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Comparison of dewatering characteristics of chemically conditioned sludge and freeze/thawed sludge

Kimyasal şartlandırılmış çamur ile dondurma/çözme ile şartlandırılmış çamurun su verme özelliklerinin karşılaştırılması

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Abstract

The objective of this study was to compare dewatering properties of chemically conditioned sludge and freeze/thawed sludge as determined by mainly specific resistance to filtration (SRF), dry solids content of sludge cake (DS), and capillary suction time (CST) parameters. The experimental studies were carried out with mixed sludge samples taken from a municipal wastewater treatment plant in Turkey. In chemical conditioning experiments, sludge samples were conditioned with different dosages of polymer using classical jar test method. In freeze/thaw conditioning experiments, samples were frozen at -16.5 °C at different freezing rates and then thawed at 21±1 °C at different times in order to determine the effect of thawing time on dewatering performance. 25 mg/L polymer dose and 2.71 mm/h freezing rate were found to be optimum in terms of sludge conditioning. Rapid freezing that is higher than 8.13 mm/h could not sufficiently condition the sludge and there was no significant effect of thawing time on conditioning performance. Dewatering properties of chemically conditioned sludge and freeze/thawed sludge was determined as very close to each other. While CST and SRF reductions were calculated as 76% and 75%, respectively at 25 mg/L polymer dosage, 2.71 mm/h freezing rate application caused 79% and 76% reduction in CST and SRF, respectively.

Keywords: Sludge, Dewatering, Chemical conditioning, Polymers, Freeze/Thaw

Öz

Bu çalışmanın amacı kimyasal olarak şartlandırılmış çamur ve dondurulup çözdürülmüş çamurun su verme özelliklerinin özgül filtre direnci (ÖFD), çamur keki katı madde içeriği (KM) ve kapiler emme süresi (KES) parametre değerlerinin belirlenmesi ile karşılaştırılmasıdır. Deneysel çalışmada, İzmir (Türkiye)'de bulunan bir kentsel atıksu arıtma tesisi çamurları kullanılmıştır. Kimyasal şartlandırma deneylerinde çamurlar farklı dozlardaki polimer ile klasik jar testi metodu kullanılarak şartlandırılmıştır. Dondurma/çözme yöntemi ile şartlandırma çalışmalarında ise çamur örnekleri -16.5 °C'de farklı donma hızlarında dondurulmuş ve sonra 21±1 °C'de çözme süresinin su alma performansına etkisini belirlemek amacıyla farklı çözme sürelerinde çözdürülmüştür. 25 mg/L polimer dozu ve 2.71 mm/sa. donma hızı çamur şartlandırma için en uygun koşul olarak belirlenmiştir. 8.13 mm/sa.'ten daha hızlı dondurma işlemi çamurun şartlandırılması için yeterli olmamıştır. Yanı sıra, çözme süresinin çamur şartlandırma performansı üzerinde önemli bir etkisi olmadığı belirlenmiştir. Çalışmanın bir sonucu olarak, kimyasal şartlandırılmış çamur ile dondurma/çözme ile şartlandırılan çamurların su verme özellikleri birbirine oldukça yakın olduğu belirlenmiştir. 25 mg/L polimer uygulamasında KES ve ÖFD değerlerindeki azalma sırasıyla %76 ve %75 iken ve 2.71 mm/sa. dondurma hızı uygulaması sırasıyla %79 ve %76 KES ve ÖFD azalmasına sebep olmuştur. Çalışmanın diğer bir sonucu ise dondurma/çözme ile şartlandırılmış çamurların kimyasal şartlandırılmış çamurlara oranla vakum filtrasyonu sonrasında daha yüksek katı madde içeriklerine ulaşmasıdır.

Anahtar kelimeler: Çamur, Susuzlaştırma, Kimyasal şartlandırma, Polimer, Dondurma/Çözme

1 Introduction

The biological treatment of wastewater results in the generation of a considerable amount of waste activated sludge (WAS) that has to be treated. Sludge treatment and disposal represents a decisive factor for design, operation and costs of wastewater treatment especially for large treatment plants. Since the costs of sludge treatment are high, representing 50–60% of the total operating costs of the wastewater treatment [1, 2] Dewatering process, which is commonly applied operation to sludge before final disposal, have many advantages such as reduction of transporting costs, facilitating of handling processes, prevention of odor problem, and reduction of leachate production in land fill areas [3]. Sludge conditioning is the most significant process to improve sludge dewatering properties and to provide the separation of flocs from the liquid phase to achieve high solids content of sludge in mechanical dewatering processes. Dentel [4] have stated the conditioning process is intended to alter sludge properties in important ways to provide both environmental and economic benefits and, in order to obtain a high degree of separation in a short period of time and a relatively small process volume, conditioning step should be very effective since the dewatering process heavily depends on it. Eckenfelder [5] have reported that during the chemical conditioning process, small and amorphous gel like particles are transformed into larger and stronger aggregates. This leads to increasing the rate and/or extent of water drainage and solid separation. The performance of a physical process, mechanical dewatering, depends on impact of a chemical process, conditioning. Therefore, the both processes are strongly interrelated [6]

Although there have been different conditioning strategies like elutriation, freeze-thawing [7] and oxidation processes such as electro-oxidation [8], Fenton Process [9, 10], and ultrasound conditioning [11], chemical conditioning is the most commonly applied method in sludge management. The chemical alterations to sludge structures have been accomplished using organic polyelectrolyte and cationic polymers are invariably used for conditioning purposes [12]. In chemical conditioning applications, optimum conditioner dosage is very important phenomena [13]. Werle et al. [14] have expressed that the insufficient polymer additions to sludges result in floc breakage and deterioration of dewaterability. Christensen et al. [15] have also reported that the good control of polyelectrolyte dose was critical in conditioning process since overdosing would increase the operation costs and reduce sludge dewaterability.

Another conditioning strategy is the freeze/thawing process that can significantly improve certain sludge dewatering characteristics. This method transforms the floc structure into a compact form and, reduces the sludge bound water content [16, 17]. In freeze/thaw treatment, freezing time and freezing speed are the critical parameters. Instant freezing is considered inadequate for improvement of dewatering characteristics of sludge [17]. Randall et al. [18] have demonstrated that sludge dewatering efficiency was generally decreased with the increasing freezing rate, however; a long freezing time was economically unfeasible. Lee and Hsu [16] have investigated the freeze/thawing process at average freezing speed up to 40 mm/h, indicating that such a “fast” treatment can not only reduce the sludge bound water content to 50% but also largely decrease resistance to filtration. In another study, Chen et al. [19] have expressed that the freezing speed lower than 21.6 mm/h was called as low freezing speed. Hung et al. [20] have studied on the freeze/thaw treatment for waste activated sludge conditioning. They concluded that there was no any strict definition of critical freezing speed and in order to improve sludge settleability and reduce the bound water content of waste activated sludge samples, the freezing speed should be less than a critical value, i.e., approximately 10.8 mm/h.

The objective of this study was to optimize the polymer conditioning and freeze/thaw conditioning for dewaterability of municipal sludge and to compare the effects of two conditioning method for the same sludge sample.

2 Materials and methods

2.1 Sludge properties

Mixed (primary + waste activated sludges) sludge samples were taken from Cigli Municipal Wastewater Treatment Plant in Izmir, Turkey. Characteristics of the sludge sample are given in Table 1.

2.1 Chemical conditioning method

A cationic polymer was used in chemical conditioning experiments as a conditioner. The properties of the polymer are given in Table 2. In conditioning studies, classical jar test method was used. A 0.5% stock polymer solution was prepared according to Dentel et al. [13] for conditioning applications. Standard 1-liter beakers were used with 500 ml sample. Different polymer concentrations ranged between 5 to 100 mg/L were added to sludge samples, then a rapid mixing at 200 rpm for 1 minute and then slow mixing at 25 rpm for 30 minutes finally 30 minutes settling were applied to the mixture of sludge and polymer.

Table 1: Properties of raw sludges.

Parameter	Value
Dry Solids Content (DS), %	1
Organic Matter Content (OM), %	61
Electrical Conductivity (EC), µmho/cm	3500
pH	6.84
Sludge Volume Index (SVI), mL g	144
Capillary Suction Time (CST), s	34.2
Specific Resistance to Filtration (SRF), m/kg	0.76×10^{14}

Table 2: Properties of cationic polymer.

Parameter	Property
Type	Cationic
Appearance	White
Density	0.70 g/cm^3
Particle Dimension	98 % < 1750 ∝m
Molecular Weight	Very high

2.2 Freeze/Thaw conditioning method

200 mL of sludge samples in 250 mL beakers, which is 6.5 cm in diameter were frozen at temperature of -16.5 ºC in a deep-freezer and then thawed at 21±1 ºC in water bath. In order to determine the effect of freezing speed and thawing time on the conditioning efficiency, four different freezing speeds (16.25, 8.13, 5.42, 2.71 mm/h) and 6 and 12 h thawing time were applied to the sludge samples. Average freezing speed was considered as the ratio between the radius of the sample chamber and the time required for completing the freezing [21].

2.3 Analysis

DS content, organic matter content, pH, electrical conductivity, SVI, SRF, and CST analysis were done according to procedures given in Standard Methods [22]. pH and electrical conductivity measurements of raw sludge samples were carried out with a 890 MD pH meter and a YSI Model 33 conductivity-meter, respectively. For filterability evaluations, SRF and CST tests were applied to the raw and conditioned sludge samples. SRF test was performed using a Buchner Funnel with a Whatman # 2 filter paper applying 2 bar of vacuum suction. Viscosities of filtrate samples for SRF test were measured using a Brookfield RVDV III type rheometer. CST values were analyzed using a Triton A-304 M CST-meter. All CST measurements were conducted in triplicates and average values were taken into consideration for standard deviation to be less than ±1 s.

3 Results and discussion

CST is a quick test used for determination of the filterability characteristic of sludge. Since the CST test neglects the shear stresses, it cannot provide information about the performance of sludge on the mechanical dewatering processes [23]. SRF test can be considered as a simulator of vacuum filtration units. This test gives information about sludge filterability characteristics of sludge and final sludge’s cake DS content. As commonly accepted, low values of CST and SRF indicate that good dewaterability characteristic of sludge and minimum SRF and CST values indicate optimum conditioner dose for chemical conditioning. CST and SRF values of the raw sludge were too high. Polymer additions to sludge have led to drastically decreases in SRF and CST values (Figure1).

Minimum SRF (1.9 1013 m/kg) was achieved at 25 mg/L polymer dose while minimum CST value was 8.2 s at the same dose. Based on the CST and SRF test results, optimum polymer dose was determined as 25 mg/L. Beyond the optimal dose range, over dosing has caused deterioration in dewaterability of the sludge. For the optimal dose (25 mg/L), it was 20.6% as shown in Figure 2.

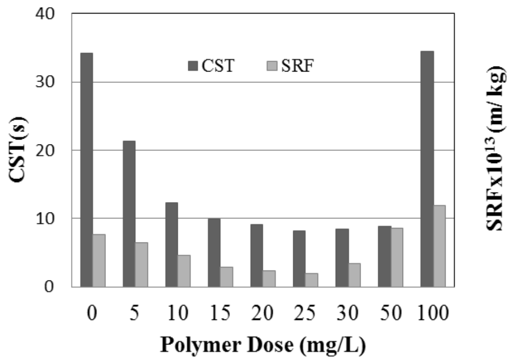

Figure 1: SRF and CST of sludge as a function of polymer dose.

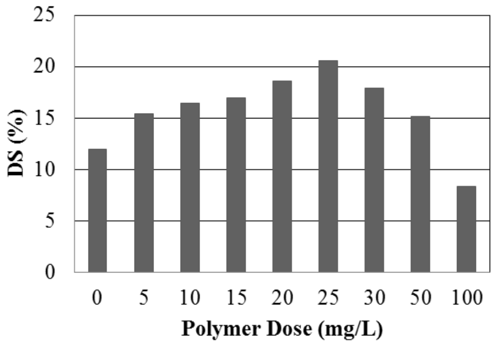

Figure 2: DS of sludge's cake as a function of polymer dose.

CST and SRF tests results of freeze/thaw experiments obtained at different freezing rates and different thawing time are shown in Figure 3 and Figure 4, respectively. Experimental results showed that CST and SRF values decreased with the decreasing freezing rate. In the freeze/thaw treatment trials, minimum CST and SRF values were obtained at 2.71 mm/h freezing rate for both 6 h and 12 h thawing time. The CST values are much closed to each other for 6 h and 12 h thawing time.

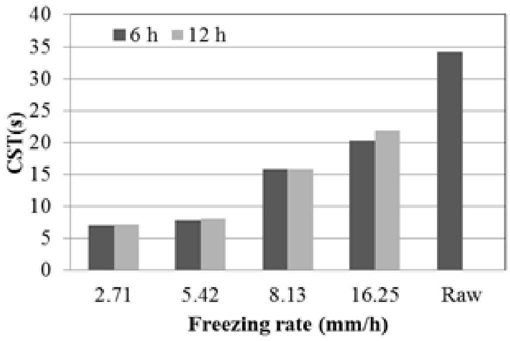

Figure 3: Variations of CST with the freezing rate at different thawing time.

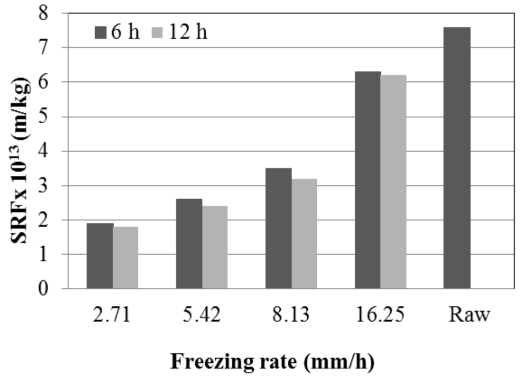

Figure 4: Variations of SRF with the freezing rate at different thawing time.

While CST value was found as 7 s for 6 h thawing application, this value was recorded as for 7.2 s thawing. Minimum SRF values were obtained as $1.9x10^{13}$ m/kg and $1.8x10^{13}$ m/kg for 6 h and 12 h thawing, respectively.

DS value of sludge's cake after vacuum application increased with decreasing freezing rate for each thawing time as plotted in Figure 5. The highest value was obtained as 23.4% at 2.71 mm/h freezing rate for 6 h thawing time. DS values did not differ too much at 6 h and 12 h thawing time. DS value was 23% for 12 h thawing at the same freezing rate of 2.71 mm/h. Obtained results showed that low freezing rates increased the conditioning performance of sludge and thawing time is not a critical parameter for freeze/thaw conditioning.

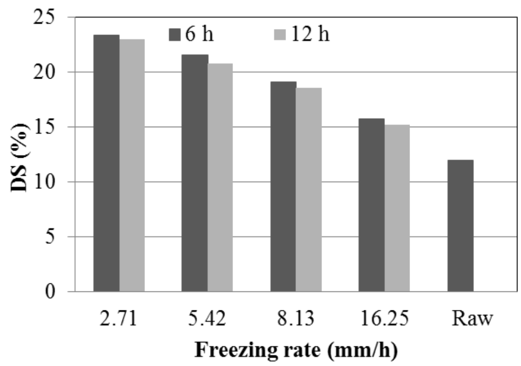

Figure 5: Variations of DS with the freezing rate at different thawing time.

For comparison of dewatering characteristics of chemically conditioned sludge and freeze/thawed sludge, decrease in CST and SRF and increase in DS were calculated as % for chemically conditioned sludge (25 mg/L polymer dosage) and freeze/thawed sludge (2.71 mm/h freezing rate, 12 h thawing time) with reference to raw sludge. Results are given in Table 3.

Table 3: Comparison of chemical conditioning and Freeze/thaw conditioning methods in terms of dewaterability.

Conditioning Method	Decrease in CST, %	Decrease in SRF, %	Increase in DS, %
Chemical	76	75	83
Freeze/ Thaw	79	76	95

CST values decreased to 76% and 79% with reference to raw sludge for chemically conditioned sludge and freeze/thawed sludge, respectively. Freeze/thawed sludge gave the higher decrease in CST value compared to chemically conditioned sludge. SRF values of sludge decreased to 75% and 76% with reference to raw sludge for chemically conditioned sludge and freeze/thawed sludge, respectively. Results very closed to each other, both of sludge will show the high performance on vacuum filtration units. Freeze/thawed sludge gave the higher increase in DS value (95%) compared to chemically conditioned sludge (83%).

4 Conclusion

Chemical conditioning application results indicated lower CST and SRF values with the increasing cationic polymer dose. SRF values decreased from 7.6x1013 m/kg to 1.9x1013, while CST values decreased from 34.2 s to 8.2 s at 25 mg/L of polymer dosage. CST and SRF reductions with respect to raw sludge were calculated as 76% and 75%, respectively at 25 mg/L polymer dosage. Freeze/thaw conditioning results have showed that CST and SRF values decreased with decreasing freezing rate and the highest DS was obtained as 18.3% at the lowest freezing rate of 2.71 mm/h. This method can improve sludge dewatering properties at slow freezing rates. Rapid freezing cannot sufficiently condition the sludge and there was no significant effect of thawing time on conditioning performance. Based on CST and SRF reductions, there was no significant difference between dewatering properties of chemically conditioned sludge and freeze/thawed sludge at slow freezing rate. But freeze/thawed sludge gave higher DS of sludge's cake compared to chemically conditioned sludge.

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