ENHANCED COAGULATION EFFICIENCY OF *MORINGA OLEIFERA* SEEDS THROUGH SELECTIVE OIL EXTRACTION

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***Abstract*:** In this laboratory based study, varying quantities of oil, corresponding to 20 % w/w, 25 % w/w and 30 % w/w kernel weight extracted from *Moringa oleifera* seeds (*S1, S2, S3)* respectively were applied in the coagulation of model turbid water (kaolin suspension) and turbid river water samples from River Batang Kali and River Selangor in Malaysia to determine the percentage oil removed which gave the best coagulation efficiency. For model turbid water (kaolin suspension) coagulation of low turbidity of 35 NTU, medium turbidity of 100 NTU and high turbidity of 300 NTU, sample S2 gave the best turbidity removal corresponding to 91.7%, 95.5% and 99% respectively. Application of sample S2 to River Batang Kali with low initial turbidity of 32 NTU and high initial turbidity of 502 NTU gave a highest turbidity removal of 69% and 99% respectively. Application to River Selangor with medium initial turbidity- of 87 NTU and high initial turbidity of 466 NTU gave a highest residual turbidity' of 94% and 98.9%, respectively.

Key words: *Moringa oleifera seed, selective oil extraction, coagulation, model turbid water (kaolin suspension), river water, turbidity removal.*

1. INTRODUCTION

Many researchers have reported on various uses of *Moringa oleifera* seed extract as a primary coagulant in turbidity removal [1-3].

Previous studies have focused mainly on the efficiency *of Moringa oleifera* seed extract as a coagulant [4-6]. Some researchers have focused on the physical factors affecting the use of *Moringa oleifera* seeds in the coagulation of model turbid water as well as the active agents in the seed extract and mechanism of turbidity removal [7, 8].

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Other studies have focused on quality of water treated by coagulation using two forms of the seed (shelled and unshelled) as well as using water extract with model turbid water (kaolin suspension) as the water source[8, 9].
Others have carried out investigations into the effect of extracting all the oil from *Moringa oleifera* seed on its coagulation effectiveness using turbid river water as the raw water source [10].
In the present study, varying quantities of oil 20% w/w, 25% w/w and 30% w/w kernel weight was extracted from *Moringa oleifera* seed. The cake remaining after oil extraction was dissolved in water and applied in coagulation of model turbid water (kaolin suspension) and turbid river water samples to determine the percentage of oil removed which gave the best coagulation efficiency.

2. MATERIALS AND METHODS

2.1 Model turbid water (kaolin suspension) samples

Five grams of kaolin, heavy grade (BDH Chemicals) was added to 500 ml distilled water. 50 mg/L concentration of sodium carbonate solution was added to the kaolin suspension and the total volume was made up to one liter. The suspension was stirred slowly at 20 rpm for 30 minutes in a jar test apparatus for uniform dispersion and allowed to stand for 24 hours for hydration of the clay particles [1].
This stock solution was used in the preparation of water with turbidity varying from 25 to 400 NTU by serial dilution. Turbidity was measured with Hach Turbidimeter (Camlab model 2100 AN).

2.2 River water samples

River water samples were collected from the raw water inlet taps at two Water Treatment Plants in Selangor State, Malaysia from River Batang Kali at Batang Kali and River Selangor at Rantau Panjang Lama.

2.3 Moringa oleifera cake preparation

Dry *Moringa oleifera* seeds used in the studies were obtained from gardeners in Serdang, Selangor, Malaysia. The seed wings and coat were removed from selected dry good quality *Moringa oleifera* seeds and the nuts ground to a fine powder using a food processor, National MJ-85CN. The dry mill attachment of the Food processor was used for the preparation of the water extraction *of Moringa oleifera* powder after oil extraction. Electro-thermal Soxhlet apparatus was used to extract oil from the *Moringa oleifera* seeds powder using hexane as solvent at a temperature of 70°C. Trial runs were initially carried out to determine the number of cycles required to achieve the desired oil extracted. Twenty percent by weight of seed was the lowest oil removable after one cycle of operation of the Soxhlet apparatus while 30% w/w of seed was the maximum amount of oil removable from the seed samples used for the studies. Samples of *Moringa oleifera* seed powder cake corresponding to three levels of oil extracted viz. 20% w/w, 25% w/w and 30% w/w seed kernel weight respectively referred to as *S1, S2, S3* in Table 2 were used for the coagulation studies in two stages. The flow diagram for the seed preparation is shown in Fig. 1.

Table 1**:** Characteristics of model turbid water (kaolin suspension) used in coagulation.

Parameter	Range of values
Turbidity(NTU)	
Low	25 - 45
Medium	50 - 100
High	150 - 400
pH	7.4 – 7.7
Zeta potential (millivolt)	0.8 – 2.16
Alkalinity(mg/L as $CaCO_3$)	24 – 32

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3. EXPERIMENTAL PROCEDURES

The coagulation studies were carried out in two stages. The first stage involved application of the three levels of water extracted solution corresponding to *S1 S2, S3* respectively to coagulate low, medium, and high turbidity model turbid water (kaolin suspension). The characteristics of the model turbid water (kaolin suspension) and river water samples viz. turbidity measured with a turbidimeter Hach model 21200P, zeta potential with Zeta meter System 3.0+, pH with pH meter Cyberscan 2000 and alkalinity using Standard Methods[11] are as presented in Tables 1 and 2.
The second stage of the investigation involved the application of the sample of *Moringa oleifera* seed powder cake that achieved the best turbidity removal in coagulation of model turbid water (kaolin suspension) to the river water samples.

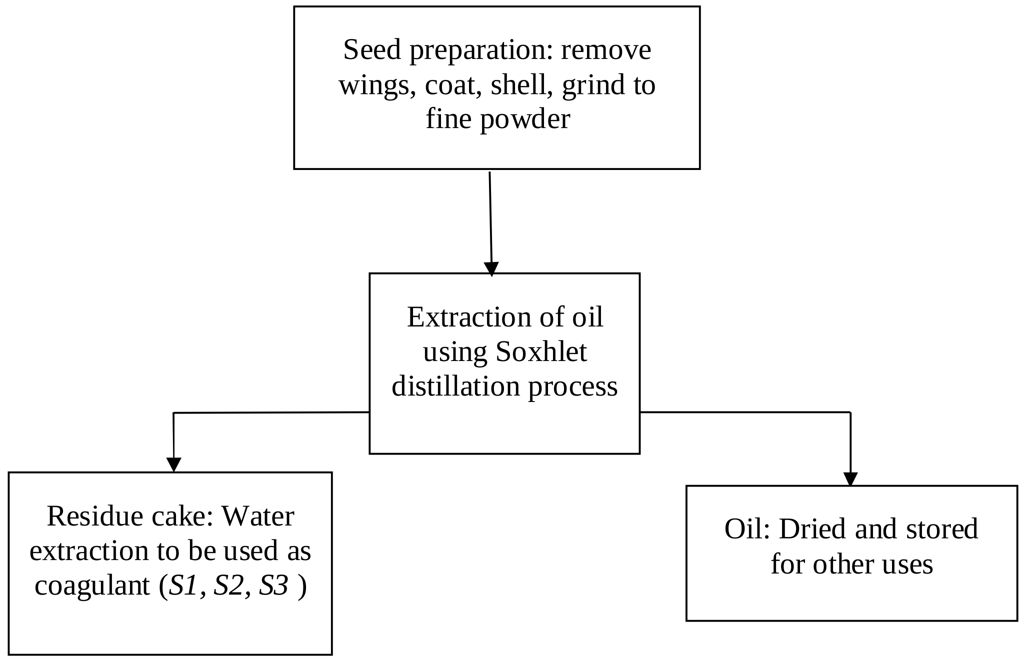

Fig. 1: Schematic of processing of *Moringa oleifera* seeds used in coagulation studies.

3.1 Coagulation of model turbid water:

500 mL of water samples for each level of turbidity was put in each of six 600 mL capacity beakers and placed under the Jar test apparatus (Jar Tester CZ 150). The apparatus was set at rapid mixing speed of 125 rpm for 4 minutes and slow mixing speed of 40 rpm for 25 minutes. Varying dosages of *S1 S2, S3* solution extracted in water was added to each beaker. A settling time of one hour was allowed after which the residual turbidity of the clarified water samples from each beaker was measured and recorded.

3.2 Coagulation of river water samples from River Batang Kali and River Selangor

Based on the results obtained from the first stage of the studies, the *Moringa oleifera* seed powder cake that gave the best turbidity removal was used in the coagulation studies using the same operating physical parameters of rapid and slow mixing rates and times. For Batang Kali River samples two levels of turbidity used were 32 and 502 NTU respectively while for River Selangor, 87 and 466 NTU were recorded respectively.

4. RESULTS AND DISCUSSION

4.1 Raw water characteristics.

Model turbid water (kaolin suspension):

Table 1 shows the raw water characteristics of model turbid water. The pH varied from 7.4 to 7.7 with the alkalinity varying from 24 to 32 mg/L. The zeta potential varied from 0.8 to 2.16 millivolts. The raw water turbidity varied from 25 to 400 NTU.

4.2 Surface water quality.

Table 2 shows the raw water characteristics of river water samples from River Batang Kali and River Selangor respectively. The pH and total alkalinity for the two raw water samples were almost the same. The pH varied from 7 .4 to 8.0 implying slight alkalinity with alkalinity varying from 24 to 32 mg/L and Zeta potential 0.90 to 1.40 millivolts for River Batang Kali water samples. For River Selangor water samples, the pH varied from 7.1 to 7.3 implying almost neutral water with alkalinity varying from 30 to 34 mg/L and Zeta potential of between 0.81 and 1.01 millivolts. The raw water turbidity for River Batang Kali varied from 32 to 502 NTU while that of River Selangor varied from 87 to 321 NTU respectively.

4.3 Coagulation of low turbidity model turbid water (kaolin suspension).

Figure 2 shows the results of coagulation studies on low turbidity model turbid water with initial turbidity of 35 NTU using *S1, S2, S3* with dosage varying from 10 to 30 mg/L. It was observed that for the three seed preparations increasing dosage resulted in rapid decrease in residual turbidity up to 10 mg/L dosage when the residual turbidity started to increase gradually until the dosage reached 30 mg/L. The gradual increase was probably due to over dosage that led to restabilization of the destabilized suspended solids, which had agglomerated into flocs. More significantly it was observed that the best turbidity removal was that from *S2* with residual turbidity of 2.9 NTU corresponding to 91.7% turbidity removal.

4.4 Coagulation of medium turbidity model turbid water (kaolin suspension).

Figure 3 shows the results of coagulation studies on medium turbidity model turbid water with initial turbidity of 100 NTU using *S1, S2, S3*. For *S3* with dosage varying from 50 to 100 mg/L, it was observed that from a rapid reduction in residual turbidity to 12 NTU at 50 mg*/L.*, increasing dosage resulted in increasing residual turbidity' implying restabilization of destabilized flocs during the coagulation process. For *S2* the residual turbidity was observed to decrease gradually to 7 NTU at 50 mg/L dosage and 4.5 NTU at 100 mg/L. Similarly for S1 there was gradual decrease in residual turbidity with increasing dosage with a final lowest residual turbidity of 20 NTU at 100 mg/L. *S2* again gave the best performance in turbidity removal corresponding to 95.5 % turbidity removal.

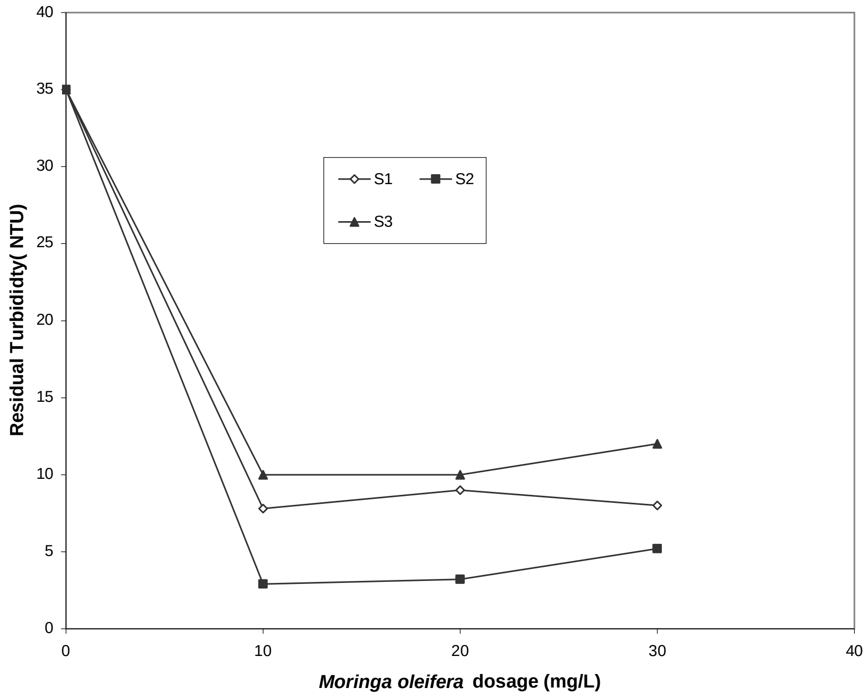

Fig. 2: Coagulation of model turbid water (kaolin suspension) with initial turbidity of 35 NTU using *Moringa oleifera* seed extract

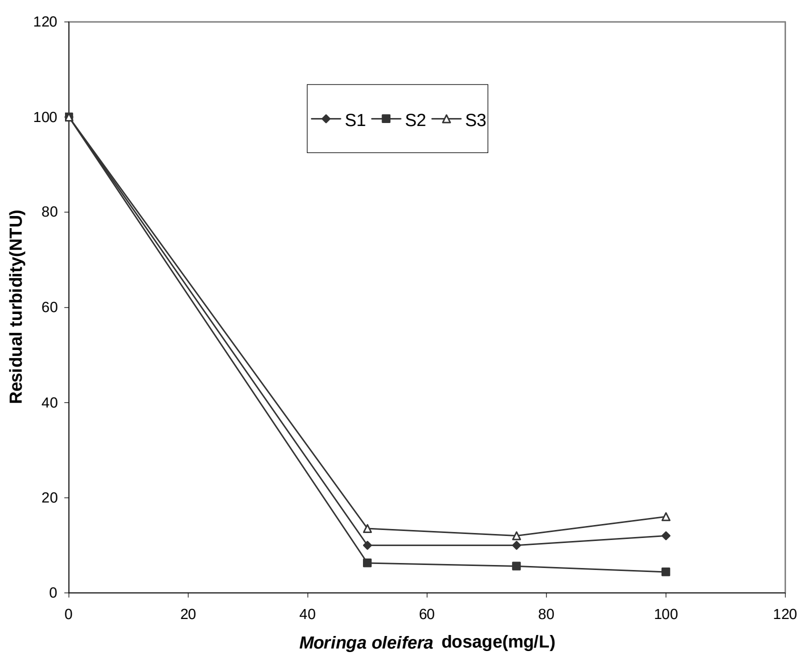

Fig. 3: Coagulation of model turbid water (kaolin suspension) with initial turbidity of 100 NTU using *Moringa oleifera* seed extract.

4.5 Coagulation of high turbidity model turbid water (kaolin suspension).

Figure 4 shows the results of coagulation studies oil high turbidity model turbid water with initial turbidity of 300 NTU using *Moringa oleifera* seed cake with *S1, S2, S3* respectively. The *Moringa oleifera* dosage applied was varied from 100 to 200 mg/L. For *S3*, the lowest level of residual turbidity of 9 NTU was recorded at a dosage of 100 mg/L after which there was a gradual increase of residual turbidity with increasing dosage. However for *S2* and *S1*, residual turbidity continued to decrease with increasing dosage with lowest residual turbidity observed at 150 mg/1, of 6 NTU and 3 NTU respectively after which there was gradual increase in residual turbidity for all the three seed preparations until the test run was terminated. The gradual increase was probably due to over dosing which led to restabilization of tile destabilized suspended solids which had agglomerated into flocs. More significantly it was observed that the best turbidity removal was that from *S2* with residual turbidity of 3 NTU corresponding to 99 % turbidity removal.

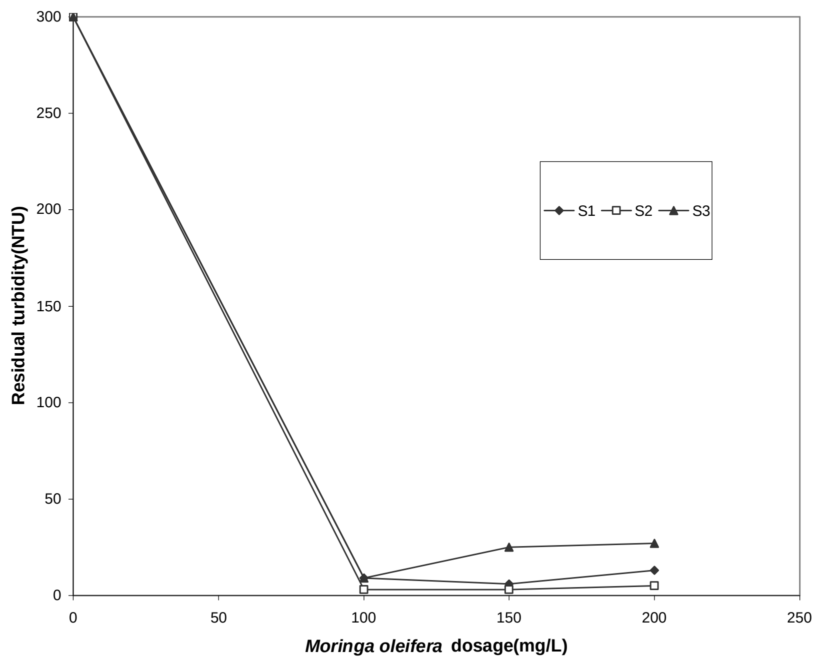

Fig. 4**:** Coagulation of model turbid water (kaolin suspension) with initial turbidity of 300 NTU using *Moringa oleifera* seed extract.

4.6 Coagulation of water sample from Rivers Batang Kali and Selangor

Since sample *S2* gave the best coagulation results with the model turbid water, it was selected for use in turbidity removal from the turbid river water samples. Figure 5 shows the results of coagulation of water samples from River Batang Kali with initial turbidity of 32 NTU and 502 NTU respectively.

For raw water sample with initial turbidity of 32 NTU, application of dosages of *S2* from 10 to 30 mg/L caused initial decrease in residual turbidity to a lowest value of 10 NTU increasing to 27 NTU and finally decreasing to 21 NTU at 30 mg/L dosage. For water sample with initial turbidity of 502 NTU with dosages varying from 100 to 250 mg/L, the residual turbidity decreased sharply to 5 NTU at 150 mg/L dosage after which there was an increase to 14 NTU at 200 mg/L followed by a gradual decrease again to a lowest value of 4 NTU at 250 mg/L dosage.

Results of coagulation of water samples from River Selangor with initial turbidity of 87 and 466 NTU respectively are shown in Fig. 6. For water sample with initial turbidity of 87 NTU, application of dosages of *S2* varying from 50 to 200 mg/L, showed decreasing residual turbidity with increasing dosage to a lowest value of 5 NTU at 150 mg/L after which it increased again to 8 NTU at 200 mg/L. Similar studies in which the raw water sample from River Selangor with initial turbidity of 66 NTU gave residual turbidity of 6.3 NTU on treating with *Moringa oleifera* seed extract with no oil extracted at 250 mg/L dosage while for 35 % w/w kernel weight oil extracted the residual turbidity was 6 NTU at 200 mg/L *Moringa oleifera* dosage [10].

For water sample with initial turbidity of 466 NTU, there was rapid decrease in residual turbidity to a lowest value of 5 NTU at 250 mg/L dosage after which there was gradual increase (due to restabilization) in residual turbidity to 12 NTU at 300 mg/L dosage.

In the present study in which 25 % w/w kernel weight oil was extracted (*S2*), it was observed that not only was the residual turbidity achieved lower than in the previous studies [3, 5, 6, 7, 9] but also importantly the dosage at which this was achieved was much lower at 150 mg/L in contrast to 250 mg/L for no oil extracted and 200 mg/1, for 35 % kernel weight oil extracted.

Similarly for raw water samples with high initial turbidity of 321 NTU application of shelled blended *Moringa oleifera* with no oil extracted gave a residual turbidity of 9.9 NTU (96.9 %) at the economic dosage of 250 mg/L whilst the shelled oil extracted *Moringa oleifera* out performed it by achieving a residual turbidity of 6.6 NTU (97.9 % turbidity removal.) [10]. The present study achieved residual turbidity level of 7 NTU at 250 mg/L, dosage using 25 % kernel weight oil extracted(*S2*) which was better than that achieved in previous studies in which 35 % kernel weight oil was extracted [10]..

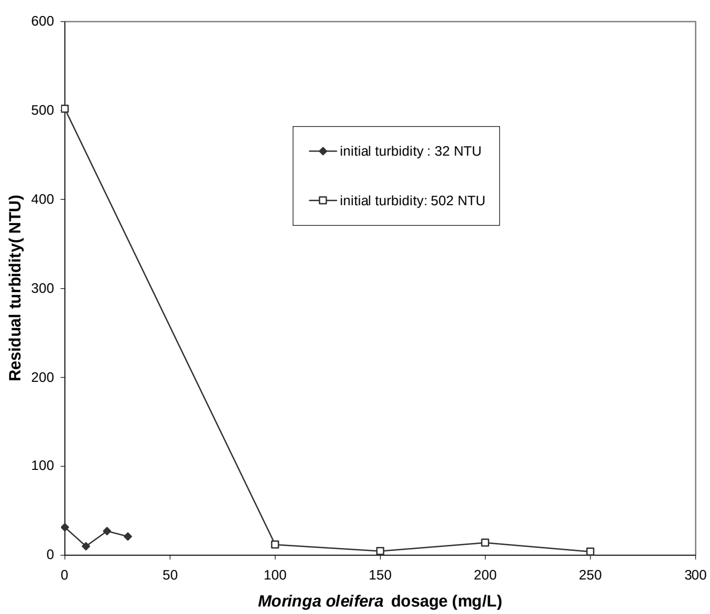

Fig. 5**:** Coagulation of turbid water from River Batang Kali using *Moringa oleifera* seed extract (*S2*).

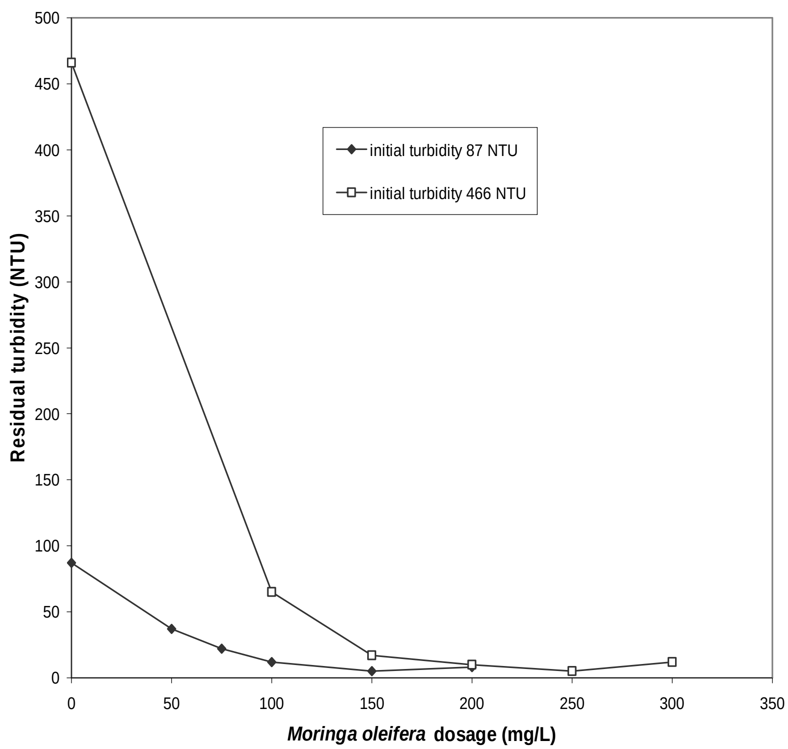

Fig. 6: Coagulation of turbid water from River Selangor using *Moringa oleifera* seed extract (*S2*).

The present study involved the use of only jar tests in which only coagulation/flocculation and settling processes were employed. It is therefore recommended that investigations be carried out through pilot plant studies that will involve the application of all unit operations and processes employed in conventional water treatment of surface water for potable use.

From the results of pilot plant studies, guidelines required for full-scale application of *Moringa oleifera* as a primary coagulant for turbidity removal may be developed.

5. SUMMARY OF FINDINGS/CONCLUSIONS

1. For model turbid water (kaolin suspension) coagulation of low turbidity (35 NTU), medium turbidity (100 NTU) and high turbidity (300 NTU) using *Moringa oleifera* seeds extract with 20% w/w, 25% w/w and 30% w/w (*S1, S2*, and *S3*) kernel weight of oil extracted respectively, 25 % oil extracted (*S2*) gave the best turbidity removal.
2. Application of *Moringa oleifera* seeds extract with 25% w/w kernel weight oil extracted (*S2*) to River Batang Kali with low initial turbidity (32 NTU) and high initial turbidity (502 NTU) gave a highest turbidity removal of 69 % and 99 % respectively.
3. Application of *Moringa oleifera* seed extract with 25 % kernel oil extracted(*S2*) to River Selangor with medium initial turbidity (87 NTU) and high initial turbidity (466 NTU) gave a highest residual turbidity of 94 % and 98.9 % respectively.

4. Turbidity removal was found to increase with increase in initial turbidity during coagulation of model turbid water (kaolin suspension) and river water samples.

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Biographies