Desalination and Water Treatment
www.deswater.com

10 (2009) 87–94

Evaluation on different forms of *Moringa oleifera* seeds dosing on sewage sludge conditioning

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Received 30 September 2008; Accepted in revised form 20 July 2009

ABSTRACT

The effect of different form of dosing using *Moringa oleifera* seeds in sewage sludge conditioning was studied. Settled activated sludge after clarification process was obtained from sludge holding tank in Sewage Treatment Plant, Taman Tun Dr. Ismail, Kuala Lumpur, Malaysia. In this study, sludge conditioning with *Moringa oleifera* seeds in 3 different forms: dry powder, distilled water extracted and salt extracted (1 N NaCl) — were studied in comparison with chemical polymer, Zetag 7653. The study applied operator's specification, Indah Water Konsortium Sdn. Bhd., Malaysia (IWK) with preparation of *Moringa oleifera* in water and salt stock solution and Zetag 7653 stock solution were done at 650 rpm for 1 h. Sludge conditioning was then operated at 60 rpm for 45 min using jar test apparatus. Using specific resistance to filtration (SRF) as a parameter, *Moringa oleifera* in dry powder form at dosage of 2000 mg/L was comparable to 50 mg/L Zetag 7653 in reducing the value from 8.0×10^{10} to 3.3×10^{10} m/kg (2.5 times of magnitude). Therefore, *Moringa oleifera* in dry powder form was as effective as Zetag 7653. There was no significant change in CST between the three methods of extraction for *Moringa oleifera*. Without applying filtration using muslin cloth, sludge solid content when dosed with *Moringa oleifera* in distilled water extracted form showed the least increment at 17.08%.

Keywords: Sludge conditioning; *Moringa oleifera*; Natural polymer; SRF; Zetag 7653

1. Introduction

Sludge is a settled solid, unstable and containing pathogenic organisms that accumulate after wastewater treatment process. Generation of sludge is unavoidable and therefore should be subjected to treatment. Sludge production in Malaysia is very dependant on the population increase and urbanization. According to Bradley and Dhanagunan [1], about 9.74 million population equivalent (PE) or estimated to be 8 million people in Peninsular Malaysia were connected to a central sewage treatment system managed by Indah Water Konsortium Sdn. Bhd., Malaysia (IWK). When the population outside the IWK concession area is also taken into account, the total quantity of domestic sewage sludge produced in whole Malaysia is estimated to be 6 million m^3/y in the year 2000 (total resident population of 22.2 million in the year 2000).

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Presented at EuroMed 2008, Desalination for Clean Water and Energy Cooperation among Mediterranean Countries of Europe and the MENA Region, 9–13 November 2008, King Hussein Bin Talal Convention Center, Dead Sea, Jordan.

Of the quantity of sludge collected in the year 2000, 60% was transported to the existing sewage treatment facilities and discharged into the process units, 30% was disposed to drying beds and lagoons while only 10% was recycled through trenching for forestry and horticulture use. Ultimate disposal point for dried sludge from treatment facilities, drying bed and lagoons is sanitary landfill but it has become less attractive in the recent years as a result of scarcity of landfill capacity and the increasing cost [1].

Sludge management normally involves processes such as conditioning, dewatering, and disposal of sludge to the environment. In the total sludge treatment process from thickening to controlled dumping, sludge dewatering is one of the most important steps in reducing sludge volume and has a very big impact on total sludge treatment costs. As sludge consists primarily of water and only a small amount of organic matter, the sludge must be dewatered so that the resultant sludge cake can be dry enough for it to be handled easily and economically.

The main aim of sludge conditioning is to increase and improve the efficiency of dewatering. Sludge particles contain enormous amount of bound water. To release and facilitate the removal of this bound water and to allow agglomeration of solids, a preliminary conditioning stage is required before the dewatering processes. The two most commonly used methods involved the addition of chemical and heat treatment. In most of the case, synthetic polymers are also used as sludge conditioner. These polymers can be either utilized alone or with other chemicals such as alum, lime, or ferric chloride. Aluminium salts that are used in wastewater treatment process are less popular as coagulant. This method produced limited success because of disadvantages and problems [4].

The cost of production for these chemical polymers is often high due to non-availability of raw materials. Moreover, the cost of these chemicals has been increasing at an alarming rate in most developing countries. Addition of these chemicals may affect public health as most of the composition of the chemicals is not known. Disposal of alum sludge to recipients is also believed to cause damage to the environment [4]. A study conducted by Chang et al. [4] indicated that acrylamide-based polymers (polyacrylamide) were the predominant source of trimethylamine (TMA) in limed sludges during sludge degradation. However, another tested copolymer, a two cross-linked Epi/DMA polymer from the reaction of epichlorohydrin and dimethylamine did not generate TMA but its optimum dosage was found to be significantly higher than acrylamide polymers during sludge conditioning. These synthetic polymers used in sludge conditioning are non-biodegradable and are hazardous to the environment. It causes toxicity to the soil when handling of disposals is not carried out properly. Moreover, sludge produced is voluminous and non-biodegradable after treatment and therefore poses disposal problems leading to increase cost of treatment and the operating cost.

Due to all these disadvantages, a natural sludge conditioner which is more economical and safe, has to be found and research need to be conducted to replace the conventionally used sludge conditioner. It would be an advantage if local material can be used as a sludge conditioner to alleviate these problems.

It is known that *Moringa oleifera* contains a natural coagulant in the seeds and has a great potential to be the natural conditioner in water and wastewater treatment. *Moringa oleifera* seeds contain water-soluble, positively charged proteins that act as an effective and excellent coagulant for treating water and wastewater [5]. Moreover, use of *Moringa* seeds in sludge conditioning for wastewater treatment works may not pose any serious problem [2]. It can be used as biosolid for agricultural and land applications.

Moringa oleifera seeds extract has been studied by others for sewage sludge conditioning [2,6]. The study compared powdered *Moringa oleifera*, ferric chloride and aluminium sulphate and it was reported that powdered *Moringa oleifera* produced comparable results with respect to cake solids concentration [2]. Another study conducted by Muyibi et al. [6] showed that *Moringa oleifera* seed powder performance was the same as *Moringa oleifera* in water solution form but both forms performed better than oil extracted *Moringa oleifera* in gravity settling for waste activated sludge. The optimum dosages ranged from 4750 to 6000 mg/L. It was noted that optimum dosage of 4000 mg/L *Moringa oleifera* produced specific cake resistance of 2.5×10^{12} m/kg from the initial of around 4.5×10^{12} m/kg.

The main objective of the present study is to evaluate the influence of extraction methods of *Moringa oleifera* on its conditioning performance. *Moringa oleifera,* which is harvested in batch will be processed into powder form, distilled water extracted form and 1N NaCl salt extracted form to act as natural sludge conditioner. Evaluation on the sludge dewaterability after conditioning with these three forms of extraction method is studied by measuring specific resistance to filtration (SRF) and capillary suction time (CST).

2. Materials and methods

The methodology used in the present study can be summarized by the flow chart shown in Fig. 1.

2.1. Collection of sludge samples

In the present study, sludge samples used was a settled activated sludge after clarification process collected from sludge holding tank in Sewerage Treatment Plant, Taman Tun Dr. Ismail, Kuala Lumpur, Malaysia. The temperature of the sludge samples on-site ranged

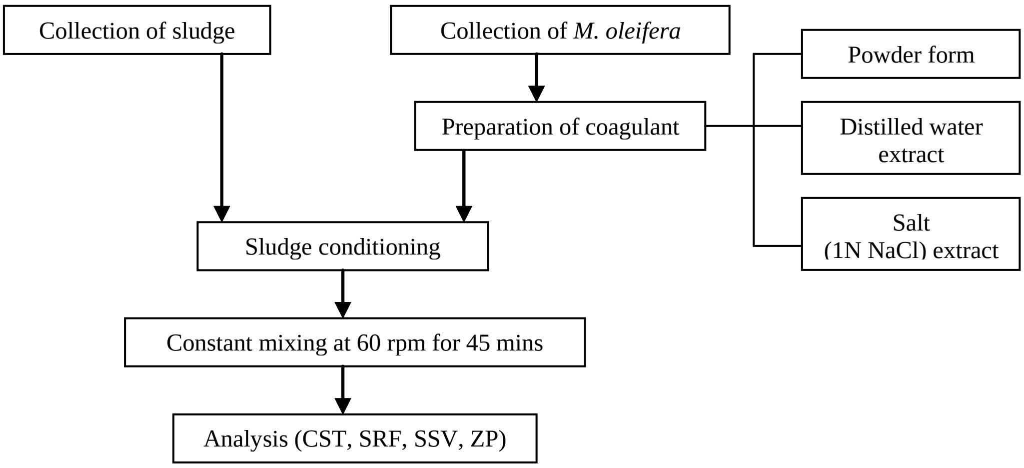

Fig. 1. Flow chart for the methodology of the present study.

from 29 to 31°C. The sludge samples were collected between 9 and 10 in the morning and stored in a 9-l plastic container. The sludge sample was then transported back to the laboratory within 1 h after sampling. The sludge samples used for the study were kept for not more than 24 h. This is to minimize changes of the sludge samples during storage at 4°C in the refrigerator. APHA standard methods of examination of water and wastewater were followed in the analysis of samples during the experimental study [7]. Characterization of sludge samples is presented in Table 1.

2.2. *Collection of* Moringa oleifera *seeds*

In this study, the dry *Moringa oleifera* seeds used as a natural coagulant were collected from Serdang area, Selangor, Malaysia. Good quality seeds were selected and the seeds coat and wings were then removed manually and dried in the oven (Model Memmert ULE 400, Germany) for 24–48 h at 45°C. After drying, the kernels were grounded for 1 min to a fine powder using household electric blender (Model National MJ-C85N). The fine powder was stored in different small glass containers with 10 g each. The containers were then capped and sealed before stored at 4°C for not more than 3 months.

Table 1
Typical characteristic of settled activated sludge

Parameters	Range	Mean value
pH	6.43–6.62	6.53
Temperature, °C	29.6–30.0	29.8
TSS, mg/L	7163–8427	7705
TDS, mg/L	67–177	129
SSV, ml/L	995–1000	997.5
SVI	118–139	130
Zeta Potential, mV	–7.93 to –9.54	–8.59
CST, s	5.7–6.6	6.2
SRF, m/kg	7.312×10^{10}–1.404×10^{11}	1.129×10^{11}
Moisture content, %	99.12–99.26	99.20

2.3. *Preparation of coagulant*

In this study, *Moringa oleifera* seeds in 3 different forms: dry powder, distilled water extracted and salt extracted (1 N NaCl) — were studied in comparison with chemical polymer, Zetag 7653. Stock solution of the distilled water extracted *Moringa oleifera* at 50,000 mg/L (5%) was prepared by dissolving 10 g of the dry powder *Moringa oleifera* in 200 ml distilled water. The mixture was then blended at 650 rpm for 1 h (as practised by IWK) with stirrer to extract active ingredients. The resulting suspension was treated as coagulant. Stock solution of salt extracted (1 N NaCl) *Moringa oleifera* was prepared similar to the preparation of distilled water extracted *Moringa oleifera* for the exception of the distilled water was replaced with salt solution. The chemical polymer, Zetag 7653 manufactured by Ciba was obtained from Quartz Chemical Sdn. Bhd., Petaling Jaya, Malaysia. Zetag 7653 is a white powder and water soluble polymer. It is an ultra-high molecular weight cationic polyacrylamide flocculant with medium to high degree of cationic charge [8]. Preparation of Zetag 7653 coagulant at 500 mg/L (0.05%) stock solution was done at 650 rpm for 1 h (as practised by IWK). The polymer emulsion was prepared fresh before each sludge conditioning was carried out.

2.4. *Sludge conditioning process*

Settled activated sludge with 300 ml volume was used for each conditioning test. The sludge was mixed well each time before pouring out from the container. The jar test apparatus (Model Stuart Scientific, Flocculator SW1) was used to enable the mixing of polymer with sludge samples. Mixing speed and duration of the conditioning process were set at 60 rpm and 45 min respectively (as practised by IWK). *Moringa oleifera* dosage was varied from 1000 to 8000 mg/L for the 3 different forms: dry powder, distilled water extracted and salt extracted (1 N NaCl), while Zetag 7653 dosage was set between 10 and 100 mg/L. After the conditioning process was terminated, the conditioned sludge was then tested for capillary suction time (CST), specific resistance to filtration (SRF), settled sludge volume (SSV) and zeta potential (ZP). The conditioning process was conducted at temperature between 28–30°C.

2.5. Analysis

The pH and temperature of the settled sludge sample was determined with the help of pH meter, model Cyberscan 500. The measurements were obtained at 1 cm below the sludge surface with mixing. Total suspended solids (TSS), total dissolved solids (TDS), SSV and sludge volume index (SVI) were determined according to APHA standard methods of examination of water and wastewater (1999). Drying of sludge for TSS and its filtrate after filtration for TDS was conducted in the oven (Memmert, Model ULE 400). To obtain zeta potential (ZP) value for the sludge, the conditioned sludge was centrifuged at a speed of 4000 rpm for 10 min. The resulted supernatant was then collected for zeta potential measurement.

The capillary suction time (CST) test determines rate of water released from sludge. It provides a quantitative measure, reported in seconds, of how readily sludge releases its water. In the present study, CST meter Model Triton Type 319 Multi-purpose CST was used. Well-mixed conditioned sludge with a volume of 6.4 ml was placed in a small cylinder on a sheet of chromatography paper. The paper extracts liquid from the sludge by capillary action. The time required for the liquid to travel a specified distance is recorded automatically by monitoring the conductivity change occurring at the two contact points appropriately spaced and in contact with the chromatography paper. The elapse time is indicative of the water drainage rate.

According to the APHA [7], SRF is performed using a standard Buchner funnel apparatus (90 mm diameter) with Whatman No.1 filter paper. In the present study, 60 mL of the conditioned sludge was sampled from beaker and subjected to an average pressure of 13 ± 1 cm Hg. The time required for the first 40 ml of the filtrate collected in a graduated measuring cylinder was recorded. The sludge cake formed on the filter was dried in the oven (Memmert, Model ULE 400) at 105°C for 24 h before weighed to find the amount of the dry sludge cake. Viscosity of the conditioned sludge was determined using viscometer, model Brookfield DV2+ at surrounding temperature of 28°C. The SRF for each conditioned sludge was determined by plotting the elapsed filtration time per corrected filtrate volume (t/V) vs. the corrected filtrate volume at designated vacuum pressure. The slope of the line is the constant b in which is used to calculate the specific resistance to filtration (SRF) value [9].

$$r = \frac{2PA^2b}{\mu W} \tag{1}$$

where b = slope of elapsed filtrate time vs. filtrate volume, s/m^6; P = filtration pressure, N/m^2; μ = viscosity, N.s/m^2; W = density of dry solids, kg/m^3; r = specific resistance to filtration, m/kg; A = area of the filter paper, m^2.

In the present study, the above Eq. (1) can be simplified to

$$r = \frac{2qb}{\mu W} \tag{2}$$

where q is equal to the product of P (filtration pressure) and A^2 (area of the filter paper) since these two parameters were found to be constant throughout the study.

3. Results and discussion

3.1. Variation of SRF with polymer dosage

Fig. 2 shows the variation of SRF with different dosages of *Moringa oleifera* in dry powder, distilled water extracted and salt (1N NaCl) extracted forms compared to chemical polymer, Zetag 7653. Generally, higher dosages of polymer led to lower SRF values. Steeper reduction in SRF was observed at earlier dosages for *Moringa oleifera* in all forms. Significant reduction in SRF with reduction of 1.8–2.3 times in magnitude was observed at 2000 mg/L of *Moringa oleifera* in dry powder and salt extracted forms. *Moringa oleifera* in distilled water extracted form also showed reduction of 2 times in magnitude in SRF but at 4000 mg/L. Meanwhile, Zetag 7653 managed to obtain reduction of 2.7 times in magnitude in SRF at 50 mg/L.

It was apparent that higher dosage of *Moringa oleifera* was needed to achieve a similar result compared to a low dosage of chemical polymer, Zetag 7653. Active agents in *Moringa* seeds are water soluble dimeric cationic proteins of 13 kDa with subunits (monomer) of about 6.5 kDa and with zeta potential of a 5% solution of non-shelled at +6 mV [11] are basically low charge density and molecular weight cationic polymer. Eriksson and Alm [12] mentioned in their study that low charge density cationic polymer flocculate with a bridging mechanism and give flocs with a flexible structure but less good filtration properties. Chemical polymer, Zetag 7653 used in the study is an ultra high molecular weight cationic polyacrylamide flocculant with medium to high degree of cationic charge [8]. Higher charge density cationic polymers interact strongly with negatively charged surfaces and will thus have flat adsorption conformation. Therefore, the flocculated particles come in close contact with each other

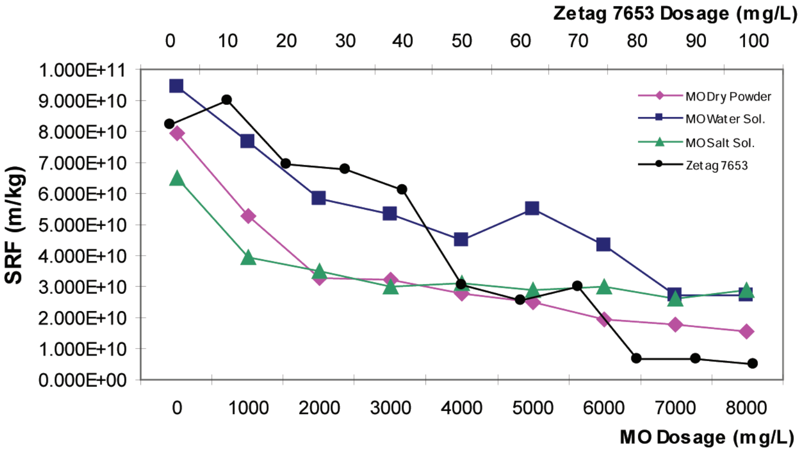

Fig. 2. Effect of *Moringa oleifera* and Zetag 7653 polymer dosage on SRF of the conditioned sludge.

and this give strong binding and reduce possibilities for movements of the particles relative to each other. This will lead to a more rigid structure which is favorable for filtration [12]. As a result, high dosage of *Moringa oleifera* was applied during the conditioning process to match the performance of Zetag 7653.

It was also found that *Moringa oleifera* in dry powder form at dosage of 2000 mg/L was comparable to 50 mg/L Zetag 7653 in reducing the value from 8.0×10^{10} to 3.3×10^{10} m/kg. It seems that during conditioning, active agents leached out from *Moringa* seeds powder and dissolved into the water part of the sludge thus involved in flocculation of sludge particles. The undissolved *Moringa* seeds powder then acted as a skeleton builder in binding with sludge particles and hence the particles readily released water, resulted in lower SRF value. Hou et al. [13] in their study also reported a reduction in both CST and SRF values in conditioned inorganic water sludge by adding fly ash. Fly ash plays a role as a skeleton builder for inorganic water sludge to form a more permeable and rigid lattice structure necessary for efficient dewatering. Therefore, *Moringa oleifera* in dry powder form was as effective as Zetag 7653.

3.2. Variation of CST with polymer dosage

Fig. 3 shows the variation of CST with different dosages of *Moringa oleifera* in dry powder, distilled water extracted and salt (1N NaCl) extracted forms compared to chemical polymer, Zetag 7653. Addition of *Moringa oleifera* during sludge conditioning generally reduced the initial CST of the sludge. The optimum dosage for *Moringa oleifera* in all forms was found to be in the range of 2000–4000 mg/L. The result obtained is in agreement with findings reported by Ademiluyi [2] and Muyibi et al [6]. The optimum dosage of 3000 mg/L *Moringa oleifera* in dry powder form reduced the initial CST from 6.8 to 5.6 s while 2000 mg/L of distilled water extracted form was slightly better in reducing the initial CST from 5.8 to 5.0 s. Reduction of CST from 5.8 to 4.7 s for 4000 mg/L of *Moringa oleifera* in salt (1N NaCl) extracted form was noted. However, there was no significant change in CST

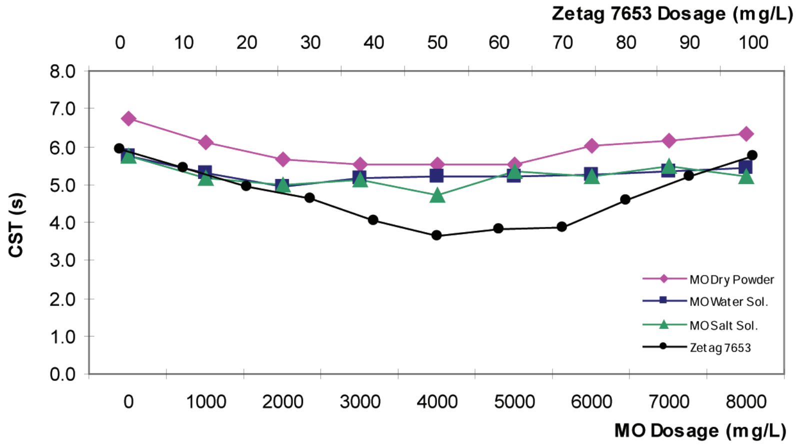

Fig. 3. Effect of *Moringa oleifera* and Zetag 7653 polymer dosage on CST of the conditioned sludge.

between the three methods of extraction. Sludge conditioning with Zetag 7653 gave the lowest CST at 3.6 s from the initial of 5.9 s at 50 mg/L dosage. Lower CST value can be justified by strong charge attraction and neutralization between chemical polymer and sludge particles followed by molecular bridge formation between suspended particles, thus squeezing out water molecules retained by the colloids [10]. The advantage of chemical polymer is the charge density and molecular weight can be manipulated to obtain higher efficiency of sludge conditioning.

3.3. Variation of SSV with polymer dosage

Fig. 4 shows the variation of SSV with different dosages of *Moringa oleifera* in dry powder, distilled water extracted and salt (1N NaCl) extracted forms compared to chemical polymer, Zetag 7653. Sludge conditioned with Zetag 7653 shows sharp improvement of settleability (980–615 ml/L) between 30 and 60 mg/L and remain unchanged after 60 mg/L. As mentioned earlier, Zetag 7653 used in the study is an ultra high molecular weight cationic polyacrylamide flocculant with medium to high degree of cationic charge [8]. With these characteristics, it is postulated that positively charged Zetag 7653 easily bonded strongly with the negatively charged sludge particles and then further enhanced by bridging mechanism due to its high molecular weight resulting in the formation of rigid flocculated particles that easily settled. However, since *Moringa oleifera* is a low charge density cationic polymer with shorter molecular weight length (13 kDa) [11] than Zetag 7653, bridging and adsorption is the most dominant mechanism [11,12] involved in producing flocs that is light and not easily settled.

Comparison between 3 methods of extraction for *Moringa oleifera* indicated that settleability were almost in similar trend and did not improve with higher dosage. However, *Moringa oleifera* in dry powder form shows slightly better settleability than the other two forms at dosages between 2000 and 4000 mg/L as the water was easily separated from the solid part after conditioning process.

3.4. Variation of ZP value with polymer dosage

Fig. 5 shows the variation of ZP value with different dosages of *Moringa oleifera* in dry powder, distilled water extracted and salt (1N NaCl) extracted forms compared to chemical polymer, Zetag 7653. For sludge conditioning with *Moringa oleifera* in dry powder form, distilled water extracted form and Zetag 7653, supernatant collected did not show any increment in ZP value at dosage of more than 1000 mg/L and 10 mg/L respectively. This implied that the zeta potential for sludge conditioned with higher dosage was closer to zero charge. Therefore, dosing of these polymers at higher concentration will not increase the zeta potential charge. However, a sharp increment in zeta potential beyond zero charge for sludge conditioned with salt extracted *Moringa oleifera* was due to the presence of NaCl salt.

3.5. Effect of dosed polymer on sludge solid content

Table 2 shows the effect of dosed polymer on the sludge solid content. Sludge conditioned with 3000 mg/L *Moringa oleifera* in dry powder form has the average increment of 0.1445 g of solids content per 60 ml of sludge filtered, represented 31.56% increment of solid content. Although sludge conditioned with *Moringa oleifera* in dry powder form had better settleability and showed more promising in SRF reduction compared to other forms of *Moringa oleifera*, however the conditioned sludge experienced slightly higher viscosity which is not viable during pumping of sludge. Sludge conditioned with 2000 mg/L *Moringa oleifera* in distilled water extracted form has slight increase of 0.0754 g of solids content per 60 ml of sludge filtered, represented 17.08% increment in solid. It must be noted that *Moringa oleifera* in distilled water extracted

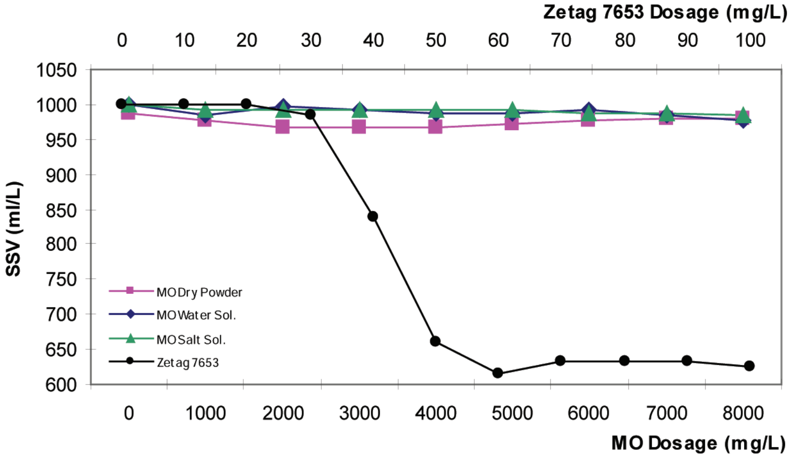

Fig. 4. Effect of *Moringa oleifera* and Zetag 7653 polymer dosage on SSV of the conditioned sludge.

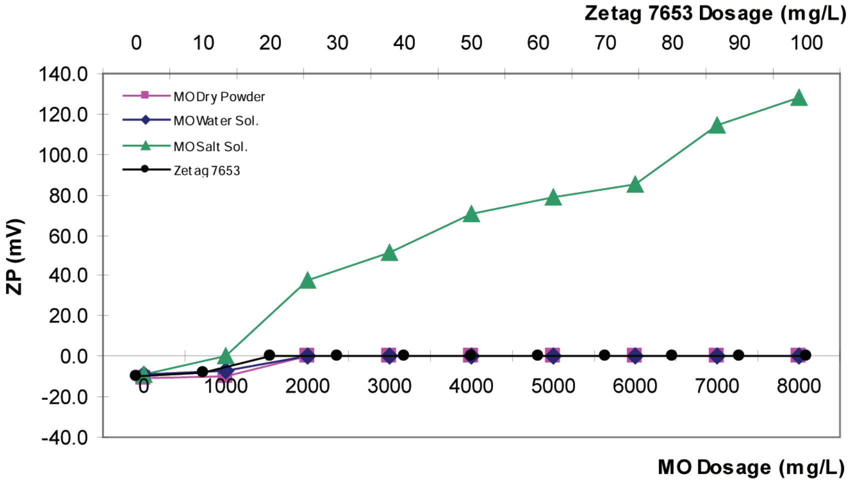

Fig. 5. Effect of *Moringa oleifera* and Zetag 7653 polymer dosage on ZP value of the conditioned sludge.

Table 2
Effect of dosed polymer on sludge solid content

	Moringa oleifera			Zetag 7653
	Dry powder	Distilled water extracted	Salt (1N NaCl) extracted	
Optimum dosage, mg/L	3000	2000	4000	50
Average increment in solid content, g per 60 ml	0.1321	0.0704	0.1438	0.1058
Average raw sludge solid content, g per 60 ml	0.4184	0.4121	0.5333	0.4826
% Increment in solid content, g per 60 ml	31.56	17.08	26.96	21.92

was prepared without filtration process using muslin cloth as normally practiced in other conventional studies. Sludge conditioned with 4000 mg/L *Moringa oleifera* in salt (1 N NaCl) extracted form has large increase of 0.1438 g (26.96%) solid content per 60 ml of sludge filtered. Similar to the preparation of *Moringa oleifera* in distilled water extracted form, *Moringa oleifera* in salt extracted form did not undergo filtration process using muslin cloth. Sludge conditioned with 50 mg/L Zetag 7653 has increment of 0.1058 g of solid content per 60 ml of tested sludge, equivalent to 21.92%. Large increment in solid content for sludge conditioned with *Moringa oleifera* in dry powder from was attributed to the addition of dosed dry *Moringa oleifera* while moderate increment in sludge conditioned with salt extracted *Moringa oleifera* and Zetag 7653 were due to additional presence of *Moringa oleifera* extract together with salt and chemical polymer respectively. However, for sludge conditioned with distilled water extracted *Moringa oleifera*, only water soluble compounds (proteins) in *Moringa oleifera* leached out into the water medium during extraction process [5,11] that eventually added into sludge in conditioning process.

4. Conclusions

Results obtained from the present study indicates that among the three methods of *Moringa oleifera* dosing, generally *Moringa oleifera* in dry powder form shows more promising results in terms of lower SRF and settleability. Generally, higher dosages for all type of polymers led to lower SRF values. Using SRF as a parameter, *Moringa oleifera* in dry powder form at dosage of 2000 mg/L was comparable to 50 mg/L Zetag 7653 in reducing the value from 8.0×10^{10} to 3.3×10^{10} m/kg (2.5 times in magnitude). *Moringa oleifera* in salt (1N NaCl) extracted and distilled water extracted form were also able to reduce SRF values of the sludge up to 2 times of magnitude at 2000 mg/L and 4000 mg/L respectively. There was no significant change in CST between the three methods of extraction for *Moringa oleifera*. Based on CST, Zetag 7653 gave lowest CST at 3.6 s from the initial of 5.9 s at optimum dosage of 50 mg/L. Without applying filtration using muslin cloth, sludge solid content when dosed with *Moringa oleifera* in distilled water extracted form showed the least increment at 17.08%.

Acknowledgement

The research was funded by the Indah Water Konsortium (IWK), Malaysia under UPM-IWK Collaboration Project. Special appreciation and thanks is directed to technical staff in Sewerage Treatment Plant, Taman Tun Dr. Ismail, Kuala Lumpur, Malaysia and also Mrs. Khor, Mr.Fan, Mr. Sasidharan and Ms. Lim from IWK headquarters. Special thanks to lab technician, Mr. Fairus and my colleague, Mr. Ahmed in their assistance. An appreciation is also given to Mr. Sim, managing director from Quartz Chemical Sdn. Bhd., Selangor for their free sample of chemical polymer used in this study.

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