 1000 mg/L stock solution) were added to 500 ml of synthetic water to get the Cd (II) concentration of (1, 3, 5, and 7 ppm). A different dose of *Moringa oleifera* leaves of (1 to 10 g) was added to the synthetic water, the sample was mixed with biosorbent at 200 rpm for 60 minutes, the suspension was allowed to settle for 30 minutes then the biosorbent was filtered using Whatman filter paper No. 42. The residual Cd (II) in water was analyzed using AAS at wave length of 228.8 using an acetylene air flame. A triplicate test was performed for every sample to get average of reproducing results. RE of Cd (II) was calculated using the equation: $RE\% = [(C_o - C_e) / C_o] \times 100$, where: C_o and C_e are the initial and residual concentration of Cd (II) in water (mg/L), respectively [10], [19].

D. Equipments

The concentrations of Cd (II) in the solutions before and after biosorption were determined by AAS 400 (Perkin Elmer). The pH of the solution was measured with a (Mettler Toledo) pH meter using combined glass electrode. Turbidity measurement was conducted using (Hach 2100Q) turbidity meter for synthetic water used in the experiments. FTIR (Perkin Elmer) was used to identify the different functional groups present in the *Moringa oleifera* leaves before and after removing Cd (II). FTIR analyses also used to determine the functional groups which are responsible for the Cd (II) binding with *Moringa oleifera* leaves. The analysis was carried out using KBr pellet and the spectral range varying from 4000 to 400 cm^{-1}.

E. Biosorption Study

Adsorption of Cd (II) in synthetic water on *Moringa oleifera* leaves were examined by different parameters such as dose concentration (1 -10 g/L), contact time (2 - 20 min), particle size (2 mm, 1 mm, 500 µm, 250 µm, and < 250 µm), Cd (II) concentration (1, 3, 5, and 7 ppm). The water pH varied from 4 to 10, the pH of water was adjusted by using 0.1N HCl or 0.1N NaOH without changing the volume of the sample.

Multi diluted standards of 1, 3, 5 and 7 ppm of Cd (II) in this study were prepared from standard stock solution (1000 mg/L).

III. Results and Discussion

The effect of different parameters was studied and the results showed different RE% with different concentration of Cd (II).

A. Biosorbent Dose Effect

The biosorbent dosage is an important parameter to determine the capacity of a biosorbent for a given initial concentration. Biosorption of Cd(II) onto *Moringa oleifera* leaves was studied by adding different dosage of *Moringa oleifera* leaves from 1 to 10 g/L in the treated water sample using different initial Cd (II) concentration of (1, 3, 5, and 7 ppm) and constant contact time of 60 min. Statistical analysis showed that the dose has an effect on the removal of Cd (II) with different concentration from synthetic water. *P value* for 1 ppm, 3 ppm, 5 ppm, and 7 ppm were 0.00078, 0.000716, 0.000571 and 0.000629, respectively which is <0.05.

Fig. 1 shows the removal efficiency for Cd (II) biosorption by *Moringa oleifera* leaves at different Cd (II) concentration. The percentage of the metal biosorption sharply increased when the biosorbent dosage increased. This result might be explained by the fact that the biosorption sites increases by increasing the biosorbent dosage [10]. Evidently, the maximum RE for 1 ppm was 81% with optimum dosage of 6 gm/L, while it was 74%, 64% and 72% for the Cd(II) concentration of 3 ppm, 5 ppm, and 7 ppm, with optimum dosage of biosorbent 6 g/L, 5 g/L, and 8 g/L, respectively. Therefore, the determined optimum doses obtained from this part of the experiments were used in the next stages of study.

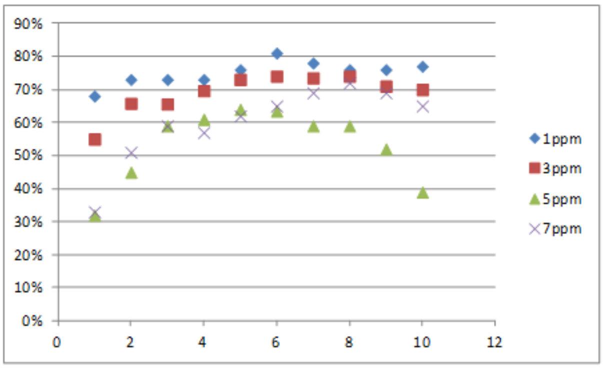

Fig. 1. RE% with different biosorbent dose.

B. Contact Time Effect

The effect of contact time on the biosorption process was studied within time range from 2 to 20 min at the optimum doses mentioned above for the different Cd (II) concentration. It can be seen from Table I, that the RE was increased by increasing the contact time. RE of 72.1% was achieved for Cd (II) removal with concentration of 1 ppm with *p value* of 0.003366. Statistical analysis results showed that the time has an effect in the first 20 min with *p value* of 0.007453, 0.005871, and 0.005098 for 3 ppm, 5 ppm, and 7 ppm Cd (II) concentration, and RE of 72%, 68%, and 71%, respectively at 18 min contact time.

C. Biosorbent Particle Size Effect

The effect of the biosorbent particle size on the biosorption process was studied using different sizes of *Moringa oleifera* leaves. The particle sizes used in this experiment were (2 mm, 1 mm, 500 μm, 250 μm, and < 250 μm). It was noted that the RE% was very low when 2 mm and 1 mm material were used, and this was probably due to smaller surface area of the biosorbent. On the other hand, statistical analysis showed that particle sizes of 500 μm, 250 μm, and < 250 μm have an effect on Cd (II) removal with *p values* < 0.05. Table II, shows the RE% using different particle sizes. It can be observed that the highest RE% was achieved by applying *Moringa oleifera* leaves with particle size of < 250 μm to remove 81% of Cd (II) in treated water.

TABLE I: CONTACT TIME EFFECT ON RE%

	Cd (II) concentration (ppm)			
Time (min)	1 ppm	3 ppm	5 ppm	7 ppm
2	26%	23%	13%	22%
4	18%	27%	17%	24%
6	20%	11%	18%	23%
8	23.30%	11%	14%	18%
10	20%	19%	18%	21%
12	29.40%	25%	55.50%	14%
14	69%	66%	67%	63%
16	72.10%	65.50%	65.40%	64%
18	71%	72%	68%	71%
20	70%	64%	66.40%	65%

TABLE II: PARTICLE SIZE EFFECT ON RE%

Biosorbent	RE% using different biosorbent particle size			
Particle size	1 ppm	3 ppm	5 ppm	7 ppm
2 mm	9.10%	9.11%	5.15%	8%
1 mm	10.20%	5.23%	4.57%	13%
500 μm	75.00%	72%	71.00%	66%
250 μm	76.70%	71.20%	76%	76%
< 250 μm	81%	74%	64%	72%

D. pH Effect

The effect of pH on the biosorption of Cd (II) onto biosorbent was studied at pH range of 4–10. It was found that there is no effect of pH on the biosorption of Cd (II). Table III, shows RE% of Cd (II) was in the range of 55% to 65% and there is no much difference in Cd (II) removal. Statistical analysis showed that pH has no effect because the *p value* was >0.05. Therefore, pH considered as insignificant factor in water treatment process using *Moringa oleifera* leaves as biosorbent.

TABLE III: pH EFFECT ON RE%

pH	Cd (II) concentration (ppm)			
	1 ppm	3 ppm	5 ppm	7 ppm
4	65.38%	56.65%	60.40%	58.49%
5	63.34%	65%	64.60%	56.95%
6	59.63%	58.30%	64.60%	56.80%
7	64.23%	60%	58.20%	57.87%
8	62.60%	57.79%	58.70%	55.41%
9	65.67%	59.39%	56.59%	57.36%
10	60.30%	58.62%	61.64%	57.56%

E. Water Turbidity Effect

Moringa oleifera leaves as biosorbent for Cd (II) removal was also investigated on different water turbidities using the optimum doses mentioned above for each concentration of Cd (II). Table IV shows the different turbidites and the optimum RE% for each Cd (II) concentration. It was found that the optimum RE% was achieved when the water turbidity was 50 NTU with 83.40% at Cd (II) concentration of 1 ppm.

TABLE IV: WATER TURBIDITY EFFECT ON RE%

Turbidity	Cd (II) concentration (ppm)			
(NTU)	1 ppm	3 ppm	5 ppm	7 ppm
50	83.40%	61.60%	61.50%	60.60%
200	81%	74%	64%	72%
400	62%	62.60%	48.30%	48.30%

F. FTIR Analysis

FTIR was used to investigate the functional groups of *Moringa oleifera* leaves and Cd (II) loaded on *Moringa oleifera* leaves. FTIR study was carried out and the spectra are shown in Fig. 2 and 3. The *Moringa oleifera* leaves display a number of absorption peaks, reflecting their complex nature. The 2D FTIR spectrum (Fig. 2) shows the *Moringa oleifera* leaves before and after biosorption of Cd (II). Fig. 2A shows that *Moringa oleifera* leaves in nature has two peaks which is considered as the finger print of *Moringa oleifera* leaves, while Fig. 2B shows those peaks after biosorption of Cd (II) are merged to be one strong peak, which means that Cd (II) is affecting the *Moringa oleifera* leaves structure.

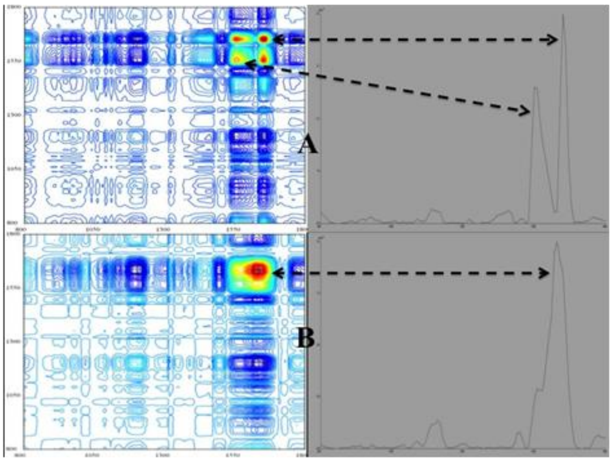

Fig. 2. 2D FTIR spectrum of *Moringa oleifera* leaves before (A), and after (B) biosorption of Cd (II).

Fig. 3 shows 1D FTIR for a comparison of the transmittance of *Moringa oleifera* leaves contents before and after biosorption of Cd (II), the lower graph is the original peaks of *Moringa oleifera* leaves while the upper is the *Moringa oleifera* leaves loaded with Cd (II). It shows the absorption peaks at 2919.70 cm^{-1} and 2850.87 cm^{-1} were elongated and sharpened, this could be because of the C-H stretching off –C=O and/or $–CH_3$ of functional groups. At absorption peak 1653.76 cm^{-1} there was elongation in the peak due to the stretch in the C=O functional group of the carboxylic acids. It was noted also that the peak at 1412.16 cm^{-1} was shifted to 1436.01 cm^{-1} and the peak at 1239.05 cm^{-1} shifted to 1243.19 cm^{-1} and this was due to the stretching of

C-O of the functional groups. Peak at 1317.11 cm^{-1} also has an elongation and this might be because of the N=O bending in the functional groups. Another change was noted on the natural composition of *Moringa oleifera* leaves which is the existence of peaks at wave number of 1378.01 cm^{-1}, 1155.9 cm^{-1}, and 1032 cm^{-1}. The repeated shift due to the C-O stretching suggests that C-O might be a functional group that Cd (II) can bind and react with it. In addition, it can be said that the shift in the absorption peaks generally observed and might indicate the existence of Cd (II) binding process on the surface of the *Moringa oleifera* leaves. The obtained results were in agreement with [10] results with some differences, and this might be because of different source of *Moringa oleifera* leaves.

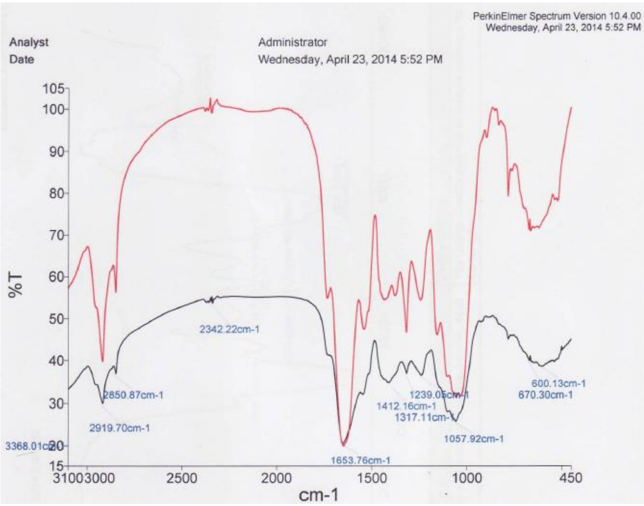

Fig. 3. 1D FTIR for a comparison of the transmittance of *Moringa oleifera* leaves before and after biosorption of Cd (II).

IV. Conclusion

This research work has focused on using *Moringa oleifera* leaves as a natural (without any modification or any kind of chemical treatment), environmentally friendly biosorbent for Cd (II) removal from water. *Moringa oleifera* leaves can be considered as an easily, locally available, low-cost adsorbent and has a considerable high biosorption capacity. It might be considered as an alternative adsorbent for Cd (II) and other heavy metals removal in water treatment. Therefore, *Moringa oleifera* leaves can be considered for adsorption of Cd (II) from water and further studies can be carried out to improve the performance of *Moringa oleifera* leaves by certain process for less dosage applications.

Acknowledgment

The authors would like to thank Research & Innovation Department/ Universiti Malaysia Pahang / Malaysia, for financial support to publish this paper under grant #: RDU 140318.

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