CONVENTIONAL TREATMENT OF SURFACE WATER USING *MORINGA OLEIFERA* SEEDS EXTRACT AS A PRIMARY COAGULANT

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Abstract: The present study involved the use of a model pilot scale water treatment plant to treat turbid surface water from a stream using processed *Moringa oleifera* seed with 25 % w/w oil extracted as primary coagulant. The water treatment plant was made up of four unit operations: coagulation, flocculation, sedimentation, and filtration (rapid sand filter). Test runs were carried out for three hours per run over a three-month period with turbidities ranging from 18 to 261 NTU. The turbidity, pH, and alkalinity as well as the filter head loss were measured every 30 minutes during the experimental runs. Average turbidity removal of up to 96 % at an effective doses of 20 and 30 mg/l of oil extracted *M. oleifera* for low (< 50 NTU) and moderate turbidity (< 100 NTU) water respectively was observed doses 50 – 80 mg/l for high turbidity (> 100 NTU) water. *M. oleifera* seed extract was found to have no significant effect on pH or alkalinity of the water. The residual turbidities measured during most of the test runs satisfied the Malaysian Guideline for Drinking Water Supplies.

Key Words*: Moringa oleifera, primary coagulant, coagulation, pilot plant, filtration.*

1. INTRODUCTION

Many coagulants are widely used in conventional water-treatment process for turbidity removal during potable water production. These coagulants may be classified as inorganic, synthetic organic polymer, and natural polymer. These coagulants are used for various purposes depending on the chemical characteristics of the water to be treated. Aluminium salts are by far the most widely used coagulant in water and wastewater treatment. However, recent studies have pointed out several serious drawbacks in using alum salts [1-3] such as Alzheimer’s disease and similar health related problems associated with residual alum in treated waters, beside production of large sludge volumes. There is also the problem of reaction of alum with natural alkalinity present in water leading to reduction of pH and a low efficiency in coagulation of cold waters [2]. Ongoing studies to produce more effective aluminium coagulants, such as polyaluminum chloride (PAC), have not corrected all the drawbacks mentioned above [2]. Ferric salts and synthetic polymers have also been used as coagulants but with limited success because of similar disadvantages manifested in the use of aluminium salts.

In addition to these problems, chemicals used for water treatment in developing countries constitute a high percentage of annual running expenditure of water treatment companies. The costs of these chemicals have also been increasing at an alarming rate because local manufacturing companies cannot cope with the demand for these chemicals in other industrial applications. Therefore, the shortfall has to be imported with scarce convertible foreign currency. These problems force many water treatment companies to resort to under-dosing of chemicals so as to meet the increasing water demand. The result is the supply of poor quality water, especially during the rainy season, when suspended solids concentration and other pollutants in surface water are very high [3, 4].

On the other hand, naturally occurring coagulants are usually presumed safe for human health. Some studies on natural coagulants have been carried out and various natural coagulants have been produced or extracted from microorganisms, animals, or plants [5].

Moringa oleifera (family *Moringaceae*) is a tropical plant known to contain coagulating/flocculating compounds in the seeds. Many researchers have used *M. oleifera* seed as a primary coagulant, for water treatment [1-4, 6, 7]. Many studies [1, 2, 6, 8, 9-12] have been carried out on the performance of *M. oleifera* seeds as a primary coagulant, coagulant aid and as conjunctive with alum. *M. oleifera* showed a high coagulation activity for the high turbidity water. The coagulation activity was low for low turbidity water. Results of only three pilot scale studies [9 – 11] using *M. oleifera* seeds extract as a primary coagulant in turbid surface water treatment worldwide have been documented.

The main objective of the present study was to investigate the use of a model pilot scale water treatment plant to evaluate the efficiency of *M. oleifera* seeds with 25 % w/w seed oil extracted in the treatment of turbid surface water from a stream. In previous studies by others [9-11], *M. oleifera* seed used was not processed to remove some of the oil content. It has, however, been found that processing of the seed to remove the oil improved the coagulation efficiency of the seeds [12, 13]. Based on results from a related study, in which selected oil removals were observed to give enhanced coagulation properties to the *M. oleifera* seed extract with the best results achieved from 25 % w/w oil extracted [13], 25% w/w oil was extracted from *M. oleifera* seed kernel.

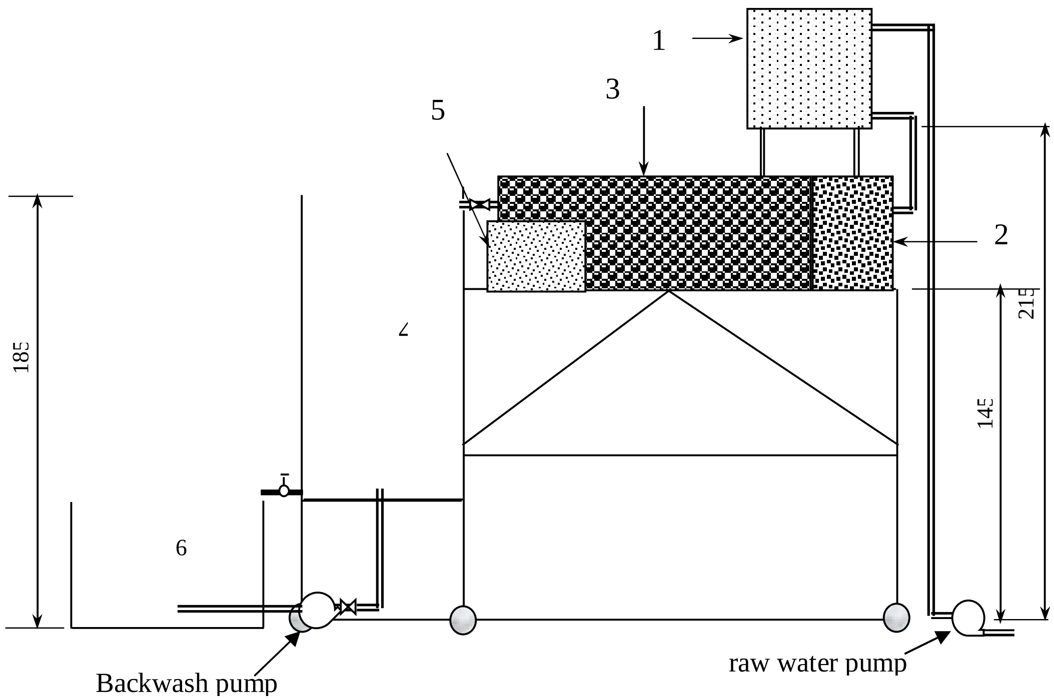
2. EXPERIMENTAL

2.1 Materials and Methods

3.1.1. Pilot Plant Design and Fabrication

A pilot water treatment plant was designed and built to a distorted scale of 1/40 horizontal and 1/15 vertical. The model treatment plant schematic is shown in Figure 1. It was located near a small stream at the hydraulic laboratory in the Department of Civil Engineering Faculty of Engineering at Universiti Putra Malaysia in Serdang, Selangor

State of Malaysia. Raw water was pumped into the overhead tank of the pilot plant. The plant was designed and constructed as a compact system that could be moved easily.



1. Raw water tank with automatic flow rate controller and flow meter
2. Coagulation tank
3. Flocculation / settling tank with inclined plates
4. Rapid gravity filter with underdrain and manometer
5. Coagulant dosing tanks with dosing pumps
6. Treated water tank with backwash pump

Fig. 1: Schematic of Pilot Scale Water Treatment Plant.

3.1.2. Pilot Plant Details.

Figure 1 shows the schematic diagram of the pilot plant. The pilot plant consisted of a raw water inlet pipe connected to a small centrifugal pump, raw water tank (1) equipped with an automatic flow level controller and flow meter. It has a coagulant dosing tank (5) equipped with variable speed Masterflex pump (Cole-Palmer Instruments, USA) which was connected to the coagulation and flocculation units (2, 3) equipped with IKA *RW* variable speed digital mixers (IKA Works, Malaysia). A settling unit equipped with inclined plates (3) and connected to rapid gravity sand filter equipped with a manometer (4), and treated water tank (6).

2.2 Water Sample

The raw water used in this study was pumped from the stream located near the Hydraulics laboratory. The raw water quality parameters measured during the experimental runs were; pH 7.1 to 7.5; Alkalinity 0.78 to 2.8 mg/l as $CaCO_3$; and turbidity 18 to 261 NTU.

2.3 Preparation of *M. oleifera* Seed Suspension

Dry *M. oleifera* seeds used in the study were obtained from trees around Sri Serdang area of Selangor state, Malaysia. The seed wings and coat were removed and the seed kernel dried in the oven at 50 ^{o}C for 24 hours. The seeds were ground using a domestic food blender. Oil was extracted from the ground seed using a Soxhlet apparatus and hexane as the solvent. Only 25 % w/w oil was extracted from the seed kernel because in a previous related study, it was observed that extraction of 25 % w/w oil from *M. oleifera* seed powder gave the best performance when applied to coagulation of turbid water [13]. Five grams of oil extracted seeds (remaining cake) powder was blended at high speed for two minutes in a variable speed domestic food processor (National MJ- C85N) with 200 ml of distilled water added. The resulting suspension was filtered through a clean muslin cloth in a beaker and the filtrate made up to a final volume of 500 ml to yield a stock solution of approximately 10000 mg/l.

2.4 Equipment

A Jar test apparatus (Jar Tester CZ 150) was used to obtain the optimum *M. oleifera* coagulant dose for each experimental run. A portable Turbidimeter (Hach model 2100P) was used to measure the turbidity. Filter head loss development was measured using a manometer (Armfield Instruments, UK) with plastic small bore tubing mounted on a wooden board connected to different levels in the rapid gravity filter.

2.5 Experimental methods

The experimental program followed in this study consisted of two parts. Firstly, a sample of raw water was collected from the overhead tank and jar tests carried out to determine the effective dose for each experimental run. The stock solution of *M. oleifera* required for the 3-hour experimental run was prepared according to the effective dose obtained from the jar tests. The flow rate was set and the dosing pump calibrated to the required flow rate. During each run water samples were taken every 30 minutes from the overhead tank (initial sample), settling tank and from the treated water. Turbidity, pH, and alkalinity were measured for both raw water and treated water from the filter outlet according to standard guidelines and procedures [14]. The filter head losses at different levels in the manometer tubing were also measured and recorded every 30 minutes.

3. RESULTS AND DISCUSSION

3.1 Turbidity removal

3.1.1. Low turbidity (< 50 NTU)

Figure 2 shows the average results of 3 runs of 9 hours duration when the surface water turbidity was low varying from 18.0 – 28.0 NTU. The residual turbidity varied from 4.5 to

5.2 NTU which was well within the Malaysian Minimum Guideline for Drinking Water Supplies. It is pertinent to note that *M. oleifera* performed very well as a primary coagulant in the removal of turbidity from water with low initial turbidity in contrast to the results obtained from previous studies [4, 2, 9, 10] which all concluded that since the bioactive constituents in *M. oleifera* seed extract is a low molecular weight short chain polyelectrolyte, it would be inefficient in the removal of turbidity from water with low initial turbidity. A possible reason which may be postulated for this observation is the method of preparation of *M. oleifera* used which involved extraction of oil of up to 25% of kernel weight (83% oil removal) from the powdered seed kernel before using the residual cake as primary coagulant. All previous studies in which *M. oleifera* seed extract was used as primary coagulant, no oil was extracted from the seed kernel before application.

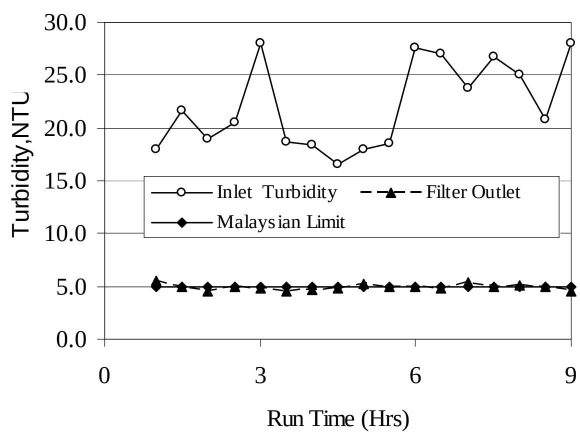


Fig. 2: Turbidity of inlet and filtered outlet at a dose of 30 mg/L using 25 % w/w oil extracted *M. oleifera* seed (Initial Turbidity of water 18 to 28 NTU)

3.1.2. Moderate turbidity (50 < turbidity <100 NTU)

Figure 3 presents the average results for moderate turbidity that varied from 65 to 90 NTU. The effective dosage of *M. oleifera* used was 30 mg/l. The turbidity dropped from 77.8 NTU to 5.6 NTU after filtration at the beginning of the experiment and reduced gradually to 4.5 NTU, satisfying the Malaysian Guideline for Drinking Water Supplies. The overall turbidity removal after filtration varied from 91.9 % - 94.9 %. The gradual improvement in turbidity removal within the experiment run may have been due to the improvement in flow conditions in the filter bed because the filter was operated for 12 hours without backwashing during the initial commissioning before the experimental runs commenced. During this period, flocs and other sediments were deposited through the sand media due to the effects of particle transport and attachment mechanisms. The deposited micro and macro particles reduced the effective pore area of the sand media, thus forming a deep bed deposit, which improved the quality of the filtered water.

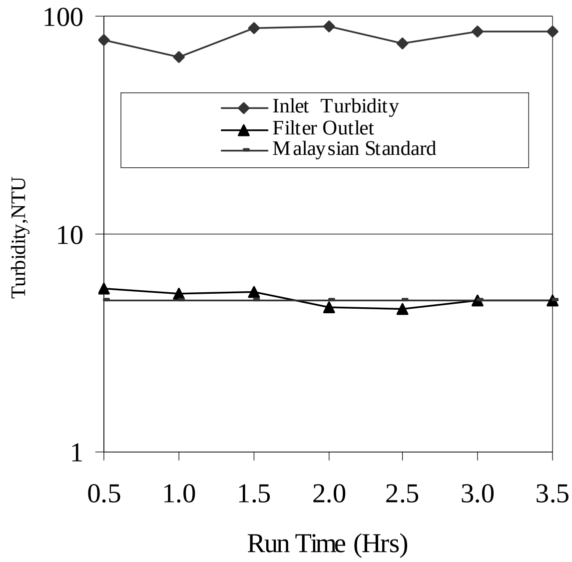


Fig. 3: Turbidity of inlet and filtered outlet at a dose of 30 mg/L using 25 % w/w oil extracted *M. oleifera* seed (Initial Turbidity of water 65 to 90 NTU).

3.1.3. High turbidity (≥ 100NTU)

Figure 4 represents the average results for high turbidity varying from 100 to 260 NTU. The effective dosage of *M. oleifera* used varied from 50 mg/l to 70 mg/l. The turbidity removal after coagulation and settling was found to improve with an increase in initial turbidity of raw water and time of filter run. For example, for water with an initial turbidity of 100 NTU, the residual turbidity recorded was 7 NTU corresponding to a removal 93 %. After two hours the initial raw water turbidity increased to 134 NTU, while the residual turbidity reduced to 5.5 NTU corresponding to 96 % removal. This observation may be explained in terms of the increase in suspended particles available with an increase in initial turbidity. This increase created more sites for adsorption and inter-particle bridge formation resulting in an increase in particle collision frequency and agglomeration rate leading to decrease in residual turbidity [4]. As much as 98 % of the solids were removed and the turbidity of the filtered water was between 4.5 and 7 NTU.

3.1.4. pH Variation

Figure 4 indicates the relationship between the pH of raw water and treated water for average results from four experimental runs. The pH of raw water varied from 7.23 to 7.84 (average of 7.43 and standard deviation of 0.144). In general the pH of the treated water was slightly lower than the pH of the raw water.

In a laboratory based study in which alum and *M. oleifera*, shelled and non-shelled seed were used as coagulants, the pH value was found to be constant in the case of *M. oleifera* while it decreased from 7.6 to 4.2 with addition of alum [2]. This implied that further chemical addition was necessary in order to correct the pH of the treated water to values between 6.5 and 9 to meet the Malaysian Standard. The effect of *M. oleifera* on the pH of the water was insignificant and no pH adjustment for the water was required after treatment. This is a major advantage when *M. oleifera* is used for coagulation.

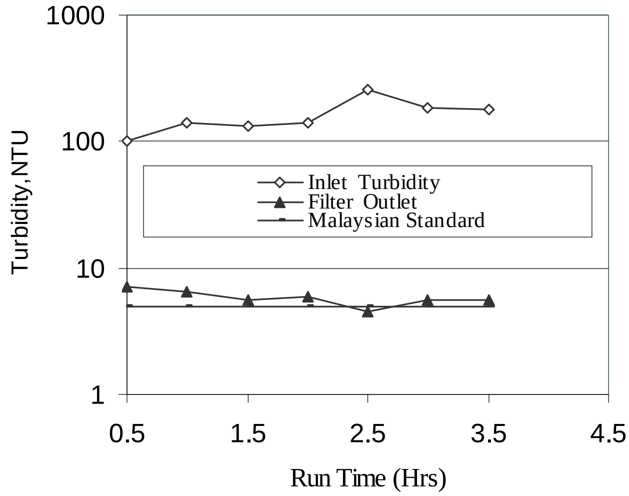


Fig. 4: Turbidity of inlet and filtered outlet at a dose of 50 to 70 mg/l 25 % w/w oil extracted *M. oleifera* seed (Initial Turbidity of water 100 to 260 NTU).

3.1.5. Alkalinity variation

Figure 5 shows the composite results of variation of alkalinity of both raw and treated water as a function of time for three experimental runs. The alkalinity of the raw water ranged between 1.5 and 2.2 mg/l $CaCO_3$. It was observed that the alkalinity of the treated water was generally equal to that of the raw water. In very few instances the alkalinity of treated water was slightly less than that of the raw water with a maximum variation of 0.2 mg/l $CaCO_3$.

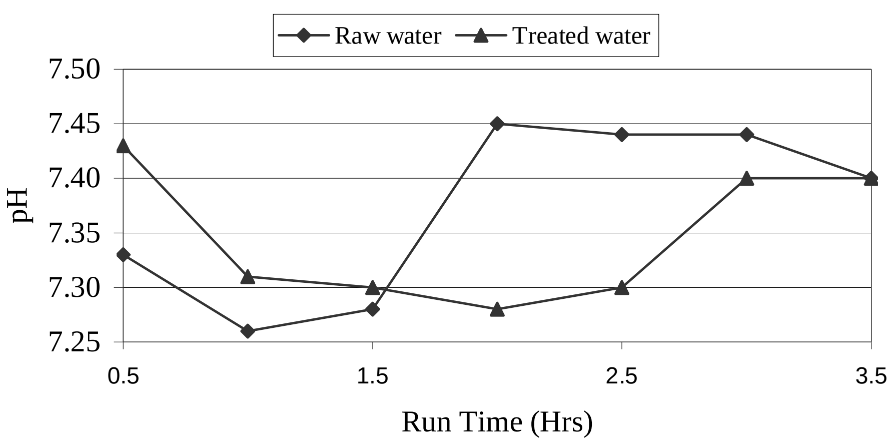


Fig. 5: pH of inlet and filtered outlet at a dosage of 30 mg/l 25 % w/w oil extracted *M. oleifera* seed.

The low alkalinity of the raw water as well as the treated water could initiate corrosion problems in the distribution networks. It is common practice in water treatment to add alkalinity in the form of bicarbonate or lime to increase the alkalinity. With *M. oleifera*, it may therefore be necessary to add lime or soda ash to alleviate the possible occurrence of such a problem.

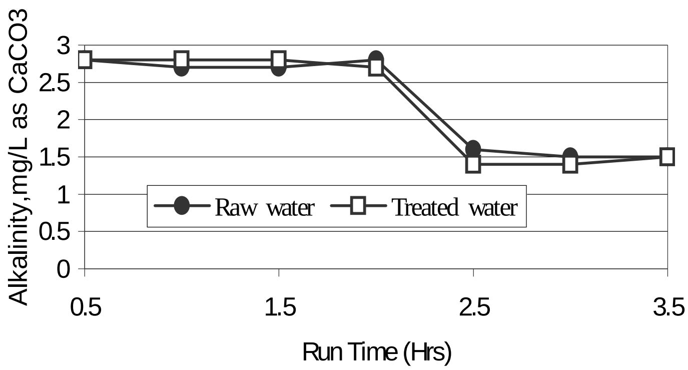


Fig. 6: Alkalinity of inlet and filtered outlet at a dose of 30 mg/l 25 % w/w oil extracted *M. oleifera* seed.

3.1.6. Head Loss Development

Development of head loss at four different depths, 10, 20, 30, and 40 cm from the sand surface are shown in Figure 7. The figure shows the average head loss development for five runs carried out after back washing. The raw water turbidity varied between moderate and high with an average of 162 NTU. The variation of head loss with time was recorded from the third run after back washing as the results of the second run after backwashing were not available because of malfunctioning of the manometers. It was observed that the head loss at 40 cm after 60 minutes was 6.3 cm, which increased gradually with time up to 24 cm after 6 trials (18 Hrs). It then dropped to 15.7 cm. Breakthrough occurred after 19 hours of operation and the turbidity of the filtered water increased from 4.5 NTU to 9.7 NTU. The experimental runs were then terminated and the filter was backwashed.

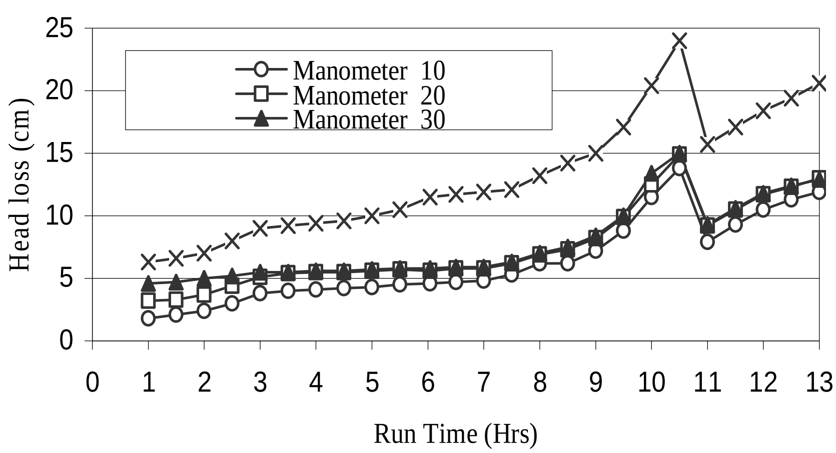


Fig.7: Variation of filter head loss at inlet and filtered outlet.

3.2 Filter Head Loss and Residual Turbidity

The relationship between the filter head loss and residual turbidity is presented in Figure 8, which represents a composite of three experiments. The average initial turbidities of low, medium and high turbidity were 18.5, 82.8 and 142 NTU respectively. It was observed that the residual turbidity decreased with increase in the head loss. The highest turbidity removal was at residual turbidity of 4.5 NTU, which was obtained for raw water with high turbidity and medium turbidity. The corresponding head loss was 9.6 and 11.9 cm respectively.

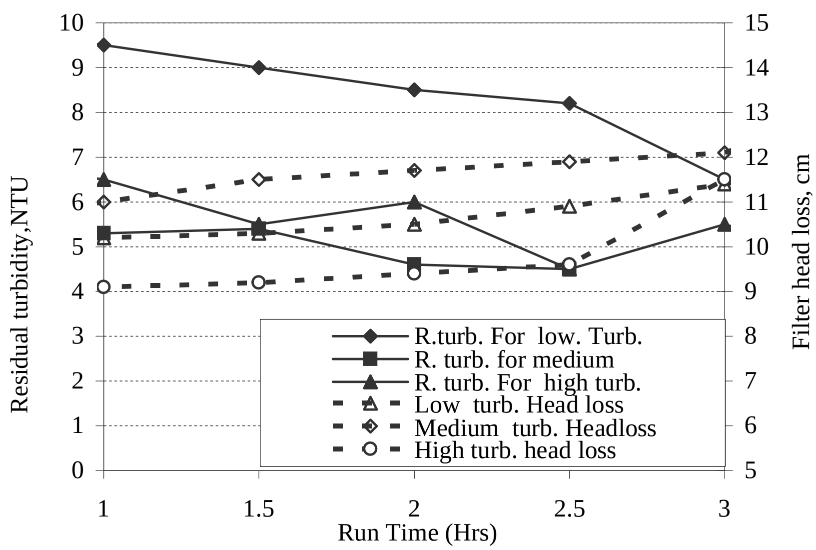


Fig. 8: Filter head loss and residual turbidity variation.

3.3 Summary of findings

1 Effective doses of 20 and 30 mg/l of *M. oleifera* for low (< 50 NTU) moderate turbidity (< 100 NTU) and 50 – 80 mg/l for high turbidity (> 100 NTU) feed water respectively removed an average 96 % of the initial turbidity of the raw water.

2 The effective dose of *M. oleifera* used for the test runs was obtained from the jar test results. For low turbidity it was 20 mg/l, moderate turbidity 30 mg/l and for the high turbidity the dosage varied from 50 to 80 mg/l depending on the initial turbidity.

3 Analysis of the water treated in the pilot plant showed that *M. oleifera* did not significantly affect the pH or alkalinity after treatment.

4 The maximum filter head loss, after which the breakthrough occurred, was 24 cm at the depth of 40 cm. The corresponding operation time was 18 hours.

5 The residual turbidities measured during most of the test runs satisfied the Malaysian Guideline for Drinking Water Supplies.

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REFERENCES

[1] A. Ndabigengesere, K.S. Narasiah, and B.G. Talbot, "Active Agent and Mechanism of Coagulation of Turbid Waters Using *Moringa oleifera*", Water Research, Vol. 2, pp. 703-710, 1995.

[2] A. Ndabigengesere, K.S. Narasiah, "Quality of Water Treated by Coagulation Using *Moringa oleifera* seeds", Water Research, Vol. 32, No. 3, pp. 781-791, 1998.

[3] S.A. Muyibi, "*Moringa oleifera* Seed Extract in Water Treatment", Journal-Institution of Engineering, Malaysia, Vol. 59, No. 3, pp. 37 – 50, 1998.

[4] S.A. Muyibi. and L.M. Evison, "Optimizing Physical Parameters Affecting Coagulation of Turbid Water with *Moringa oleifera seeds*", Water Research, Vol. 29, No. 12, pp. 2689-2695, 1995.

[5] T, Okuda, A.U. Baes, W. Nishijima, M. Okada, "Coagulation mechanism of salt solution extracted active component in *Moringa oleifera*", Water Research, Vol. 35, No. 3, pp. 830-834, 2001.

[6] S.A. Muyibi and C.A. Okuofu, "Coagulation of Low Turbidity Surface Waters with *Moringa oleifera* Seeds", International Journal of Environmental Studies, Vol. 48, pp. 263-273, 1995.

[7] S.A. Muyibi and C.A. Okuofu, "Softening Hard Waters with *Moringa oleifera* Seed Extracts", International Journal of Environmental Studies, Vol. 50, pp. 247-257, 1996.

[8] S.A. Muyibi. and L.M. Evison, "Coagulation of Turbid Water and Softening of Hard Water with *Moringa oleifera* Seeds", International Journal of Environmental Studies, Vol. 49, pp. 247-259, 1996.

[9] F. Kasser, C. Werner, and O. Nahayo, "Rural Water Treatment Using *Moringa oleifera S*eeds as Coagulant", Natural Resources Development, 33, 33-47, Institute for Scientific Cooperation, Tubingen, Germany, 1990.

[10] J.P. Sutherland, G.K. Folkard, and W.D. Grant, "Development of Robust Water Treatment Incorporating Natural Coagulants", Field Study Report, Environmental Engineering Group, Department of Engineering, University of Leicester, UK, 1992.

[11] G.L. McConnachie G.K. Folkard, M.A. Mtawali, and J.P. Sutherland, "Field trials of appropriate hydraulic flocculation process", Water Research, Vol. 33, No. 6, pp. 1425-1434., 1999.

[12] S.A. Muyibi, J.M.M.N. Megat., H.L. Lam, K.L. Tan, "Effects of oil extraction from *Moringa oleifera* seeds on coagulation of turbid water", International Journal of Environmental Studies, Vol. 59, No. 2, pp. 243-254, 2002.

[13] S.A. Muyibi, S.A. Abbas, J.M.M.N. Megat, A. Fakhrul-Razi "Enhanced coagulation efficiency of *Moringa oleifera* seeds through selective oil extraction". IIUM Journal of Engineering(in press 2003).

[14] American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF) *Standard Methods for the Examination of Water and Waste-water*, 20th edition APHA Publication Office, Washington D.C., 1999.

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