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Removal of Heavy Metals from Water and Wastewater Using *Moringa oleifera*

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Abstract

One of the contaminants in wastewater is the heavy metals. Treatment of heavy metals is of great importance because they can be harmful and dangerous for human being health. Conventional removal methods used include: ultra-filtration, reverse osmosis, ion exchange, solvent extraction, sedimentation, and chemical precipitation, and each method has some disadvantages besides high costs. In this chapter, *Moringa oleifera* cake residue, *Moringa oleifera* press cake, and *Moringa oleifera* leaves are introduced as a proposed alternative to replace conventional methods for heavy metal ions' removal. The results of using *Moringa oleifera* cake residue showed that iron (Fe) was fully removed; copper (Cu) and cadmium (Cd) were successfully removed up to 98% and reduction of lead (Pb) of 82.17%. The heavy metals were successfully reduced using *Moringa oleifera* press cake. The removal percentage of iron, copper, and chromium reached 69.99%, 88.86%, and 93.73%, respectively. *Moringa oleifera* leaves were used to remove Cd (II) from synthetic water; the optimization was performed and each parameter was affecting the Cd (II) removal with different percentages, but pH was insignificant. As a conclusion, the *Moringa oleifera* seeds and leaves can be considered as a promising alternative in water treatment for heavy metal ions removal.

Keywords: water treatment, *Moringa oleifera*, heavy metals, cadmium, copper

1. Introduction

Water is a source that is essential for life and is required by almost every living creature. Water source for human being consumption needs to be treated first, due to the contamination by different industrial advancements made over the years. In addition, there is natural contamination by soil erosion and organisms that live in water. Water pollution has contributed to negative environmental and human health impacts [1], and many pollution problems are introduced [2]. Every day, there are thousands of chemicals discharged directly and indirectly into water bodies without further treatment for elimination of the included harmful compounds. Water pollution is a serious problem in the world and needs to be solved. Aluminium sulphate and iron are the chemical coagulant salts used in the conventional method to treat water and wastewater [3, 4], but they have

many drawbacks [4–6]. Therefore, researchers are working hard to find natural alternatives. Heavy metals in water can be hazardous and harmful as they can accumulate in living organism tissue. One of the most toxic and hazardous heavy metals is Cd(II). Industries of pigments, electroplating, plastic, and metal finishing are the main sources for Cd(II) presence in water which might cause kidney damage, high blood pressure, bone fraction, renal disorder, and destruction of red blood cells [7]. There are many techniques to remove Cd(II) from aqueous solutions, such as; ion exchange, chemical precipitation, and membrane separation and adsorption, but some of these methods got several restrictions [8], such as low heavy metal concentrations, not effective and not economical [9]. As a result, the search for appropriate alternative solutions is of great importance. Recently, researchers are paying attention to Cd(II) removal from aqueous solution using adsorbents derived from low-cost tree leaves such as *Moringa oleifera* leaves [10].

Heavy metals present in water are harmful and poisonous and need to be removed from water; using natural biosorbent is one of the solutions. Few studies reported the removal of some heavy metals from water by *Moringa oleifera*.

Copper can be produced from electronics plating, paint manufacturing, wire drawing, copper polishing, and printing operations. The high presence of copper can cause acute toxicity, dizziness, and diarrhoea [11, 12]. It is an important element required by humans in trace amounts, used by the human body for enzyme synthesis and tissue and bone development [13]. However, the presence of copper in excessive amount can be toxic and carcinogenic. The copper can be deposited in the body and can cause some health problems, such as liver and kidney failure, Wilson disease, and gastrointestinal bleeding [11]. The osmoregulatory mechanism of the freshwater animals can be damaged due to the presence of Cu(II) in freshwater resources and aquatic ecosystem. Usually, chemical coagulants with high cost such as aluminium sulphate and activated carbon are used in water treatment [14].

Moringa oleifera is a member of the Moringaceae family which is a single genus family of shrubs [1, 2]. It can be found in Malaysia and other tropical countries where it was imported originally from India. It is easy to plant this tree, and it grows in soil or sand, can stand high temperature, and needs less water [15]. *Moringa oleifera* is a multipurpose tree with most of its parts being useful for a number of applications (**Figure 1**). *Moringa oleifera* seeds have been found to be a natural coagulant, flocculant, softener, disinfectant, sludge conditioner in water treatment [16, 17], and heavy metal remover in water and wastewater treatment [11, 16].

Moringa oleifera leaves are unique as a good protein supplement; it contains high amounts of minerals. In *Moringa oleifera* leaves, tannins and phytates are present with 12 and 21 g/kg on a dry basis, respectively [18]. It contains 38.6% carbohydrate, 27.2% protein, and 17.1% fat on a dry basis. It contains 2098 mg calcium, 1922 mg potassium, 406 mg magnesium, 351.1 mg phosphorus, 28.3 mg iron, and 5.4 mg zinc in each 100 gm of dry extracted leaves [19] and around 0.58–0.73 g of different proteins/g leaves dry weight [20]. Flavonoids and phenolic acids are found in *Moringa oleifera* leaves by HPLC analysis [21]. *Moringa oleifera* leaves are a rich source of vitamins [22].

Moringa oleifera seeds, leaves, husks, or press cake can remove heavy metals from water such as Cu, Cd, Pb, Fe, and Cr which will be covered in this chapter.

Microbial biomass is one of the effective natural materials as biosorbent [23], bagasse fly ash (from sugar cane), and peat are agricultural waste materials that can be an effective heavy metal biosorbent [24]. In addition, rice husks and straws [25],



Figure 1.
Moringa oleifera tree.

corn cobs, soya bean, walnut and cotton seed hull, sawdust, and banana peels [26] are good examples for alternative biosorbents.

2. Materials and methods

The *Moringa oleifera* tree parts such as seeds or leaves are mainly used to remove heavy metals from river water or wastewater in this chapter.

2.1 Seeds

Moringa oleifera seeds which are not harmful to human and do not have significant drawbacks have been applied for wastewater treatment [4–6]. The seeds showed natural coagulation activity which is similar and even better than aluminium sulphate (alum) [27, 28].

The seed oil is extracted by different methods either by solvent (cake residue) or by mechanical press (press cake). Both seed extracts were used in heavy metal removal.

Cake residue preparation: method (a): the seed husks are removed manually, the kernel is ground, and the kernel powder is then mixed with ethanol and mixed using a magnetic stirrer for 30 min. The mixture is then centrifuged at 4000 rpm for 10 min. The residual solid (seed cake) was dried at room temperature for 24 h [3]. The stock preparation was prepared with different concentrations: 10,000,

20,000, and 30,000 mg/L. The different concentrations were applied to wastewater, and jar test was performed with an initial speed of 150 rpm for 2 min, reduced to 50 rpm for 25 min, and then left to settle for 1 h [29].

Method (b): oil was extracted by Soxhlet extraction method [29]. Extraction thimble is filled with 10 g of *Moringa oleifera* seed powder. Hexane solvent (170 mL) was poured into a round bottom flask. The heater is turned on until the solvent is boiling; the oil was extracted within around 45 min. *Moringa oleifera* cake residue was collected from the thimble and dried in an oven at 50°C overnight. Once the oil was fully removed from the *Moringa oleifera* seed, the seed cake residue could be used in water treatment [30]. The oil was extracted from the seeds because the presence of oil in the *Moringa oleifera* seed would affect the coagulation activity and heavy metal removal [19]. The higher the oil content in *Moringa oleifera* seed, the lower the performance of the *Moringa oleifera* cake residue in water treatment process.

Press cake preparation: the seeds were pressed mechanically by Mitomasa Sdn. Bhd., Kuala Lumpur, Malaysia, and the press cake was bought from the company and applied in water treatment [31]. Press cake was soaked with water overnight to get the remaining oil. And the clean press cake was used in this experimental work. The moisture content was calculated to get the right mass for the biosorbent added to water [31]. The synthetic turbid water was used for biosorption test on Cu(II) removal from water by *Moringa oleifera* press cake.

2.2 Leaves

Moringa oleifera leaves were collected from a nearby area at Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia, dried and ground, and sieved using a sieve shaker to 2, 1 mm, 500, 250, and < 250 µm.

Moringa oleifera leaf extract was used in aqueous solutions as a good sorbent for Pb(II) [32]. It was used for optimization of Cd(II), Cu(II), and Ni(II) biosorption [33] and removing of Cd(II) from wastewater [34].

2.3 Synthetic water preparation

To prepare synthetic water, kaolin with laboratory grade (k7375-500G Sigma-Aldrich) was used, and 5 gm was dissolved in 500 ml of distilled water. Sodium bicarbonate solution was prepared by dissolving 100 gm of sodium carbonate (Hamburg Chemicals) in 1000 ml of distilled water to get a concentration of 100 mg/L. 500 ml of the sodium bicarbonate solution was added to kaolin solution and mixed at 200 rpm for 1 h to get uniform dispersion of kaolin particles which was left for 24 h for complete hydration of the kaolin [29].

2.4 Jar test

Each beaker in jar test was filled with 500 mL of wastewater sample. 10 mL of *Moringa oleifera* press cake with different concentrations prepared were added into each beaker. The stirring speed was set at 200 rpm for 4 min followed by 40 rpm for 30 min [35].

2.5 Atomic absorption spectrometer

Atomic absorption spectrometer (AAnalyst 400, Perkin Elmer) was used to measure initial and residual heavy metal in treated water. Stock solution prepared from each standard at different concentrations was used to get calibration curve for

each metal [30]. Wavelength of 324.80 nm was used to measure the Cu(II) concentration and 228.8 nm for Cd(II) measurement using an acetylene air flame [10, 31].

2.6 *Moringa oleifera* solution preparation

The stock solution was prepared by adding the distilled water to *Moringa oleifera* cake residue and forming a paste at different concentrations of 10,000, 20,000, and 30,000 mg/L by dissolving 50, 100, and 150 mg of the seed powder in 5 ml distilled water to obtain 1, 2, and 3%, respectively [36].

2.7 Water samples

The water samples of the Cu(II), Cd(II), Fe(II), Pb(II), and Cr(II) study were collected from “Sungai Baluk” river (Gebeng River {GR}), Gebeng Industrial Estate, Kuantan, Pahang State, Malaysia [30].

The synthetic water was prepared for measuring Cd(II) removal [10].

3. Results

The heavy metals of Cu, Cd, Fe, and Pb were high in the GR water samples. After a tenfold dilution, the concentration of these metals is still more than 1 mg/L. *Moringa oleifera* cake residue showed that iron (Fe) was fully removed, while copper (Cu) and cadmium (Cd) were successfully removed up to 98%. The reduction of lead (Pb) by 82.31% was achieved (Table 1). The initial amount of Fe was 1.306 mg/L and fully removed by *Moringa oleifera* cake residue. This result was totally agreed with [4] study, while [37] had reported that a reduction of Fe by using *Moringa oleifera* cake residue was up to 92% if compared to other heavy metals. Fe was fully removed, and the level of Fe achieved the water standards since concentration of Fe in water should be less than 0.30 mg/L (National Water Quality Standard from Malaysia). In this study, the removal of Pb was within the range of the previous research [37, 38] which indicated that Pb can be removed within 80–89% by using *Moringa oleifera* seed if compared to other natural sources such as beans and peanuts. Copper removal was better than [38] results of Cu which was 90%. The results of Cd removal were in contrast with [37] since the latter results showed 48% of Cd was removed which might be due to the absence of oil extraction from seeds.

In a different study, it was found in Balok River wastewater, Gebeng, Kuantan, that the concentration of Fe and Cr metal were 1 mg/L, while Cu concentration was 0.4 mg/L. *Moringa oleifera* solution was added into the wastewater with different doses to determine the optimum dose. The heavy metals were successfully reduced after the treatment with the *Moringa oleifera* press cake. The removal percentage of iron, copper, and chromium reached 69.99, 88.86, and 93.73%, respectively

Metal	Initial mg/L	Final mg/L	Removal percentage
Fe	1.306	0	100%
Cu	1.054	0.019	98%
Cd	1.718	0.035	98%
Pb	1.64	0.29	82.31%

Table 1.
Heavy metal removal from Gebeng River, Kuantan, Malaysia.

Metal	Initial mg/L	Final mg/L	Removal percentage
Fe	1	0.3001	69.99%
Cr	1	0.0627	93.73%
Cu	0.4	0.04456	88.86%

Table 2.
Heavy metal removal from Gebeng River, Kuantan, Malaysia.

Parameter	Initial mg/L	Final mg/L	Removal percentage
Particle size $\leq 250\mu\text{m}$	1	0.19	81%
Contact time (min)	1	0.28	72%
<i>Moringa oleifera</i> dose (6gm/L)	1	0.19	81%
Turbidity (50 NTU)	1	0.166	83.40%

Table 3.
The optimum results for Cd (II) removal with different parameters.

(**Table 2**). The removal of iron in this experiment was lower than the research done by [37], which had a removal of 92.14%. The removal percentage of chromium in this research was higher than the research done by [39], which was only 60% and almost similar to [40], which was 73%. The copper removal efficiency in this research is approximately similar to the literature statement of [39], which was approximately 90%. The trend of the removal percentage of copper and chromium was found to be alike with the trend in the research done by [31, 41].

Moringa oleifera leaves were used to remove Cd(II) from water, and the results showed that there are many parameters that affect the results, such as dose effect, contact time, particle size, pH, and water turbidity effect [10]. In this study, the pH value was insignificant, and other results showed that *Moringa oleifera* leaves are a potential alternative for heavy metal removal at a different percentage as shown in **Table 3**.

4. Conclusions

This chapter focused on the potential use of natural material for heavy metal removal from water and wastewater. The *Moringa oleifera* seeds which can be processed to get the press cake (mechanical process) or cake residue (chemical process) using solvents can be applied to polluted water and remove heavy metals Fe, Cu, Cd, Pb, and Cr.

Moringa oleifera leaves can be applied as a natural adsorbent to remove heavy metals from water (without any modification or chemical treatment); it is an environmentally friendly biosorbent. It is available in Malaysia and other tropical countries which make it a low-cost adsorbent with high biosorption capacity.

Acknowledgements

The author would like to thank Research & Innovation Department/Universiti Malaysia Pahang/Malaysia, for financial support to perform the research work for a few projects which is summarised in this chapter.

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