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Advances in Environmental Research 7 (2003) 599–602

Advances in Environmental Research

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Correlation between dewatering index and dewatering performance of three mechanical dewatering devices

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Abstract

Efficient sludge conditioning can improve sludge dewatering characteristics and promote the separation of flocs from the liquid phase to achieve a high solid content. To optimize this process, a reliable dewatering index must be established. Although numerous researches investigated sludge conditioning, few are devoted to the correlation between the conditioning index and the dewatering efficiency. In this study, sludges were conditioned with both synthetic and natural polymers, and their dewatering characteristics after three different mechanical dewatering devices, the filter press, belt press, and the centrifuge, were compared. The result shows that the traditionally used dewatering index may not reflect sludge conditioning properly. Correlation between sludge conditioning indices and dewaterability depends upon both the type of sludge and the means of sludge conditioning and dewatering. It is therefore concluded that dewatering index must be properly chosen for optimum sludge conditioning.

Keywords: Sludge conditioning; Dewatering index; Sludge dewatering; *CST*; *SRF*

1. Introduction

Because of the higher standard and more stringent government regulations for drinking water, annual production of sludge from water treatment plants (WTPs) is increasing rapidly. Most WTPs utilize sludge conditioning to improve sludge dewatering. To optimize sludge conditioning, sludge dewatering characteristics such as capillary suction time (*CST*), specific resistance to filtration (*SRF*), zeta potential (ZP), and rheological properties, must be carefully monitored. *CST* represents the filterability and *SRF* represents the permeability. Although *CST* has many advantages, such as easy operation, it is far from realistic since no pressure is applied. Over-dosing of sludge conditioning by polymers as a result of *CST* measurement has been reported (Wu et al., 1997). The process of *SRF*, on the other hand, is similar to the operation of a filter press. Large errors are generally encountered when dealing with sludge of low solid content.

The correlation between the variations in SRT and the *CST* measurement for sludge has been observed in several studies. Tay and Jeyaseelan (1997a,b), in studying the conditioning of oil-containing sludge with fly ash and lime and aluminum salt, discovered that *CST* and *SRF* were highly related. Christensen et al. (1993) showed that there is a relationship between the *CST* and *SRF*:

$$CST = c_1 \times SRF \times \mu_f \times w + c_2 \times \mu_f$$

in which c_1 and c_2 are coefficients related to *CST*, μ_f is the viscosity of the filtrate, and w is the solid content in unit volume of the filtrate. They suggested that the resistance value came from two sources, the sludge and

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PII: S1093-0191(02)00052-7

the equipment. In an AWWA publication in 1998, a series of experiments were performed to evaluate the dewatering capacities of fresh water sludge with *CST*, *SRF* and *TTF* (time to filter). It was concluded that there was a good relationship among dewatering indices. However, there was no significant relationship between the dewatering index and the physical properties of the sludge, such as the particle size. In studying sludge conditioning with organic polymers, they found that the optimal dosage determined from *SRF* was higher than that from *CST*. Two measurements were similar in quantity when sludges were conditioned with inorganic conditioners (Christensen et al., 1993). Later, other researchers discovered that in sludge conditioning with polymers, optimal dosages determined from the *CST* test were higher than those from the *SRF* test (Wu et al., 1997; Papavasilopoulos, 1997; Papavasilopoulos and Bache, 1998).

Various studies have shown that the type of sludge and dewatering device affect the efficiency of sludge dewatering (Chu and Lee, 1999; Rehmat et al., 1997; Nellenschulte and Kayser, 1997). Filter press, belt press, and centrifuge are the most commonly used dewatering equipment. Rehmat et al. (1997) used a laboratory-scale filter press and a belt press to dewater activated sludge and discovered that solid contents of the sludge cakes produced from both devices were approximately the same. By applying pressure from 3000 to 20 000 kPa on a filter press, Chu and Lee (1999) discovered a three-stage behavior of sludge dewatering depending upon the type of water. Many researchers have focused on improving sludge dewatering by searching for the optimal sludge conditioner and dosage. However, they ignore the critical role of the dewatering device and its effect on dewatering index. In this study, we studied the dewatering characteristics of sludges from different sources under three mechanical dewatering devices in an attempt to investigate the correlation between the sludge dewatering index and dewaterability.

2. Materials and methods

Both fresh water sludge and biological activated sludge were used in this study. The fresh water sludge was collected from the concentration basin at the Hsin-Chu Water Treatment Plant in Hsin-chu, Taiwan. In this plant, polymeric aluminum chloride (PACl) is used in the coagulation. The activated sludge samples were obtained from the wastewater treatment plant of the Neili Bread Plant, President Enterprise Co., Taoyuan, Taiwan. The characteristics of the raw sludge samples were analyzed and summarized in Table 1. The analyses were performed in the laboratory within 2 h of sampling to prevent the aging process, while all tests were finished within 2 days. Sludge samples were divided into two parts. One part was for experiments performed under room temperature. The other part was stored in a freezer set at −4 °C for 24 h, followed by thawing for another 12 h under room temperature. The raw and cold-treated sludge samples were referred to as the 'original sludge' and the 'cold-treated sludge'.

Table 1
Characteristics of raw activated and fresh water sludge samples

Sludge	Original PH	TS (%)	VS (%)	VS/TS (%)	ZP (mv)
Activated sludge	6.82–7.12	0.49–0.75	0.41–0.65	83–87	−15.4 to −27.6
Fresh water sludge	7.05	6	0.2	3	−22

Cationic polyelectrolyte (Polymer-PC-325) and chitosan were applied for separate sludge conditioning experiments. Polymer-PC-325 was obtained from the Taiwan Polymer Company. It is a copolymer of acrylamide and diallyldimethyl-amonium chloride, with an average molecular weight of 1.1×10^7–1.2×10^7, and a 25% charge density. Polymer solution (0.1% w/w) was prepared according to methods proposed by the polymer manufacturer. Chitosan was obtained from the Bioscience Company.

Various amounts of Polymer-PC-325 were added to 1 l of sludge sample. After mixing at 100 r.p.m. for 1 min, sludge dewatering characteristics of the conditioned sludge were determined. The *CST* was determined using a Triton CST Apparatus Model 200 with a Whatman no. 17 paper filter. A standard Buchner funnel apparatus with a 9-cm funnel was used for the *SRF* determinations. The detail experimental procedures for *CST* and *SRF* measurements can be found in the study of Wu et al. (1997).

Three laboratory-scale mechanical dewatering devices, namely a filter press, belt press and centrifuge, were adopted for expressing water from conditioned sludge samples. The pressure applied on the belt press and filter press was 10 kg/cm^2, and the centrifuge was operated at a speed of 1200 r.p.m. for 60 s to obtain equivalent performance. The dewatering efficiency was represented by the water content, which was determined from the difference in the weight of the pressed sludge cakes before and after drying at 105 °C for 24 h.

3. Results and discussion

Activated sludge samples were conditioned with various concentrations of Polymer-PC-325 and chitosan. Optimal dosages corresponding to each mechanical dewatering device were determined from the *CST* values. Sludges obtained from the optimal conditioning were divided into three parts and dewatered with a belt press, filter press and centrifuge. Water contents of the

Table 2
Water contents (% wt.) of optimal conditioned activated sludge cakes under various mechanical dewatering procedures

Sludge conditioner	Activated sludge	Belt press	Filter press	Centrifuge
Chitosan	Original	86	86	84
	Cold-treated	88	87	85
Polymer-PC-325	Original	85.5	85.5	84
	Cold-treated	87	86.5	85.5

sludge cakes generated from the three dewatering processes are summarized in Table 2. The water content was reduced from the original 99% in the raw sludge to between 84% and 88% in the pressed sludge cakes. No significant difference in conditioning efficiency was observed between chitosan and Polymer-PC-325. Cold-treatment did not improve the dewaterability of the activated sludge. Although the dewatering by centrifuge seems to be slightly better than the other two dewatering devices, this difference may be caused by experimental error because of the relatively small scale involved.

To truly reflect the efficiency of sludge conditioning, the dewatering index monitored must have a good correlation to the final water content of the sludge cakes. In this section, original and cold-treated sludge samples were conditioned with various amounts of chitosan and Polymer-PC-325. *CST* and *SRF* of each conditioned sludge, were analyzed against the corresponding water content of the sludge cake. Their correlation coefficients are reported in Table 3. A higher value of correlation coefficient means that the dewatering index can better represent the final product of sludge conditioning. Table 3 shows that more consistent results are found among activated sludge samples conditioned with chitosan. In general, the dewaterability through centrifuge dewatering can be best represented by the *CST* values, because in both operations no pressure is exerted on flocs. *CST* is not a reliable index for filter press or the belt press. This is because pressure is exerted on flocs when a belt press and filter press are used for dewatering. Since no pressure is given in the process of *CST* measurement, the *CST* value cannot reflect the strength of the floc and therefore, the filterability of the sludge. On the other hand, *SRF* is a better option for filter press dewatering because of the similar filtration behavior. Very inconsistent results are associated with belt press dewatering. No conclusion can be made for the belt press, mostly due to the great experimental error involved in the scraping of sludge cake from the belt. It is also observed that when the sludge sample was pretreated with low-temperature, the dewaterability became unpredictable especially by *CST*, as evidenced by the low correlation coefficients. This is probably due to the destruction of the floc structure in

Table 3
Correlation coefficients of *CST* and *SRF* vs. dewaterability of mechanical dewatering devices for activated sludges subjected to various conditioning methods

Sludge conditioner	Activated sludge	Belt press	Filter press	Centrifuge
CST				
Chitosan	Original	0.69	0.94	0.96
	Cold-treated	0.14	0.73	0.79
PC-325	Original	0.64	0.31	0.88
	Cold-treated	0.08	0.31	0.66
SRF				
Chitosan	Original	0.74	0.97	0.58
	Cold-treated	0.43	0.89	0.66
PC-325	Original	0.75	0.89	0.39
	Cold-treated	0.52	0.89	0.21

the freeze/thaw process. The much higher correlation coefficients between *CST* and chitosan-treated activated sludge samples suggest that more consistent results occur between the dewatering index and the more effectively conditioned sludge.

Fresh water sludge contains less organic materials, with more solid content. Similar analyses were performed on the chitosan-conditioned fresh water sludge. The entire experiments were conducted at room temperature. The water content of sludge cake and correlation coefficients of *CST* and *SRF* vs. water contents of sludge cakes are listed in Table 4. Sludge cakes from all three dewatering procedures retain much less water. Coefficients fall into a much narrower range, from 0.73 to 0.87, than those of the activated sludge samples.

4. Conclusions

The pressed cakes of optimally conditioned activated sludge contained 84–87% water regardless of the means of dewatering. Correlation analysis showed that a more consistent result was found between the dewatering index and the more effectively conditioned sludge. The dewaterability of sludge by means of centrifuge dewa-

Table 4
Water content of sludge cake and their correlation coefficients to *CST* and *SRF* for three mechanical dewatering devices

	Belt press	Filter press	Centrifuge
Water content of sludge cake	64%	64%	64%
Correlation coefficient			
CST	0.77	0.73	0.8
SRF	0.78	0.87	0.84

Sludge samples consist of fresh water sludge subjected to chitosan conditioning.

tering can be best represented by *CST* values due to the similar mechanism of operation. *SRF* is a practical index for filter press dewatering, because of their similar filtration behavior. No conclusion can be made for the belt press. The dewaterability of samples that went through a freeze/thaw process became unpredictable especially by *CST*, probably due to the destruction of floc structure. Although no universal dewatering index exists, selecting a good dewatering index is a challenging, yet a critical procedure for optimizing sludge conditioning.

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