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Natural Polyelectrolyte in Waste Sludge Treatment

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ABSTRACT

The study involved laboratory based investigations to determine the efficacy of a Natural Polyelectrolyte, *Moringa oleifera* seeds as a waste sludge conditioner. Waste sludge samples are activated sludge from Taman Tun Dr. Ismail Wastewater Treatment Plant, Kuala Lumpur, Malaysia. *Moringa oleifera* seed was applied as dry powder(shelled blended), solution(shelled blended) and solution(shelled blended oil extracted) . Results of the studies showed that *Moringa oleifera* improved the filterability of waste sludge up to 62 % in the optimum dosage range of 3000 to 6000mg/l. Sludge volume reduction of up to 65% was also achievable using gravity filtration compared to the control (no *Moringa oleifera* added). The specific cake resistance of sludge conditioned with *Moringa oleifera* averaged 2.5 x 10 12 m/kg at the optimum dosage of 4000mg/l. The shelled blended category applied in dry powder form performed the same as the solution of shelled blended but better than shelled blended oil extracted categories of *Moringa oleifera*. Vegetable oil from the shelled *Moringa oleifera* seed of up to 30% was obtained as a by product.

Keywords: *Moringa oleifera*, natural polyelectrolyte, sludge conditioner, gravity settling, vacuum filtration, specific cake resistance

INTRODUCTION

With increasing population especially in urban areas, Malaysia like other emerging industrialised economies is faced with the problem of increasing waste sludge generation from its wastewater treatment plants. In 1994, for example, the total waste sludge collected from septic tanks and connected services amounted to 3.02 Mm^3 made up of 1.13 Mm^3 (37%) from septic tanks and 1.89Mm^3 (63%) from connected services, increasing to 3.4 Mm^3 in 1998. There is, however, a reduction in sludge production of 32 % from septic tanks, with increase in those from connected services to 68 % during the four-year period. The overall increase in sludge production is about 15% in four years (Indah Water 1997). In 20 years, the projected increase in sludge production will be about 75 % using 1998 as base year. The current method of sludge disposal is made up of oxidation pond/aerated lagoons (50 %), drying beds (30 %), others (oxidation ditch, bio-filter, SBR etc. 20%. All these technologies especially oxidation ponds, and drying beds require the use of large areas of land which is a dwindling resource with increasing industrialisation and urbanisation.

The conditioning of waste sludge involves pre-treatment in order to facilitate water removal during subsequent hickening and or dewatering operations. During conditioning, small and amorphous particles are transformed into larger and stronger aggregates. This process increases the rate of water drainage and solid separation. In most dewatering operations, the ability of sludge to form and maintain a porous structure that enhances its compressibility is the desired goal (Clarke *et al.* 1997).

Sludge conditioners may be physical conditioners e.g. fly ash, diatomaceous earth etc or chemical conditioners viz. inorganic compounds (ferric chloride, lime etc) and synthetic polymers. Synthetic polymers that can be used to alleviate this problem are expensive and have to be imported with scarce foreign currency. A natural polymer that is affordable and environmentally friendly (highly biodegradable), *Moringa oleifera* seed has a potential to be used as a sludge conditioner for thickening and dewatering.

Moringa oleifera belongs to the family *Moringaceae* and is cultivated for a variety of purposes across the whole tropical belt (Jahn 1989). Many researchers have reported on its various uses as coagulant, Muyibi & Okuofu (1995), Ndabigengesere *et al.* (1995) and Muyibi (1998). The purpose of the present study, the first of its kind, was to evaluate the potential of *Moringa oleifera* seed as a natural polymer for use as sludge conditioner prior to dewatering and/ or thickening.

The study that is laboratory based involved using two methods of preparation of *Moringa oleifera* used in the investigation. The forms of *Moringa oleifera* used are, shelled blended, shelled dry powder, and shelled oil extracted. Waste sludge samples used for the studies were obtained from Taman Tun Dr. Ismail Wastewater Activated Sludge Treatment Plant, Kuala Lumpur, Malaysia.

METHODOLOGY

Equipment

A six place jar test apparatus, Jar-Tester CZ150 was used for mixing the *Moringa oleifera* seed with the waste sludge to enhance uniform and thorough distribution/mixing. National model MJ-C85N Juicer-blender with dry mill was used for the preparation of *Moringa oleifera* into powder and solution for use. Sohxlet apparatus was used to extract oil from *Moringa oleifera* seeds. Vacuum pump connected to a Buchner funnel attached to graduated thick walled flask was used for the determination of specific cake resistance. For gravity settling studies, 250ml graduated measuring cylinders were used.

Materials

Waste sludge samples used for the studies were collected from Taman Tun Dr. Ismail Wastewater Treatment Plant, Kuala Lumpur. The dry *Moringa oleifera* seeds used for the studies were obtained from Kano, Nigeria.

Procedure for Preparation of Moringa oleifera Seeds

The seed wings and coat were removed from selected dry good quality *Moringa oleifera* seeds and the nuts ground to a fine powder using the National MJ-85CN. The ground powder was divided into three portions. One portion had the oil extracted using the Sohxlet apparatus.

Stock solution of the seed powder with and without oil extracted were prepared by dissolving 5 grams of each type in 500 ml tap water and mixing it thoroughly at high speed in the National blender to extract the active ingredients. Any insoluble powder was filtered out using a muslin cloth and the concentrated stock solution of 10,000 mg/ l prepared. The third portion, the dry powder, was also set aside for use.

EXPERIMENTAL PROCEDURE

Determination of Sludge Volume Reduction with Increasing Moringa oleifera Dosage

200 ml of sludge samples were put into six, 500ml beakers and placed in the Jar Tester. The six paddles were inserted in the beakers and the speed set at 100 rpm. From the previously prepared stock solution of *Moringa oleifera* (shelled blended and shelled oil

extracted dosages with varying concentration of 1000 mg/1 to 6750 mg/1 were added simultaneously to all six beakers and mixed thoroughly for 1 minute. The six samples were immediately transferred into 250 ml measuring cylinders and the initial sludge heights recorded. A control sludge sample with no *Moringa oleifera* applied was also put in a measuring cylinder and the initial sludge height recorded. The sludge height after 30 minutes settling was recorded. The experiment was also carried out using varying doses of the dry *Moringa oleifera* (shelled) seed powder in the range of 500 mg (2500 mg/l) to 1400 mg(7000 mg/l). The results of the trial test gave the effective dosage in the range 3750 to 5000 mg/l.

Determination of Specific Cake Resistance

The specific cake resistance is used to evaluate the effect of different dosages of chemical conditioners and combination of sludge and conditioning agents on the specific resistance and quality of the cake. A plot of specific resistance versus dose can be used to determine the optimal operating condition.

Theory

Flow through the sludge cake and filter medium may be considered as flow through porous media. Darcy's law may be used to model the process.

$$Q = \frac{dV}{dt} = \frac{kA\Delta h}{\Delta L} \tag{1}$$

where Q = flow rate of filtrate
V = Volume of water
A = Area of flow
k = conductivity
h = head
L = distance
t = time

The resistance parameter depends on Reynolds number, porosity of the media, distribution of grains, and other characteristics of the media. Using the Hagen-Poiseuille law for pipe flow,

$$K = \frac{kg}{v} \tag{2}$$

where K = intrinsic permeability
v = kinematic viscosity
g = gravity

$$\frac{dV}{dt} = \frac{KA\Delta P}{\mu\Delta L} \tag{3}$$

where ΔP = positive pressure differential
ΔL = depth of the medium
μ = dynamic viscosity of the filtrate

The intrinsic resistance, r, may be defined as r = 1/k. The cake resistance Rc is given by

$$R_c = r_c \Delta L \qquad (4)$$

where r_c = intrinsic resistance of cake.

The cake resistance and filter medium resistance are independent, so the total resistance, R of cake and filter may be added together to get,

$$R = R_c + R_f \qquad (5)$$

where R_f = resistance of the filter medium

The volume of cake formed, V_c is

$$V_c = A\Delta L \qquad (6)$$

Let the specific deposit, be the volume of cake formed per unit volume of filtrate, then

$$\sigma V = A\Delta L \qquad (7)$$

Equation (3) becomes;

$$\frac{dV}{dt} = \frac{\Delta\Delta PA^2}{\mu(r_c\sigma V + R_f A)} \qquad (8)$$

Expressing the intrinsic resistance, r_c, in terms of mass of dry cake solids formed per unit volume of filtrate,w,the specific resistance, r_{wc} is related to r_c by;

$$R_{wc} w = r_c \sigma \qquad (9)$$

Substituting in equation(8) we have

$$\frac{dV}{dt} = \frac{\Delta\Delta PA^2}{\mu(r_{wc} wV + R_f A)} \qquad (10)$$

$$\int_0^t dt = \mu \int_0^V \left(\frac{wr_{rc} V}{\Delta PA^2} + \frac{R_f}{\Delta PA} \right) dV \qquad (11)$$

At constant pressure, on integration over time,

$$t = \frac{\mu wr_{wc} V^2}{2\Delta PA^2} + \frac{\mu R_f V}{\Delta PA} \qquad (12)$$

$$\frac{t}{V}=\frac{\mu w r_{wc} V}{2\Delta P A^{2}}+\frac{\mu R_{f}}{\Delta P A} \qquad (13)$$

The specific resistance r_{wc} is calculated from the slope m of the line

$$r_{wc}=\frac{2\Delta P A^{2}}{\mu w} m \qquad (14)$$

Procedure for the Determination of Specific Cake Resistance

200 ml of the sludge sample was placed in 500 ml beakers and varying dosages(1000 to 6000mg/l) of *Moringa oleifera* powder was added. The beakers were placed in the jar test apparatus. The paddles were inserted and thoroughly mixed at 100 rpm for 1 minute. The speed was reduced to 40 rpm and continuously stirred to prevent sludge settling. 50 ml of each of the prepared samples was added to the Buchner funnel containing a filter pad and connected to the vacuum pump. Vacuum pressure of 69000 N/m^2 was applied at 15 seconds intervals and the volume of the filtrate measured. Observations were made until the vacuum broke or the filtrate volume remained constant.

RESULTS AND DISCUSSION

Gravity Settling Studies

Table 1 shows the summary of the results of gravity settling of waste activated sludge for varying dosages of *Moringa oleifera*, shelled blended and shelled blended oil extracted from 3750 to 5000 mg/l. It was observed that increasing dosage of *Moringa oleifera* resulted in increasing reduction in sludge volume compared to the control. For the shelled blended category, from a control with sludge reduction of 4.6%, increasing dosage of *Moringa oleifera* resulted in increase in sludge volume reduction reaching a peak at 12% at 4750 mg/l dosage and reducing to 10 % at 5000 mg/l dosage. For the shelled blended oil extracted category, increasing dosage of *Moringa oleifera* also resulted in increased reduction in sludge volume from the control of 4% reduction to 6.7% at 3750 mg/l, to 8.7% at a dosage of 4250 mg/l and decreasing to a minimum of 7.3 % at 5000 mg/l dosage. Similarly, in Table 2 for the dry powder(shelled blended) application, it was observed that sludge volume reduction increased with increasing dosage of Moringa powder from 5 % at control to 13 % at 1200 mg (6000 mg/l). After which continued dosage gave constant sludge volume reduction.

When the results are compared to the control, it was observed that the shelled blended category was able to achieve a maximum of 2.6 times reduction in sludge volume compared to the control at a dosage of 4750 mg/l. The shelled blended oil extracted category was able to achieve a maximum of 1.9 times sludge volume reduction at dosage of 4250 mg/l . Application of the dry powder(shelled blended) was also able to achieve a maximum of 2.6 times sludge volume reduction compared to the control.

In general, application of the dry seed powder (shelled blended) was found to be more effective than using the shelled blended oil extracted solution. Further studies need to be carried out in terms of cost and ease of application, as well as equipment and facilities which will be required for each application method so as to select the most efficient method application. The findings from this study the first of its kind, has a potential for its application to existing sludge holding tanks and drying beds as well as new sludge treatment plants. The capacity of new sludge holding tanks and drying beds can be reduced considerably whilst existing ones can be retrofitted with *Moringa oleifera* dosing system after pilot scale studies to enhance the filterability and settling characteristics of the sludge. It is pertinent to note that up to 30% vegetable oil was extracted from the shelled *Moringa oleifera* seed. Further studies may be carried to explore possible commercial use of the oil.

TABLE 1

Summary of results of gravity settling studies of waste activated sludge on application of varying dosages of *Moringa oleifera* seed (shelled blended and shelled oil extracted)

Dosage (mg/l)	Sludge volume reduction (%) after gravity settling for 30 mins.		Ratio of sludge volume reduction after gravity settling to control	
	Shelled Blended	Shelled blended oil extracted	Shelled blended	Shelled blended oil extracted
Control	4.6	4.6	1	1
3750	7.3	6.7	1.6	1.5
4000	8	8	1.7	1.9
4250	9.3	8.7	2	1.7
4500	9.3	8	2	1.7
4750	12	8	2.6	1.7
5000	10	7.3	2.2	1.6

TABLE 2

Summary of results of gravity settling studies of waste activated sludge on application varying dosages of dry *Moringa oleifera* seed powder (shelled)

Dosage of shelled blended Dry *Moringa* powder (mg)	Sludge volume reduction(% after gravity settling for 30mins.	Ratio of sludge volume reduction after gravity settling to control
Control	5	1
500(2500 mg/l)	9	1.8
600(3000 mg/l)	10	2
700(3500 mg/l)	11	2.2
800(4000 mg/l)	11	2.2
900(4500 mg/l)	11.5	2.3
1000(5000 mg/l)	12	2.4
1100(5500 mg/l)	12.5	2.5
1200(6000 mg/l)	13	2.6
1300(6500 mg/l)	13	2.6
1400(7000 mg/l)	13	2.6

Determination of Specific Cake Resistance and Optimum Dosage

For each dosage of shelled blended *Moringa oleifera* applied, plot of t/V versus V was plotted which gave straight lines from which the specific resistances were calculated using equation 14. From Fig. 4, it is observed that the optimum dosage of *Moringa oleifera* was 4000 mg/l with specific resistance, rwc of 2.5 x 10 12 m/kg for vacuum filtration. This value compares well with that reported by Droste(1997) for synthetic polymers.

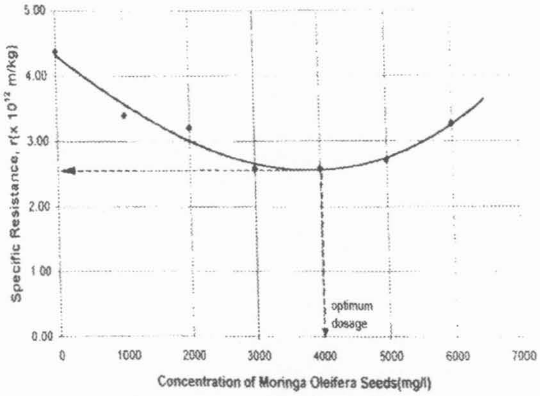

Fig. 1 Specific cake resistance variation with Moringa oleifera dosage

CONCLUSIONS

1. Within the economic dosage range of *Moringa oleifera* of 3750 to 5000 mg/l, sludge volume reduction increased with increasing dosage.
2. The shelled blended category applied in dry powder form performed better than the solution of shelled blended oil extracted categories of *Moringa oleifera*.
3. For vacuum filtration, the specific cake resistance was found to decrease with increasing dosage of *Moringa oleifera* to an optimum of 2.5 x 10^{12} m/kg at a dosage of 4000 mg/l.
4. Up to 30% vegetable oil was extracted from the *Moringa oleifera* seed using the Soxhlet method.

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