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ORIGINAL ARTICLE

The use of *Moringa oleifera* seed as a natural coagulant for wastewater treatment and heavy metals removal

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Abstract *Moringa oleifera* (MO) is a multipurpose tree with considerable potential and its cultivation is currently being actively promoted in many developing countries. Seeds of this tropical tree contain water-soluble, positively charged proteins that act as an effective coagulant for water and wastewater treatment. Based on this, water quality of "Sungai baluk" river was examined before and after the treatment using MO seed. MO seed exhibited high efficiency in the reduction and prevention of the bacterial growth in both wastewater and "Sungai baluk" river samples. The turbidity was removed up to 85–94% and dissolved oxygen (DO) was improved from 2.58 ± 0.01 to 4.00 ± 0.00 mg/L. The chemical oxygen demand (COD) and biological oxygen demand (BOD) were increased after the treatment from 99.5 ± 0.71 to 164.0 ± 2.83 mg/L for COD and from 48.00 ± 0.42 to 76.65 ± 2.33 mg/L for BOD, respectively. Nevertheless, there was no significant alteration of *pH*, conductivity, salinity and total dissolved solid after the treatment. Heavy metals such as Fe were fully eliminated, whereas Cu and Cd were successfully removed by up to 98%. The reduction of Pb was also achieved by up to 78.1%. Overall, 1% of MO seed cake was enough to remove heavy metals from the water samples. This preliminary laboratory result confirms the great potential of MO seed in wastewater treatment applications.

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Keywords *Moringa oleifera* · Wastewater · Treatment · Dissolved oxygen · Turbidity · TDS · Heavy metals · Antibacterial assay

Introduction

Water is a resource that is essential for life and is required by almost every living organism. This resource is, however, becoming very limited in its pure state due to the many anthropogenic means of contamination which arise from the different industrial advancements made over the years. Water pollution is a serious problem for the entire world. Water pollution has contributed to negative environmental and human health impacts (Briggs 2003). *Moringa oleifera* (Saijan or drumstick), a cosmopolitan tropical, drought-tolerant tree, available throughout the year, has been well documented for its various pharmacological importance, viz., its analgesic, antihypertensive and anti-inflammatory effects (Joshi et al. 2012). The powdered seed of the *M. oleifera* has coagulating properties that have been used for various aspects of water treatment such as turbidity, alkalinity, total dissolved solids and hardness (Arnoldsson et al. 2008). However, its bio-sorption behavior for the removal of toxic metals from water bodies has not been given adequate attention. The purpose of wastewater treatment is generally to remove, from the wastewater, enough solids to permit the remainder to be discharged to receiving water without interfering with its best or proper usage. Although many water treatment methods have been utilized, most of them still require high investments (Sumathi and Alagumuthu 2014; Ghebremichael et al. 2005). Plants including rice, peanut, bean and *M. oleifera* (MO) are considered as the most common natural source used for treating wastewater (Ghebremichael 2004; Subramanium et al. 2011). *M. oleifera* (MO) seed, which is not harmful to human and does not have significant drawbacks, has been applied for wastewater treatment (Bina et al. 2010; Alo et al. 2012; Eman et al. 2014). In this way, MO seeds were used as alternative natural materials for drinking water treatment. MO seed further showed coagulant activity similar to aluminium sulfate (Vikashni et al. 2012; Mangale et al. 2012a; Egbuikwem and Sangodoyin 2013). The effort to elucidate the coagulation and heavy-metal-removing properties of *M. oleifera* plants in general, and MO seeds in particular, include many important physicochemical parameters such as the biological oxygen demand (BOD), the chemical oxygen demand (COD), dissolved oxygen (DO), total dissolved salts (TDS), salinity and electrical conductivity (EC) have not been clarified well. Therefore, in this work these various physicochemical parameters were being investigated using different concentrations of MO seed cake and applied for the treatment of the "Sungai baluk" river and wastewater (WW) samples. This knowledge would contribute to the understanding of the mechanisms of coagulation of MO seeds, as well as its application to removal of heavy metal and bacterial population in contaminated water samples.

On one hand, several disadvantages such as high cost and *pH* alteration have been exhibited by using chemical coagulant. On the other hand, MO coagulant is biodegradable, non-toxic, non-corrosive and easy to use (Meneghel et al. 2013). Many studies have concluded that seeds of MO do not yield any toxic effect when they were used for wastewater treatment (Bina et al. 2010; Vikashni et al. 2012; Mangale et al. 2012a). The natural coagulant derived from MO seed is the by-product that is produced from oil extraction process (Eman et al. 2014). MO seed cake residue can be used directly in wastewater treatment without further preparation (Arnoldsson et al. 2008). The extracted part of MO seed prevents the growth of coliforms and pathogens (Arnoldsson et al. 2008; Bina et al. 2010; Eman et al. 2014). This implies the reduction of the disinfection requirements (Srivastava 2014; Jabeen et al. 2008). These seed cakes also help to remove dirt, solid particles and even some bacteria and fungi (Bina et al. 2010; Eman et al. 2014). However, the water was almost never completely free of germs by using this method (Amagloh and Benang 2009). Ndibewu et al. (2011) had stated that the components of MO seed cake residue possess heavy metal adsorption properties. A formation of complexes was formed when MO seed cake is bound with heavy metals (Meneghel et al. 2013).

This study aims to investigate different parameters of water quality (BOD, COD, DO, TDS, salinity and conductivity) using different concentrations of MO seed cake on the "Sungai baluk" river and wastewater (WW) samples, as well as the coagulant properties of MO protein application to heavy metal removal and bacterial-consortium reduction in the water samples.

Materials and methods

Sampling site

The water samples of this study were collected from two target sites which are "Sungai baluk" river, Gebeng Industrial Estate and landfill (Fig. 1). "Sungai baluk" river is located at main industrial area Kuantan, Pahang State, Malaysia. The studying of water quality for "Sungai baluk" river is considered very significant due to the huge volume of industrial effluents discharged into this river leading to deterioration in the quality of water.

The type of wastewater used in this study was leachate. The samples were collected from landfill located along Jabor-Kerangau Road, District of Kuantan, Pahang State, Malaysia. The location of the landfill is at 3°56′53″N, 103°21′03″E.

MO seeds pre-treatment

Oil extraction by ethanol

MO pod shells were removed manually; kernels were grounded in a domestic blender and sieved through 600-μm stainless steel sieve. Oil was removed by mixing the seed powder in ethanol. This was mixed with a magnetic stirrer for 30–45 min, and subsequently, separation of the residue from the supernatant was done by centrifuging for 10 min at 4000 rpm. The supernatant was decanted and the residual solid was dried (seed cake) at room temperature for 24 h (Gidde et al. 2012).

Stock solution preparation

The stock solution was prepared by adding distilled water to MO seed cake in different concentrations to form a paste which possesses the coagulant properties. The different concentrations of the seed powder (50, 100 and 150 mg) were suspended in the distilled water to obtain 10,000, 20,000 and 30,000 mg/L (Alo et al. 2012).

Wastewater treatment

Wastewater treatment was performed using a PB-700 6 Paddle Jar Test apparatus. Six beakers were labeled and about 500 mL of water sample was added into each beaker and placed into the Jar Test apparatus. The correct concentration of stock solution was added into each beaker and

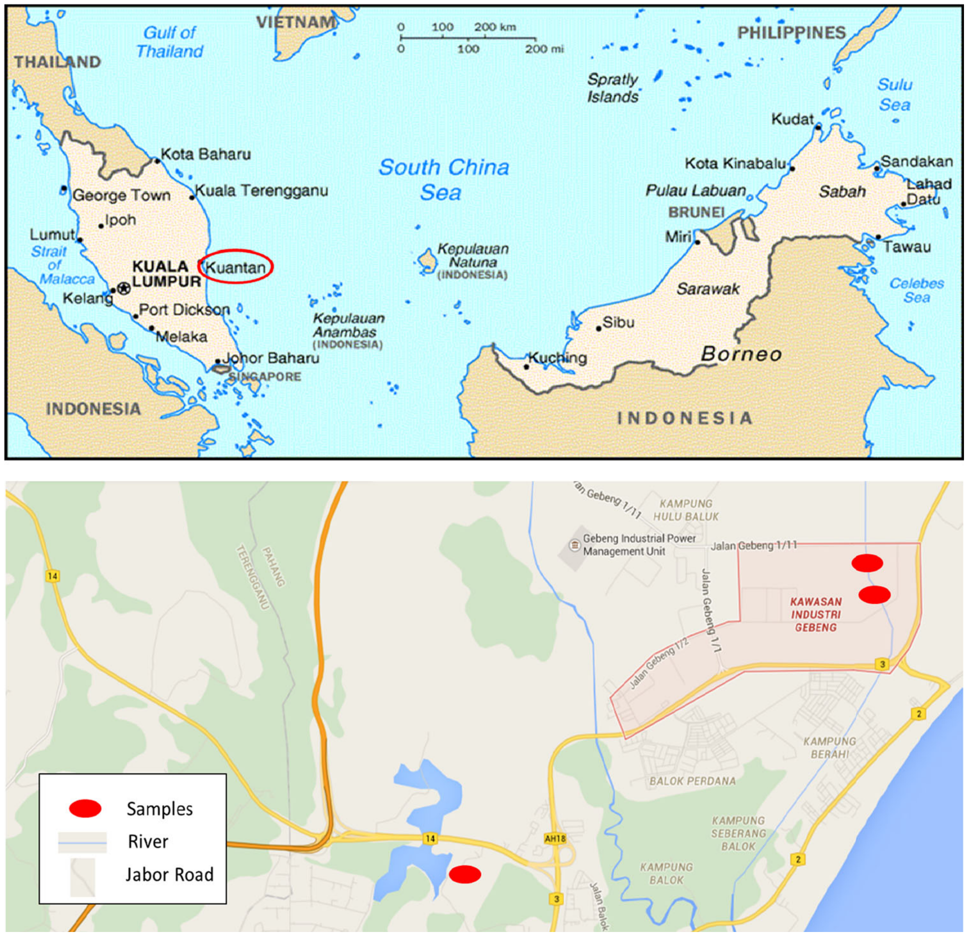

Fig. 1 Geological map of the study area showing the sampling points

operated with initial speed of 150 rpm for 2 min. Then, the speed was reduced to 50 rpm and continued for 25 min. The paddles were stopped and the water was left to settle for 1 h (Alo et al. 2012; Lea 2010). After 1 h, clear water sample was collected into conical flask and stored at 4 °C for further analysis.

Heavy metal removal measurement

Heavy metal removal tests were carried out using a PerkinElmer AAnalyst™ 800 high-performance atomic absorption spectrometer (AAS). A series of calibration solutions such as copper, iron, lead and cadmium were prepared from standard stock solution (1000 mg/L). Each element was prepared to five different concentrations from 0.5 to 7 ppm (Vikashni et al. 2012). Each treated water sample was diluted tenfold before analyzing by AAS.

Turbidity measurement

Turbidity test of water samples was measured using 2100P (HACH) turbidity meter and compared before and after treatment (Amagloh and Benang 2009).

Chemical oxygen demand (COD) measurement

A DR2800 spectrophotometer was used to measure the COD value. About 2 mL of the water sample prior to and after treatment was pipetted into COD reagent vials and inserted into a COD reactor. The sample was heated at 150 °C for 2 h with a strong oxidizing agent, potassium dichromate solution, which oxidizes organic matter chemically (Forster 2000).

Biochemical oxygen demand (BOD) measurement

BOD was measured using a dissolved oxygen (DO) meter. About 1 L of diluted water was prepared by adding 1 mL of phosphate buffer, magnesium sulfate, calcium chloride and ferric chloride solution to 996 mL of distilled water. About 10 mL from water sample prior and after the treatment was transferred into each BOD bottle. Then, 300 mL of diluted water was added to BOD bottle. Besides that, 300 mL of diluted water was transferred into BOD bottle and allocated as the control. Each sample after mixing was then measured using a DO meter. After that, the diluted water was added to the flared mouth of the bottle and covered with aluminium foil to prevent evaporation from the solution. All bottles were then incubated into BOD incubator for 5 days at 20 °C. DO value was measured after 5 days (Suhartini et al. 2013).

Electric conductivity, pH, total dissolved solid (TDS), dissolved oxygen (DO) and salinity measurement

The electrical conductivity, pH, TDS, DO and salinity were examined using a multifunction PCD 650 waterproof portable meter (CyberScan Waterproof Portable pH/ORP/Conductivity Meter from Eutech Instruments, Metex Corporation Limited). The wastewater samples were investigated directly in situ before the treatment, and then, they were measured after treatment.

Antibacterial assay test

The antibacterial assay was carried out to investigate the microbiological quality of water sample. Pour plate method was used to examine the reduction of bacterial population from wastewater samples (Arafat and Mohamed 2013). This test was conducted prior and after the treatment by different concentrations of MO seed cake. A serial dilution of the wastewater samples was performed using plating onto the nutrient agar (NA) plate before and after the treatment (Alo et al. 2012). About 0.1 mL aliquot of each dilution was transferred onto the NA surface and then evenly spread onto the agar surface using an L-shape glass rod. The NA plates were then incubated at 37 °C for overnight. The numbers of colonies that are allowed to grow on the plate were counted. The numbers of colonies before and after the treatment were compared.

Results and discussion

Oil extraction

Oil was extracted using ethanol to obtain seed cake without oil. However, the oil has not been fully extracted from the MO seed; only 12.78% of oil was extracted from the MO seed. In general, MO seed contains 35–40% oil (Garcia-Fayos et al. 2010). The remaining seed cake residue could be used in the wastewater treatment. The presence of oil in MO seed has an effect on the coagulant and heavy metal removal activities; therefore, MO seed's high oil content would have a negative impact on the wastewater treatment process (Garcia-Fayos et al. 2010).

Water analysis parameters results

River water

Data recorded in Table 1 revealed that the pH of the"Sungai baluk" river sample has not been significantly changed after the treatment with MO seed cake. *pH* values were less than 8.5 or greater than 6.5. This proved that MO seed cake is not affecting *pH* values in the water samples, in agreement with published observations (Ghebremichael et al. 2005; Arnoldsson et al. 2008; Alo et al. 2012).

Moreover, conductivity value has been increased to no more than 50 µS. Conductivity value was from 347 ± 0.00 to 390 ± 0.00 µS. Salinity and TDS increased from 353 ± 0.00 to 410 ± 0.00 ppm and from 307 ± 0.00 to 400 ± 0.00 ppm, accordingly. The results obtained were similar with what was concluded by Arnoldsson et al. (2008). However, TDS result was not in agreement with Mangale et al. (2012b) who stated that TDS was reduced after the treatment with MO seed cake. This may have been due to the different pre-treatment step used in the experiment. Conductivity and TDS values were high in the water samples. This is possibly because the ions from the dissolved solids in the water samples create an ability of water to conduct an electrical current. Furthermore, one of the components of TDS is a salt (Ellis 2004). Salinity can also carry an electrical charge and make the water able to generate the electricity. Hence, salinity was directly proportional to the conductivity. Ellis (2004) stated that high levels of conductivity value are not suitable for certain organisms to survive. Thus, the levels of conductivity, TDS and salinity were slightly increased after the treatment.

COD of the "Sungai baluk" river samples was 132.0 ± 2.83 mg/L before the treatment, but increased to 164.0 ± 2.83 mg/L after the treatment. This refers to the high level of COD that is generally associated with threats to the human health. The results in Table 1 have not met what had been found by Bhuptawat et al. (2007). However, the overall treatment processes have not been affected by the increase of COD due to the natural coagulant used in the wastewater treatment. The MO seed cake was reported as non-toxic agent utilized for water purification (Arnoldsson et al. 2008). Besides that, the solvent used to extract the oil from MO seeds leads to an increased COD value. MO seed cake concentration was directly proportional to the COD. The best concentration for the COD reduction was 1% of MO seed cake.

BOD was dramatically reduced after the treatment. Based on the research performed by Folkard and Sutherland (2001), 50% of BOD could be reduced after the treatment by MO seed cake (Table 1). This implies that the MO seed cake concentration has an influence on BOD; BOD value was reduced from 100.10 ± 0.00 to

Table 1 Water analysis parameters for "Sungai baluk" river samples water treatment at different concentrations of MO seed cake

Parameters	Before treatment	MO concentration, % (mean ± SD)		
		1.0	2.0	3.0
pH	8.06 ± 0.03	8.02 ± 0.03	7.98 ± 0.03	8.07 ± 0.07
BOD (mg/L)	100.10 ± 0.00	48.00 ± 0.42	56.85 ± 1.48	76.65 ± 2.33
COD (mg/L)	132.0 ± 2.83	99.5 ± 0.71	117.5 ± 2.12	164.0 ± 2.83
Conductivity (µS)	347 ± 0.00	352 ± 0.00	380 ± 2.83	390 ± 0.00
Salinity (ppm)	353 ± 0.00	366 ± 1.41	398.5 ± 0.71	410 ± 0.00
TDS (ppm)	307 ± 0.00	325 ± 0.00	343 ± 0.00	400 ± 0.00
DO (mg/L)	2.58 ± 0.01	3.03 ± 0.00	3.70 ± 0.01	4.00 ± 0.00
Turbidity (NTU)	67.25 ± 0.07	8.98 ± 0.04	6.48 ± 0.06	5.07 ± 0.04

48.00 ± 0.42 mg/L. This result was similar with what was concluded by Folkard and Sutherland (2001). However, Sajidu et al. (2005) had reported that there was no alternation on BOD value after the treatment.

Regarding the DO, it improved from 2.58 ± 0.01 to 4.00 ± 0.00 mg/L after the treatment by 3% of MO seed cake. MO seed cake concentration is directly proportional to the DO value. DO value was between 3–5 mg/L after the treatment. Therefore, it was concluded that MO seed has an important role in decreasing the DO value. Most aquatic organisms have an optimal range of DO value. This refers to the low amount of DO causing the deterioration of the organisms and results in oxygen depletion. To our knowledge, this is the first report investigating DO value after treatment by MO seed cake. MO seed cake also plays an essential role in the reduction of turbidity value. The initial turbidity of the "Sungai baluk" river sample was 67.25 ± 0.07 NTU. 85–93% of turbidity was removed from the "Sungai baluk" river sample using MO seed cake. These results totally agreed with results reported by previous investigations which indicated that the turbidity was reduced from water samples after treatment with MO seed cake (Muyibi et al. 2004; Ghebremichael et al. 2005; Arnoldsson et al. 2008; Lea 2010; Subramanium et al. 2011; Vikashni et al. 2012). The high concentration of MO seed cake is believed to lead to a reduction in the residual turbidity. According to Table 1, the turbidity value has been reduced from 67.25 ± 0.07 to 5.07 ± 0.04 NTU by using 3% of MO seed cake, while turbidity values were 6.48 ± 0.06 and 8.98 ± 0.04 NTU after the treatment by 2 and 1% of MO seed cake, respectively. According to the water classification from National Water Quality Standards for Malaysia (NWQSM), the values in Table 1, the treated water could almost be classified as drinkable water.

Wastewater

Data recorded in Table 2 showed that *pH* of the WW was not significantly changed after treatment. MO seed cake concentration has not shown any effect on the *pH* value of treated water. This result agreed with the findings of Amagloh and Benang (2009) and Arnoldsson et al. (2008). The *pH* for normal water should be from 6.5 to 8.5 (WHO 2006). Thus, no additional step has been required to adjust the pH value after the treatment. It is suggested that MO seed cake could be the best choice to the industry for wastewater treatment.

On one hand, there is no alteration on conductivity, TDS and salinity values after the treatment. Conductivity, TDS and salinity of the WW sample before the treatment were 402 ± 1.41 µS, 412 ± 0.00, and 421 ± 0.85 ppm, respectively. On the other hand, and based on Table 2, the results for previous three parameters using 2% of MO seed cake for the treatment were slightly higher than the values after treatment by 1 and 3% of MO seed cake. These results have not agreed with what had been found by Amagloh and Benang (2009). Amagloh and Benang (2009) had mentioned that the increasing of MO seed cake concentration resulted in a decrease in the conductivity value. However, the previous report from Arnoldsson et al. (2008) indicated that the MO coagulant has not been an influence on the conductivity and TDS values. Thus, the results of the WW sample were similar to the findings of Arnoldsson et al. (2008). Also, the COD value has increased dramatically after the treatment because of the oil content of MO seed cake which has not been removed completely. The remaining organic matter in the MO seed cake leads to an increase in the COD value (Arnoldsson et al. 2008).

Apart from the above observations, other parameters such as BOD also have the same trend as the COD. The result of BOD value improved after treatment, especially using 3% of MO seed cake. Based on Table 2, the initial BOD was 120.5 ± 2.12 mg/L; however, BOD value has been boosted progressively by increasing the MO seed dosage. These results obtained did not meet with drinking water quality standards (WHO 2006) and had not agreed with results of investigations carried out by Folkard and Sutherland (2001) and Sajidu et al. (2005).

Table 2 Water analysis parameters for wastewater (WW) treatment using different concentrations of MO seed cake

Parameters	Before treatment	MO concentration, % (mean ± SD)		
		1.0	2.0	3.0
pH	7.15 ± 0.01	6.92 ± 0.01	6.92 ± 0.00	6.82 ± 0.01
BOD (mg/L)	120.5 ± 2.12	188.0 ± 0.00	212.5 ± 2.12	303.0 ± 4.24
COD (mg/L)	520.5 ± 0.71	529.5 ± 2.12	766.5 ± 2.12	987.0 ± 2.83
Conductivity (μS)	402 ± 1.41	418.2 ± 0.14	465 ± 0.00	455.3 ± 3.68
Salinity (ppm)	421 ± 0.85	419.8 ± 2.40	476.9 ± 1.27	454 ± 0.00
TDS (ppm)	412 ± 0.00	382 ± 1.41	446 ± 0.00	427.5 ± 0.71
DO (mg/L)	1.06 ± 0.04	2.67 ± 0.03	3.76 ± 0.01	4.34 ± 0.05
Turbidity (NTU)	148.3 ± 0.42	8.02 ± 0.02	6.51 ± 0.01	5.40 ± 0.01

The possible reason for the increase of the BOD value after treatment may be due to the presence of the natural and organic compounds content of MO seed cake. High level of BOD value results in the depletion of the dissolved oxygen which has detrimental effects on the aquatic life (Irenosen et al. 2012). On one hand, DO value was significantly increased after the treatment. After the treatment, DO value was improved up to 4.34 ± 0.05 mg/L. Hence, it is strongly suggested that MO seed cake has been used to improve DO value. The mode of action to improve DO value after the treatment by MO seed cake is still ambiguous. There is no research dealing with this parameter since most of the investigation was mainly focused on COD, BOD and turbidity. However, it is good to improve DO since lower value of DO means dissolved oxygen depletion. On the other hand, turbidity has been reduced by 96% using MO seed cake. This result agreed with the findings of Suhartini et al. (2013). The percentages of turbidity removal after the treatment by 1, 2 and 3%, respectively, of MO seed were 94.6, 95.61 and 96.36%, accordingly. This means that better removal of turbidity could be achieved using high concentration of MO seed cake.

Heavy metals removal

"Sungai baluk" river water

The initial levels of heavy metals including Cu (1.401 mg/L), Cd (1.887 mg/L), Fe (1.414 mg/L) and Pb (1.854 mg/L) were high, and after tenfold dilution, there was no decrease in their concentration (more than 1 mg/L) (Fig. 2). High levels of heavy metals are typically associated with severe health effects. (Vikashni et al. 2012; Meneghel et al. 2013). MO seed cake acts as natural adsorbent to remove the heavy metals from water samples (Ndibewu et al. 2011). After removing the oil from MO seed, polyelectrolyte was activated and combined with the heavy metals leading to complex formation (Meneghel et al. 2013). The polyelectrolyte is released after the oil extraction since it is not soluble in the lipid (Sajidu et al. 2005). In this study, the increasing MO seed cake concentration showed high efficiency in the removal of the heavy metals from the "Sungai baluk" river samples.

Subramanium et al. (2011) reported that MO seed cake has been able to remove copper (Cu) up to 90%. The concentration of Cu after the treatment was in the range of the standard drinking water. Obviously, more than 90% of Cd was removed. The result was similar with what was found by Meneghel et al. (2013). However, Vikashni et al. (2012) confirmed that only 60% of Cd could be removed by using MO seed cake. The level of Fe was fully removed by MO seed cake. This result totally agreed with what was concluded by Sajidu et al. (2005). According to National Water Quality Standards for Malaysia (NWQSM), Fe level in the water should be less than 0.30 mg/L. Therefore, it was noticed from our results that Fe level has met the water standards. Regarding Pb level, although MO seed cake showed some reduction of Pb in the treated water, the result was not good enough to meet the drinking water standards (WHO 2006). Pb has been reduced up to 0.537 mg/L; however, this value was considered higher

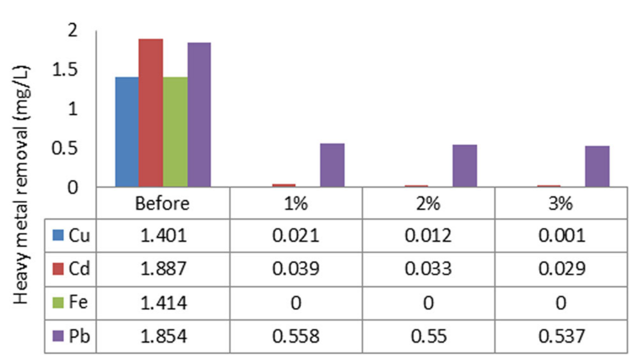

Fig. 2 Effect of different concentrations of MO seed cakes on heavy metal removal from "Sungai baluk" river

than the acceptable concentration of Pb which should be less than 0.05 mg/L. The percentage of the removed Pb at our study was 70%, whereas it had been 89 and 80% in the studies carried out by Sajidu et al. (2005) and Subramanium et al. (2011), respectively.

Wastewater

The concentrations of heavy metals in the WW were higher than the "Sungai baluk" river. The results showed that the WW was worse than the GR, but the removal of Pb in the WW was better than the "Sungai baluk" river. Treatment with 3% of MO seed cake led to reduced Pb concentration of up to 78.1%. The result of 2 and 3% MO seed cake were similar since both of them showed 77.8% of Pb reduction. Thus, these findings agreed with what was deduced by Subramanium et al. (2011) (Fig. 3).

First and foremost, the concentration of Fe was completely removed by MO seed cake. Based on an investigation performed by Sajidu et al. (2005), the removal of Fe using MO seed cake reached up to 92%. Besides that, there is no difference between MO seed cake concentrations used in the treatment. This is due to the fact that no trace of Fe was detected after the treatment of the GR sample (Figs. 2 and 3). The concentration of Cu was successfully reduced to 0.115 mg/L (98%). This result totally agreed with the findings of Subramanium et al. (2011) and Vikashni et al. (2012). Although Cu was not fully removed from treated water, however, MO seed cake has showed the ability to reduce Cu concentration. Other than that, Cd is another heavy metal that was decreased after the treatment. It was reduced to 0.036 mg/L (98%) (Fig. 3). The result from Fig. 2 agreed with the findings of Meneghel et al. (2013). While this result has not met with what was found by Sajidu et al. (2005) who revealed that the Cd removal percentage was 48%. This might have been due to the absence of pre-treatment step.

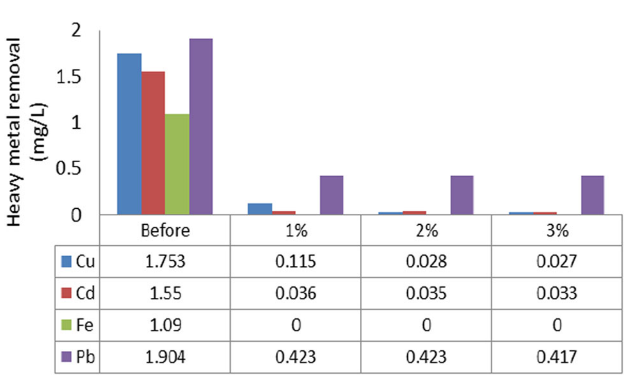

Fig. 3 Effect of different concentrations of MO seed cakes on heavy metal removal from waste water (WW)

Table 3 Effect of different concentrations of MO on bacterial count of river and wastewater samples

MO concentration (%)	Bacterial count from different water samples (CFU/mL)	
	"Sungai baluk" river	WW
0.0	1.70×10^5	1.06×10^6
1.0	9.50×10^4	2.10×10^5
2.0	8.60×10^4	9.70×10^4
3.0	7.50×10^4	10^4

Antibacterial activity

Data recorded in Table 3 represent the reduction of bacterial count for water samples that have been treated by MO seed cake. Both samples were unsafe for human consumption due to high amount of bacteria (WHO 2006). MO seed cake possesses antimicrobial function and exhibits antipyretic effect (Onyuka et al. 2013).

Results from Table 3 proved that MO seed cake was able to reduce the growth of microorganism in the water samples after the treatment. The bacteria from water sample have not been fully removed using MO seed cake; however, MO seed cake dose helped to prevent the growth of microorganism. The concentration of bacteria was reduced to 7.50 × 104 and 8.90 × 104 CFU/mL for the GR and WW samples, accordingly. These results agreed with what was concluded by Alo et al. (2012) and Arafat and Mohamed (2013).

Conclusion

Promotion and development of *M. oleifera* as a natural coagulant offers many diverse advantages to many countries of the developing world. It could be viewed as sustainable, appropriate, effective and robust water treatment means. The effective enhancement of particular wastewater treatment processes can decrease reliance on the importation and distribution of treatment chemicals, creating a new cash crop for farmers and employment opportunities for the rural dwellers in particular. MO seed oil was extracted using ethanol. MO seed cake oil yield was 12.78%. MO seed cake reduced the bacterial growth for the WW and "Sungai baluk" river water samples. Turbidity was removed up to 85–94% after the treatment and DO was significantly improved. There was no significant change on the *pH* value but was slightly so for some of the water physicochemical parameters such as electrical conductivity, salinity and TDS. However, COD and BOD values were increased due to the organic matter content in the MO seed cake but showed no toxic effects. Besides that, MO seed cakes were successfully used to remove the heavy metals from the wastewater. The iron (Fe) was completely removed, whereas copper (Cu) and cadmium (Cd) were successfully reduced up to 98%. The reduction of lead (Pb) has also been achieved up to 78.1%. Overall, 1% of MO seed cake was enough to remove heavy metals from all samples treated.

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