Enhancingthe Efficiency of Primary Sedimentation in Wastewater Treatment Plants with the Application of MoringaOliefera Seeds and Quicklime

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Abstract: This research investigates the enhancement of wastewater primary sedimentation using Quicklime and Moringaoliefera seeds as primary coagulants. Samples of municipal wastewater from Abu-Rawash wastewater treatment plant, Egypt were treated by coagulation-flocculation and sedimentation. The quality of the treated wastewater samples was analyzed. Experiments were conducted at various doses of the coagulants using jar-test equipment. Parameters of wastewater quality were measured before and after treatment to evaluate the removal efficiencies of suspended solids (TSS), Biochemical oxygen demand (BOD), chemical oxygen demand (COD) and microorganisms. Results showed that, application of Quicklime and Moringaoliefera seeds improved the primary effluent quality. Application of 500 mg/l of Quicklime caused increase in the removal efficiency of TSS to reach 97.8%, both total and fecal coli forms to 99.9%, while BOD and COD removal efficiencies reached up to 78.9% and 78.2% respectively. Application of 10ml/l of water extract of dry Moringaoleifera seeds 5% (wt/v) caused increase in the removal efficiency of TSS to reach 92%, Total and fecal coli forms to reach 89.6% and 89.1% respectively, while BOD and COD removal efficiencies were limited to 32% and 48% respectively.
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1. Introduction

Sewage treatment played a major challenge for civilizations during the last decades. Recently it has been at the forefront of major concerns in most new and existing communities. The increase in population, rise in cost of treatment and tough regulatory standards have made it necessary to analyze how we deal with our waste. Across the country, scientists working with communities are attempting to find alternative solutions to upgrade wastewater treatment processes focusing on increasing the removal efficiency of pollutant loads from municipal and industrial wastes [1].

Wastewater contains a great variety of contaminants such as solids, organic and inorganic compounds present either in dissolved or undissolved forms, heavy metals, adsorptive organic halogen compounds. These wastewater contaminants may be toxic or mutagenic. They may be biodegradable, difficult to biodegrade or non-biodegradable. Wastewater treatment processes varies from mechanical, chemical, physical and biological process. Conventional biological treatment is employed to treat wastewater to meet the regulations requirements however, treatment technologies are usually too expensive, therefore more attention should be given for innovative and alternative solutions [2].

Egypt is facing a great challenge dealing with wastewater problems due to the rapid growth of population and consequently the increase of wastewater production. Technological progress allowed the realization of advanced wastewater treatment systems, but the cost of these advanced and specialized systems can not be afforded.

Abu Rawash wastewater treatment plant (ARTP), located at the western outskirts of Greater Cairo, and provides primary treatment for industrial and domestic wastewater, It was designed to treat an average flow of 400,000 m^3/day and a peak flow of 600,000 m^3/day [1]. Inlet wastewater loads indicated that ARTP requires a larger capacity as it actually receives an average flow of 950,000 m^3/day where only 400,000 m^3/day is being treated and the excess flow is by passed directly without any treatment to the nearby Alrahawy drain which makes enhancement of the existing primary treatment highly recommended to increase the removal efficiency of pollutant loads in addition to increase plant capacity.

Enhancement of primary treatment through coagulant addition to primary sedimentation tanks is considered as innovative physico-chemical technology. Chemicals are used for pH adjustment, neutralization, a nutrient source for biological systems, phosphorous and nitrogen removal, aids to sedimentation and precipitation, disinfection, adsorption of dissolved refractory organics and as conditioning and stabilizing agents in sludge digestion and dewatering [2].

This research investigates the application of Quicklime and Moringaoliefera seeds as primary coagulants. Samples of municipal wastewater were treated by coagulation-flocculation and sedimentation using jar-test equipment to evaluate the removal efficiency of total suspended solids TSS, Biochemical oxygen demand (BOD), chemical oxygen demand (COD) and microorganisms. Production of Calcium Hydroxide is expected after adding Quicklime (Calcium Oxide) to water, and then Calcium Hydroxide reacts with both Carbonic acid and Calcium bicarbonate to produce Calcium Carbonate which is the coagulant formed [3]. Large quantity of lime is required before lime work as sweep coagulant. The addition of lime is strongly dependent on the pH and alkalinity of the wastewater [4].

Moringaoleifera is a fast growing, aesthetically pleasing small tree adapted to arid, sandy conditions. The species is characterized by its long, drumstick shaped pods that contain its seeds. Virtually every part of the tree is beneficial in some way; within the pods are possibly the best parts of the tree is the seeds. Not only can they be pressed for high grade oil, comparable to olive oil, moreover the press cake remaining after oil extraction has been shown to retain the active ingredients for coagulation, making it a marketable commodity. Moringaoleifera has been compared to alum in its effectiveness at removing suspended solids from turbid water, but with a major advantage. Because it can be produced locally, the potential for Moringa to create a new market for a community is there, and studies and projects are taking place examining this potential [5].

In 1997, Chemically Assisted Primary Treatment for wastewater was investigated at Abu Rawash wastewater treatment plant with jar test using Ferric chloride and Alum [6]. The results of that research will be compared to the results obtained within this research for the application of Moringa and quicklime results.

2. Materials and Method

In order to study the effectiveness of Quicklime and Moringaoliefera seeds, jar test was used to find the optimum conditions for best performance andto evaluate the parameters controlling the process. Parameters considered in this research were the coagulant type, concentration of dose, time of slow mixing and settling time. Samples for jar test were taken from the effluent of the grit removal chamber.

The selected samples were tested at Abo Rawash wastewater treatment plant laboratory and the composition of the raw municipal wastewater is summarized in table (1).

Table (1): Composition of the raw municipal wastewater during trials

Parameter	Result analysis		
	Maximum	Minimum	Average
pH	7.3	6.9	7.1
Turbidity (NTU)	96.8	31.6	64.2
TSS (mg/l)	208	100	154
COD (mg/l)	292	224	258
BOD(mg/l)	252	96	174

Freshly collected sewage samples were distributed among the six jars. Quicklime doses were added in varying proportions (according to experimental plan) followed by the initiation of flash mixing, 150 rpm. After 1 minute, mixing speed was reduced for a certain time. Finally, a quiescent settling for different periods was allowed. At the end of the settling period, a sample of the supernatant was analyzed for the various parameters.

For the application of Moringaoliefera, the husk enveloping each seed was first removed manually, good quality seeds were then selected, and the kernel was ground to a fine powder using an ordinary electric kitchen blender. The active agents of coagulation were then extracted from the powder using tap water. A concentration of 5% (5gm of powder in 100ml tap water) was used throughout this study. The whole mixture was stirred for 10 minutes at room temperature using a stirrer [7]. The suspension was filtered through a 474 grade filter paper. The resultant filtrate solution was then used as coagulant. In order to prevent any aging effects, such as changing in pH, viscosity and coagulation activity due to microbial decomposition of organic compounds during storage, a fresh solution was prepared for each sequence of experiments [7]. The pH and COD parameters of this water extract of Moringaoleifera seeds were analyzed using standard methods. It should be noted that, the water extract from dry Moringaoleifera seeds had a pH value of 6.22 and the concentration of the COD was 13650 mg/l.

As for quicklime, 10 gm of its powder was added to one liter of water and stirred for five minutes then added directly into jars. Storage of liquid lime might cause calcification so fresh amounts were prepared just before the experiments. Table (2) shows the characteristics of quicklime used.

Table (2): Characteristics of quicklime (calcium oxide)

CaO	Percentage
Minimum assay (acidimetric)	90%
Carbonate (as $CaCO_3$)	1%
Substances insoluble in HCl	0.10%
Chloride (Cl)	0.05%
Sulfate (SO_4)	0.50%
Iron (Fe)	0.03%
Substances not precipitated by ammonium oxalate (as sulfate)	3%
Loss in ignition (800 c)	Max. 10%

3. Results and Discussion

A- Quicklime application

Quicklime (CaO) was applied as coagulant to primary sewage; different doses were added into jars 100, 200, 300, 400, 500, 600 mg/l in addition to a blank jar with no coagulant.

Flash mix was set to 150 rpm/1min, slow mix and settling time were 60 rpm/15 min & 15min, respectively as shown in figure (1). The optimum quicklime dose was found to be 500mg/l. Initial turbidity was 84.9 NTU. Adding 500 mg/l of quicklime caused reduction in turbidity to a minimum level of 3.8 NTU at the optimum conditions. Removal efficiency of turbidity was recorded to be 95.52%, while it was limited to 55.83% for the blank sample (figure, 1). On the other hand, TSS reduced from 184 mg/l to a minimum level of 4 mg/l with 97.83% removal efficiency, while for the blank sample it was limited to 66.3%.

The volatile suspended solids removal efficiency was recorded to be 98.65 % while, it didn't exceed 64.86% for the blank sample.

For the same dose of quicklime the BOD removal efficiency reached up to 78.89% in comparison to 40% for the blank sample while COD removal efficiency 78.2% in comparison to 46.3% for the blank sample. Figure (2) shows, the increase of the pH value up to 10.65, while the settable matter reached 22ml/l.

On the other hand, coli form was reduced from about $53*10^6$ colonies/100ml.to6000 colonies/100ml with 99.99% removal efficiency, while it was reduced in blank sample to $19*10^6$ colonies/100ml with limited removal efficiency of 64.15%. Same pattern of results were recorded for the removal of feacal coli form from about $36*10^6$ colonies/100ml to 3000 colonies/100ml with 99.99% removal efficiency, while it was limited to 30.55% removal efficiency for the blank sample. Results for total and fecal coli form removal are shown in figure (3).

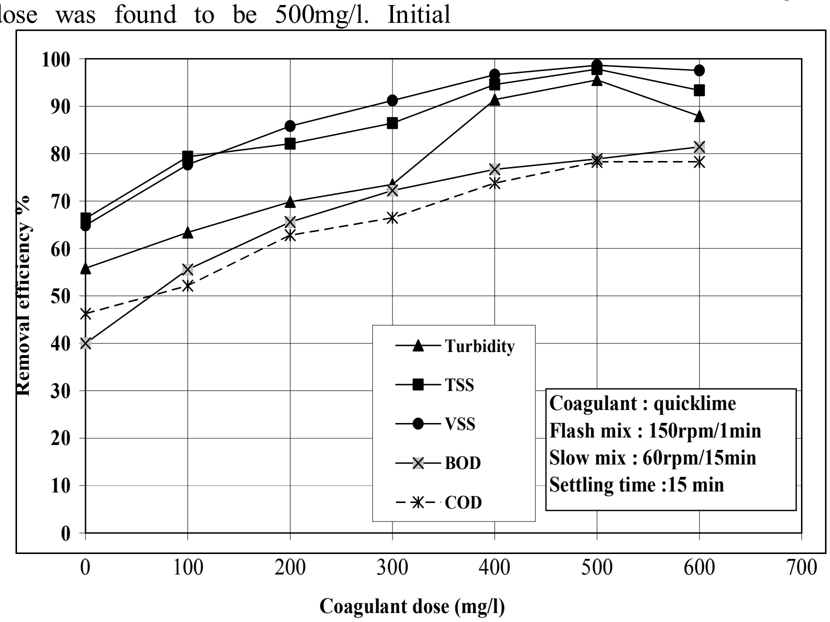

Figure (1): Effect of quicklime doses on Turbidity, TSS, VSS, BOD and COD removal efficiencies

Results showed that, application of quicklime increased removal efficiencies for all parameters specially fecal coli forms, which reached 99,99 % due to the excessive increase in pH value that eliminates those microorganisms. However, the increase in pH value to high levels means that further chemical addition is needed to correct pH value.

On the other hand, the optimum coagulation time was found to be 15 min as Quicklime creates flocs rapidly, the flocs were large and can be seen by the naked eye. Further time is not necessary, as the removal efficiencies had no noticeable effect. The optimum velocity was set to be 60 rpm. It was found that increasing agitating mixing velocity enhances the flocs formation and obvious improvement in settlement properties can be easily seen within 5 to 15 minutes.

Due to the rapid settlement of the sludge with the application of quick lime, optimization of existing primary sedimentation tanks should take place in such a case where additional loads can be easly handeld. Figure (4) shows a brief of quicklime results at the optimum conditions.

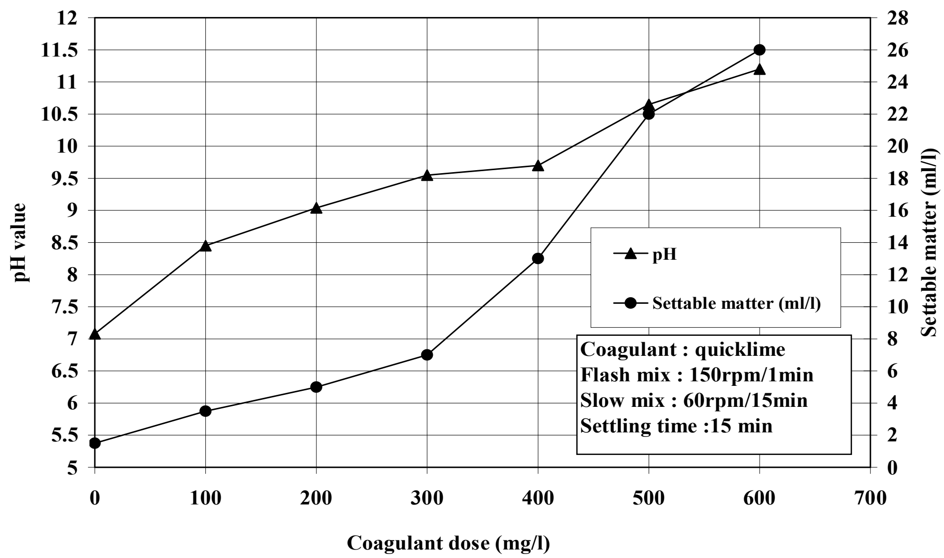

Figure (2):Effect of quicklime doses on pH and settable matter

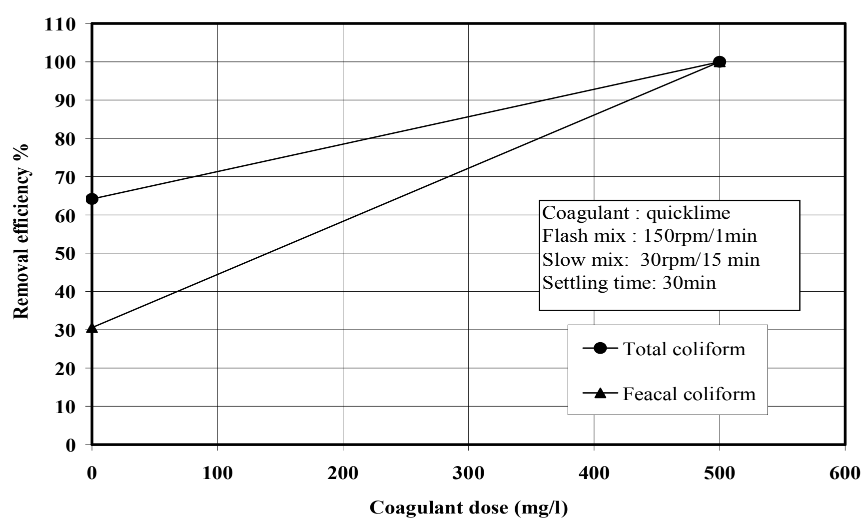

Figure (3): Effect of quicklime doses on total and fecal coliform

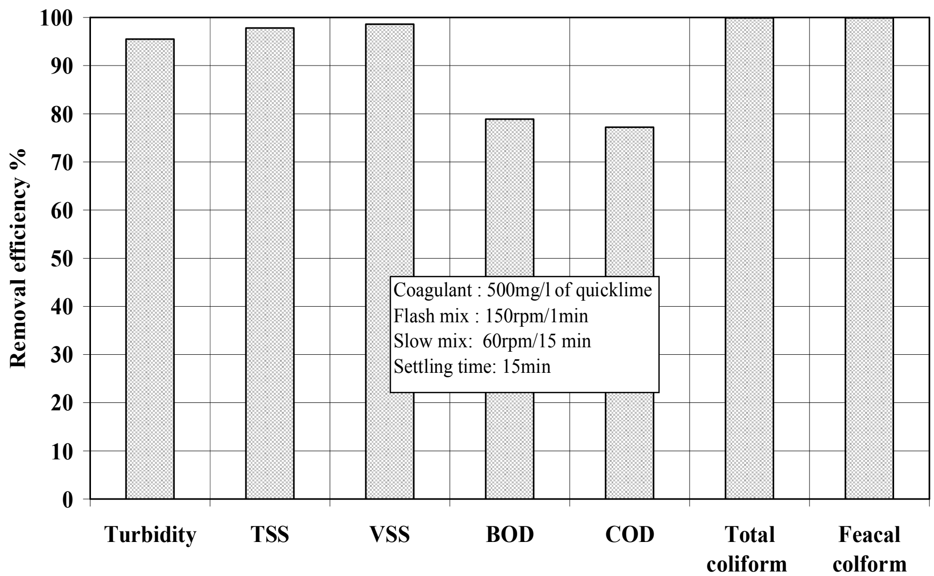

Figure (4): The removal efficiencies of turbidity, TSS, VSS, BOD, COD, total and fecal coliform using 500 mg/l of quicklime

B- Moringaoleifera application

Crude 5% (wt/v) water extract of dry seeds of Moringaoleifera was applied as coagulant to primary sewage, In order to find the optimum dose; different doses were added into jars with different concentrations and different mixing velocities, where the optimum Moringa dose was found to be 10 ml/l.

Turbidity was reduced from average of 44 NTU to a minimum level of 5.2 NTU. Removal efficiencies ranged from 78.43 % to 90.88%. While it ranged from 44.3 % to 50.7% for the blank samples. The turbidity removal efficiencies were shown in figure (5).

On the other hand, the removal efficiencies of TSS ranged from 83.33 % to 91.43 %, while it ranged from 60.78 to 66.67 %, for the blank samples as shown in figure (6)

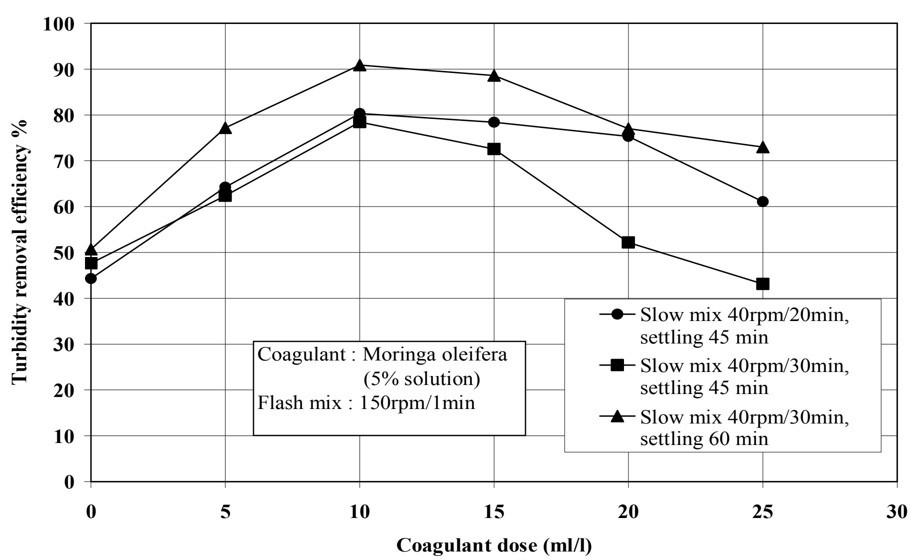

Figure (5): Effect of Moringadose on turbidity removal efficiency

With the application of 10ml/l of Moringaoleifera the BOD removal efficiencies ranged from 24.56% to 28.43%, while it ranged from 9.33% to 12.28% for the blank sample as shown in figure (7). On the other hand, COD removal efficiency was not improved as it was limited to 39.29 % compared to 45.54%. For the blank sample (figure, 8) this could be referred to the high concentration of organic matter in Moringa seeds water (13650 mg/l), therefore, purified proteins are recommended [8].

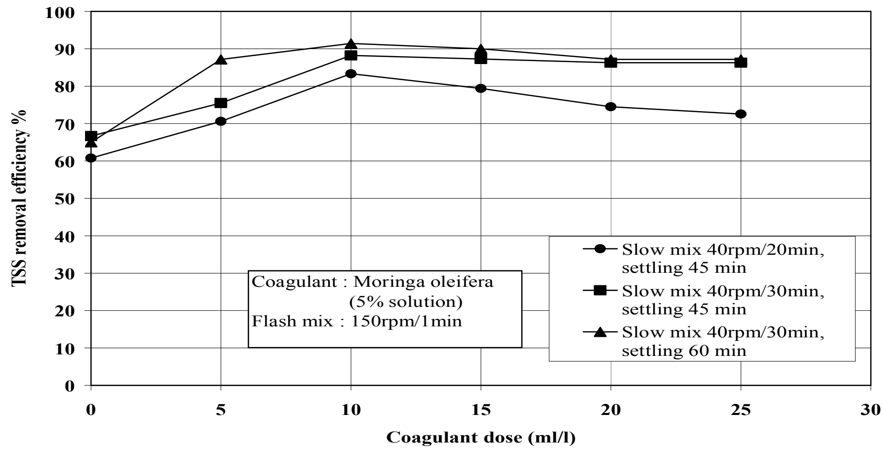

Figure (6)Effect of Moringadose on TSS removal efficiency

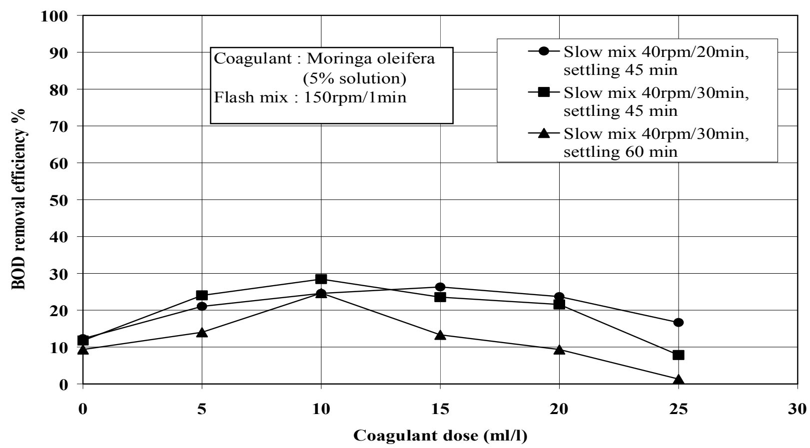

Figure (7): Effect of Moringadose on BOD removal efficiency

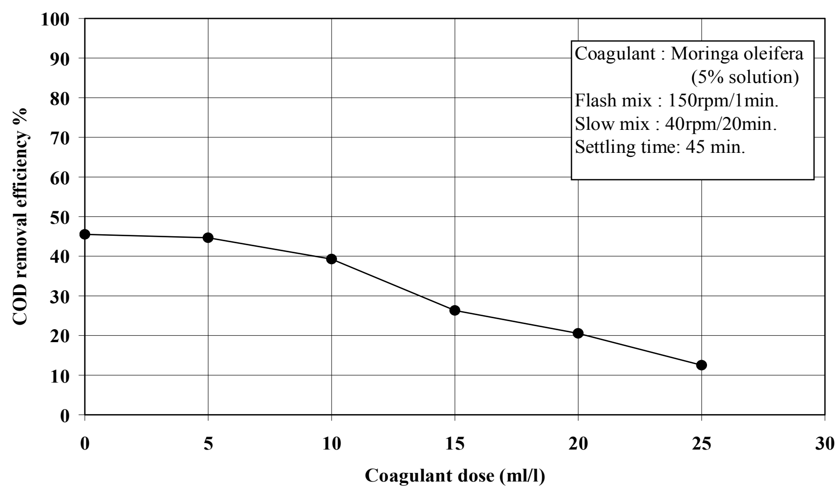

Figure (8): Effect of Moringadose on COD removal efficiency

Application of different doses of Moringa seeds did not affect the pH values, further more a reduction in the production of sludge as settable matter was recorded. Total coli form was reduced from $120*10^6$ colonies/100 mL.to $125*10^5$ colonis/100 ml with 89.6% removal efficiency, while the blank total coli form was reduced to $80*10^6$ with 33.3% removal efficiency.

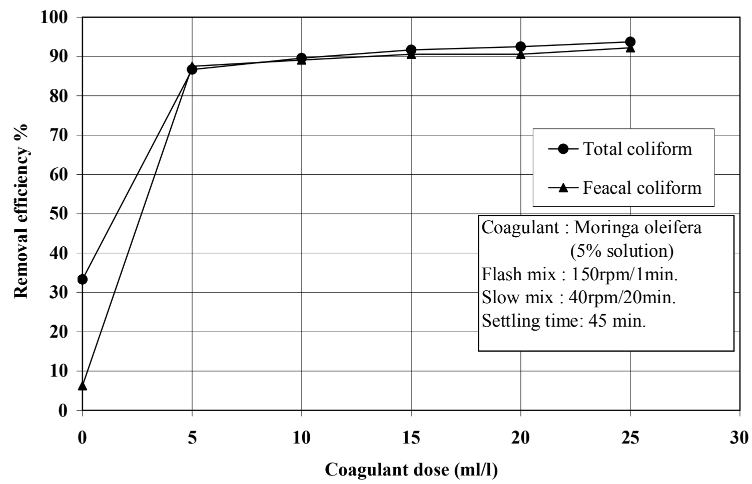

Figure (9): Effect of Moringa dose on total and fecal coliform removal efficiencies

On the other hand, Fecal coli form was reduce from $32*10^6$ colonies /100 ml to $35*10^5$ colonies /100 ml with 89.1% removal efficiency in comparison 6.25% removal efficiency for the blank sample. (figure, 9).

Moringaoleifera required at least 30 min as coagulation time to create flocs, longer period had no significant effect on flocs formation and consequently on the removal efficiencies. Agitating velocity of 40 rpm achieved the highest efficiencies, while slow mixing velocity did not achieve the same removal efficiencies which can be reefed to incomplete flocs formation. On the other hand, rapid mixing velocity (60 rpm) produced weak flocs leading to less removal efficiencies A settling time of 45 min were enough to achieve good results for TSS, VSS and BOD removal which was not significantly affected by increasing settling time than 45 min.

Applying the optimum conditions, Moringa seeds water is a very good coagulant for improving turbidity removal efficiency up to 85%, TSS to 92% and VSS to 94% due to active proteins contained in the kernel. BOD and COD removal efficiencies were 32% and 48 % respectively. Good removal efficiency for total and feacal coli forms that attached to the settled flocs is obtained as shown in figure (10).

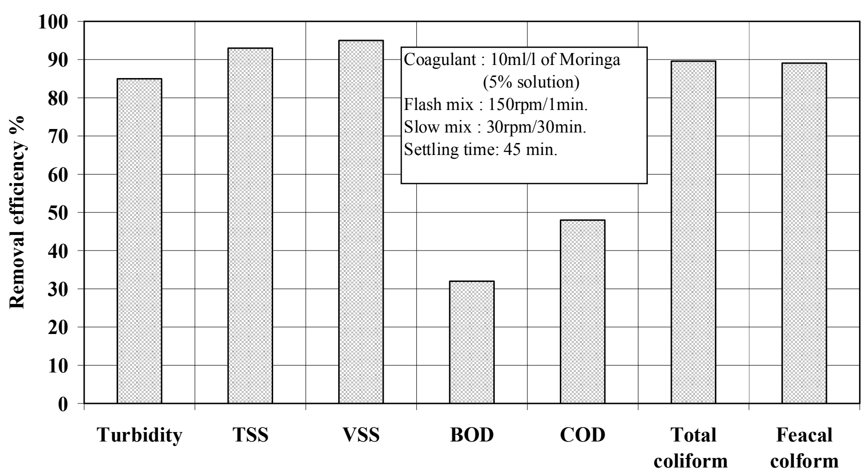

Figure (10): The removal efficiencies of turbidity, TSS, VSS, BOD. COD, total and feacal coliform using 10ml/l of Moringa

Comparison between quicklime, Moringa seeds and pervious research applying ferric chloride and Alum for the same WWTP [6] is shown in figure (11) and table (3).

Table (3): Removal efficiencies using quicklime and Moringa seeds in comparison with ferric chloride and Alum

Coagulant	Dose	Turbidityremoval %	TSSremoval %	CODremoval %
Moringa seeds	10 ml/l	85	93	48
Quicklime	500 mg/l	95.5	97.8	77.2
Ferric chloride (6)	40 mg/l	79	91	74
Alum (6)	80 mg/l	85	90	74

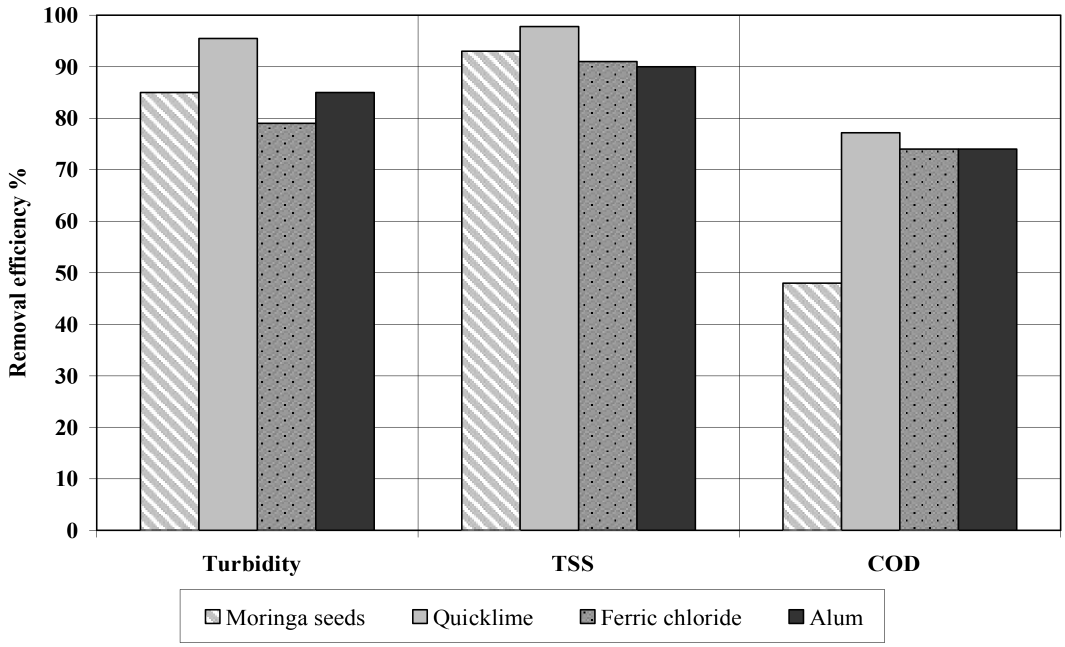

Figure (11) Removal efficiencies when applying quicklime and Moringa in Comparison with ferric chloride and Alum

Economic Assessment

Assuming the effective doses are 40 mg/l for ferric chloride, 80 mg/l for alum and 500mg/l for quicklime, cost estimation would be as follows in table (4).

Table (4): Alum, ferric chloride and quicklime cost estimation

	Alum	Ferric chloride	Quicklime	Recycled Quicklime
dose	80 mg/l	40 mg/l	500 mg/l	500 mg/3l
dose/ m3	0.00008 ton/m3	0.00004 ton/m3	0.0005 ton/m3	0.00016 ton/m3
cost/ton	1250 L.E/ton	1000 L.E/ton	150 L.E/ton	150 L.E/ton
cost/m3	0.1 L.E/m3	0.04 L.E/m3	0.075 L.E/m3	0.024 L.E/m3

Moringaoleifera is a natural seed which in a favorable environment an individual tree can yield 50 to 70 kg of pods in one year [9] and it is strongly recommends cultivating of this tree in Egypt.

Conclusions

- Application of quicklime and Moringa seeds improved wastewater primary effluent quality
- Application of quicklime caused reduction in turbidity reached up to 95.5 % whileTSS and VSS removal efficiencies reached up to 97.8% and 98.6%, respectively.
- The removal efficiencies of BOD and COD reached up to 78.9% and 78.2% respectively with the application of qiucklime while Total

and fecal coliforms removal efficiencies reached up to 99.99%.

- Application of Moringa caused reduction in turbidity to 85 %. while TSS and VSS removal efficiencies reached up to 92 % and 94% respectively.
- The removal efficiencies of BOD and COD reached up to 32 % and 48 % respectively with the application of Moringa while Total and feacal coliforms removal efficiencies reached up to 89.6% and 89.1% respectively.
- Quicklime produces large quantities of sludge and increases pH value. While no major effect on pH value was recorded for Moringa seeds.
- Although there are minor draw back in each application which can be easily overcome but the excellent improvement in the primary treatment efficiency opens a great number of alternatives for developing countries like Egypt specially on the strategic planning for a country that suffers from lake of wastewater treatment and faces the fact that the required investments on the short term as well as the long term is fairly huge.
- One great advantage of the results that the improvement of the existing effluent quality of the primary treatment at Abo Rawash Waste Water Treatment Plant and similar once can be achieved and extensions for the existing wastewater treatment plants without additional units can be also recognized.

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