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Contributed Paper

Feasible Use of Electrical Conductivity for Optimizing Polymer Dosage and Mixing Time Requirement in Sludge Conditioning

Tongchai Sriwiriyarat*, Kreethaphon Siriphrom, Nut Kaewpanao, and Anucha Puansuchjar
Department of Chemical Engineering, Faculty of Engineering, Burapha University, Chon Buri, 20131, Thailand.
*Author for correspondence; e-mail: sriwiri@buu.ac.th

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Abstract

The feasible use of electrical conductivity was evaluated in this study for optimizing polymer dosage and mixing time required in the municipal biological wastewater treatment plant sludge conditioning process. The electrical conductivity could be adopted as a key indicator because it is a low cost device with acceptable accuracy and is available in any laboratory. The cationic polymer concentrations of 0, 2, 4, 6, 8, and 10 kg polymer/ton of dry sludge were applied on the 1% solids at different mixing time of 60 minutes. The centrate viscosity was used to determine the optimal dosage of polymer for the sake of comparison to the results obtained from the electrical conductivity. It was found that the electrical conductivity exhibited a similar trend to the kinematic viscosity and provided the same optimal polymer dosage of 4 kg polymer/ton of dry solids. The mixing time requirement for conditioning sludge with polymer monitored by the electrical conductivity at a 5 minute- interval was longer than 55 minutes at the mixing intensity of 120 rpm. The electrical conductivity profiles suggest that sufficient mixing time resulting in the homogenous mixture be provided, so that the optimal polymer dosage could be clearly identified.

Keywords: Electrical Conductivity, Centrate, Viscosity, Polymer, Sludge Conditioning.

1. Introduction

The conditioning of biological wastewater treatment sludge requires a polymer as a conditioning agent to improve the dewaterability of sludge, which results in the reduction of sludge volume or mass in a great extent. The expenses of polymer are usually greater than 50% of overall solid handlings costs [1]. An optimal dosage of polymer used is thus critical to effectively optimize the handling costs. Analytical laboratory techniques such as capillary suction time (CST), filter leaf test, and specific resistance to filtration (SRF) are typically used to evaluate the dewaterability of the conditioned sludge reflecting the effects of chemical conditioning; therefore, they can be used to indicate the optimal polymer dosage [1]. The linkage between rheology of sludge describing the strain of sludge under the influences of applied stress and the analytical techniques has been established by various researchers [2-6]. The highest peak of the rheogram curve may be used to indicate the optimal dose of polymer for sludge conditioning. Abu-Orf and Dentel [7] reported that there was no correlation between the rheological parameters and the optimal dosage indicated by CST, centrate streaming current and viscosity, and solid measurements at different mixing conditions. The mixing parameters resulted in the different rheology characteristics of sludge. However, the aforementioned techniques could not be used to evaluate the dewaterability of sludge at full scale operation with online monitoring and continuous polymer feeding. Two techniques based on the liquid stream viscosity and current measurements could potentially be used to determine the optimal dose of polymer at such operations [8]. For the streaming current measurements, a streaming current detector (SCD) is used to measure the transition of particle charge from negative to positive as a result of the charge neutralization mechanism between colloids and polymer. It is normally reported that the biological wastewater sludge is a negatively charged particle [9]. The near-zero SCD reading indicates the optimal polymer dosage which is consistent with the analytical laboratory methods including CST, solid measurement and recovery, filtrate turbidity, filtrate viscosity, and filterability time [8,10,11]. The minimum centrate viscosity could also be used to identify the optimal polymer dosage which has been verified with the CST and solid measurements in both laboratory and full-scale studies [8,12,13]. The centrate viscosity of the diluted concentration is independently controlled by water, turbidity, and residual polymer. The total dissolved solid (TDS) is suggested to be used as an additional component contributing to the viscosity in the centrate [8,12]. A decrease in viscosity through a minimum, and then an increase with the increasing polymer dosages is the result of residual turbidity and excess polymer in the centrate, respectively [12]. The components contributing to the centrate viscosity including biological solids, water, polymer, and TDS are associated with the ionic properties and would possibly be evaluated by the electrical conductivity.

The objective of this study is to evaluate the feasible use of electrical conductivity to indicate the optimal dosage of polymer and mixing time requirement for conditioning biological wastewater sludge as the electrical conductivity measuring equipment is a low cost device and is available in any laboratory. If the electrical conductivity could be used to provide the optimal dosage and mixing time requirement with the acceptable accuracy, simple and inexpensive operation and control the dosage of polymer including sufficient mixing time requirement could be achieved.

2. Materials and Methods

The study was carried out at the Chemical Engineering Laboratory of Burapha University, Chonburi, Thailand. The sludge was taken from the final clarifier of municipal wastewater treatment plant at Sirindhorn College of Public Health, Chonburi, Thailand. The biological solids were kept in the laboratory for one day to acclimatize with the room temperature and to stabilize the sludge characteristics. The sludge was then either diluted by supernatant collected from the wastewater treatment plant or concentrated by an Imhoff cone so that the sludge could be maintained at the concentration of 1% or 10,000 mg/L solids throughout this study. The solid concentration was analyzed in accordance with Standard Methods for the Examination of Water and Wastewater, 19th Edition, 1995 [14]. The cationic polyelectrolyte polymer Waterfloc 5803® (Water Doctor, Co.Ltd.) was used to condition the sludge in the jar test consisting of six 1-Litre beakers. Fresh stock solution of polymer was prepared one hour before the experiments at the concentration of 1% w/v. The concentrations of polymer were then prepared to provide the concentrations ranged from 0, 2, 4, 6, 8, and 10 kg polymer/ton dry solids. Three experiments runs were conducted to measure the electrical conductivity and centrate viscosity parameters at the room temperature in the range of 29-30 °C. The pH of the polymer and sludge mixture was about 7.9. For each experimental run, the amount of biological solids was filled up to 800 ml in each beaker of the jar test. The paddles were rotated at the speed of 120 rpm for 60 minutes. The conductivity meter (Model no. D-54 HORIBA) was submerged into the mixtures to monitor the electrical conductivity at 5 minutes interval for a total time of 60 minutes. The samples were collected after 60 minutes mixing time and then centrifuged in the Seta Oil Test Centrifuge 90,000-0 at 2000rpm for 5 minutes. The centrate was then analyzed for the kinematic viscosity by the Kinematic Viscosity device (ASTM D445) and the electrical conductivity by the conductivity meter.

3. Results and Discussion

To identify the optimal polymer dosage with electrical conductivity, the correlation between electrical conductivity and centrate viscosity must be established. The minimum centrate viscosity in accordance with the findings of Dentel and Abu-Orf [8] was determined to specify the optimal polymer dosage. The optimal polymer concentrations were then compared with the ones obtained by the electrical conductivity in this study. Figure 1 represents the relationship between the centrate kinematic viscosities and polymer concentrations at 5 and 60 minutes mixing periods. As a result of different sludge characteristics owing to different wastewater treatment system performances for each batch of experiments, three sets of kinematic viscosity data are plotted. The lines are connected between points to represent the trends of kinematic viscosities and the scale on y-axis is not started at zero to facilitate the minimum viscosity readings. The trends of

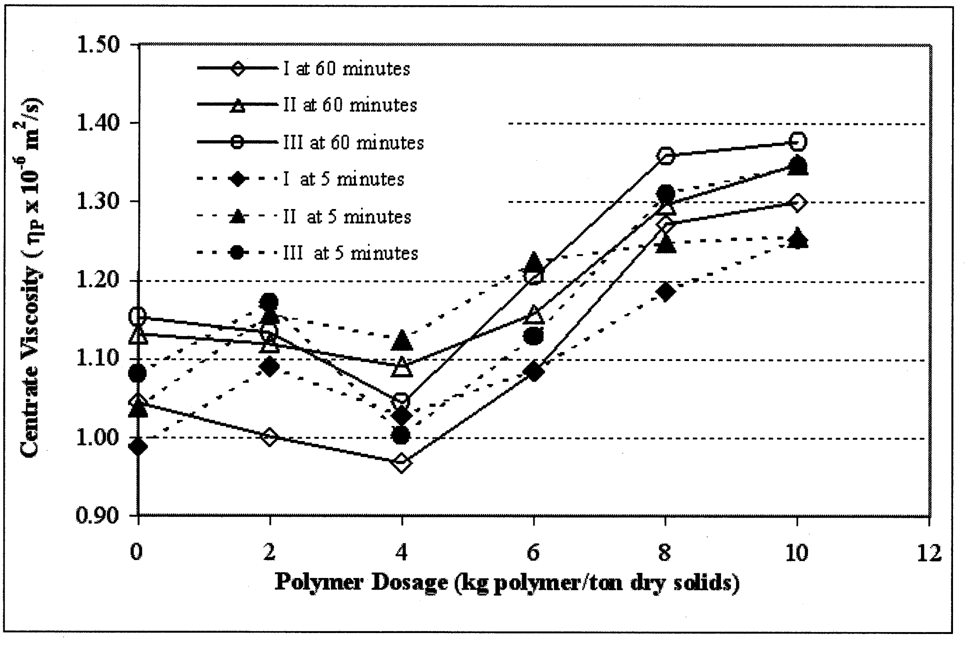

Figure 1. Kinematic viscosity of centrate as a function of polymer concentrations.

the kinematic viscosity are similar to the one reported by Dentel and Abu-Orf [8]. All kinematic viscosities of centrate at 60 minutes mixing time reached the minimum at the polymer dosage of 4 kg polymer/ton dry solids corresponding to the kinematic viscosities of 0.968×10^{-6}, 1.091×10^{-6}, and 1.045×10^{-6} m^2/s for the experimental runs I, II, and III, respectively. After the centrate kinematic viscosities of conditioned sludge passing through the minimum, the viscosities increase with the polymer concentrations. Bache et al. [12] explained that, initially, the viscosity decreases as the polymer increases is the consequence of finer sludge agglomeration resulting in lower turbidity and viscosity in the centrate. As the polymer exceeds the optimal dosage, residual polymer in the liquid stream increases the centrate viscosity. Additionally, the profiles of centrate viscosity at 5 minutes mixing time illustrated by Figure 1 are different from the ones at 60 minutes, which is probably a result of heterogeneous matrix of the mixture. However, the optimal polymer dosage could be identified at the 4 kg polymer/ton dry solids at 5 minutes mixing time. Therefore, the amount of 4 kg polymer/ton dry solids is the optimum polymer dosage for the wastewater sludge used in this study.

The relationship between the electrical conductivity and polymer dosage at the mixing time of 60 minutes is illustrated by Figure 2. The electrical conductivity exhibited similar trend to the kinematic viscosity providing the minimum electrical conductivities of 31.0, 35.6, and 36.7 °S/cm at the experimental runs I, II, and III, respectively, and this corresponds to the optimal polymer dosage 4 kg polymer/kg dry solids. A possible explanation is that the centrate initially has a relative high electrical conductivity as a result of the mobility of residual negatively charged wastewater solids. The centrate electrical conductivity decreases gradually with increasing polymer dosages to a minimum because there are possibly less residual fine solids in the centrate. After the electrical conductivities reach the minimum point, they keep increasing as a result of the residual cationic polymer. Note that the

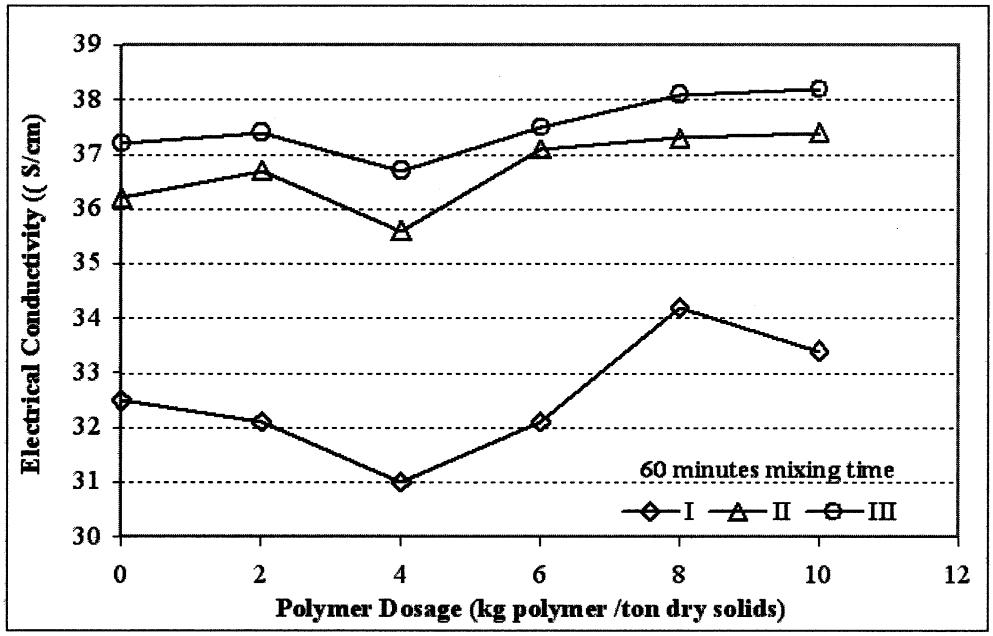

Figure 2. Electrical conductivity of centrate as a function of polymer concentrations.

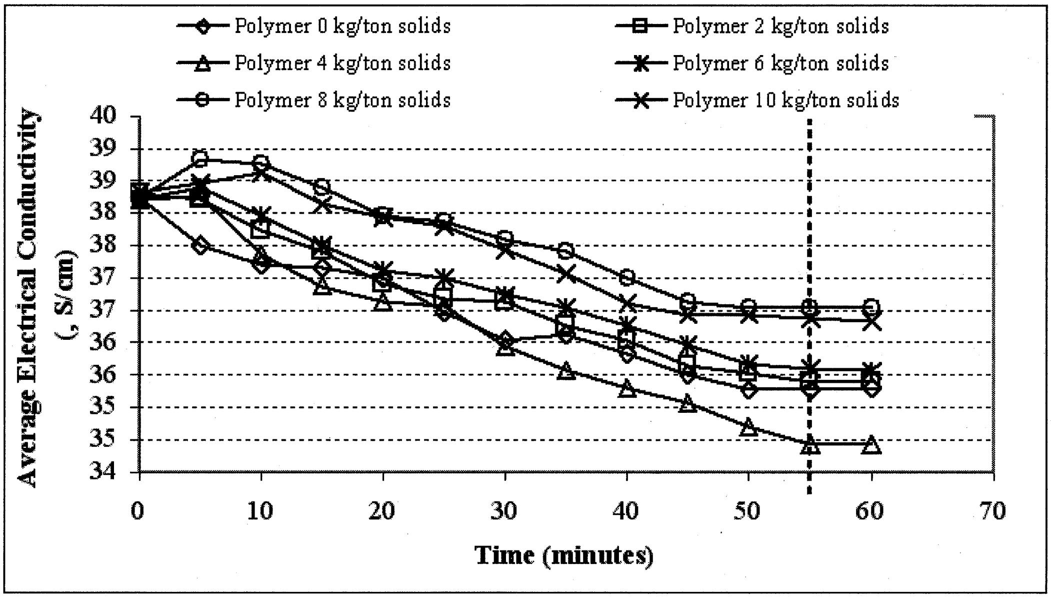

Figure 3. Average electrical conductivities of mixtures at different mixing times.

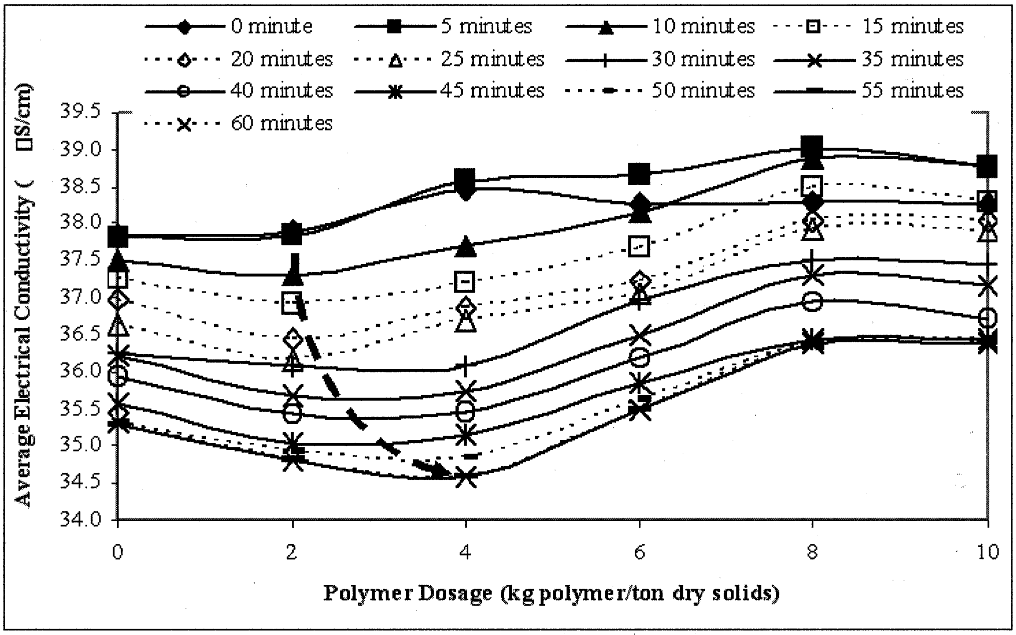

Figure 4. Average electrical conductivities of mixtures under different polymer concentration

profile of centrate viscosity illustrated in Figure 1 in the experimental run I is lower than other two runs (II and III) at the same the solid concentrations and polymer concentrations. The measurement of electrical conductivity presented in Figure 2 shows the electrical conductivities of the experimental runs II and III, which are significant greater than that of runs I. Bache et al. [12] suggested that the contribution of electrolytes to the centrate viscosity as a result of total dissolved solids (TDS) may explain this finding.

The in-situ monitoring of electrical conductivity at a 5-minute interval for a total time of 60 minutes as illustrated in Figure 3, while the sludge was being mixed, reveals that the electrical conductivities decline gradually over time at different polymer concentrations. All electrical conductivity profiles are stabilized at the mixing times of greater than 55 minutes. It is interesting to note that the electrical conductivities of the sludge without polymer also develop similar trends as other sludge conditioned with different polymer dosages. It could be explained that the decrease of electrical conductivities in the sludge is possibly the results of some charge neutralization between negatively charged solid particles and ionic components in the mixture. The dosages of polymer caused the electrical conductivities below or above the one of sludge without polymer which would be a result of positively charged cationic polymer in the charge neutralization. Figure 4 illustrated the electrical conductivity profiles under different polymer concentrations and at different mixing times. The electrical conductivity profiles are fluctuated at the mixing times less than 55 minutes. The optimal dosage of polymer would possibly be a faulty identification, if the mixing time was not sufficient. Therefore, the mixing time should be sufficient at a given degree of mixing intensity indicated by the electrical conductivity to achieve the optimal dosage of sludge conditioning.

4. Conclusions

The feasible uses of electrical conductivity were evaluated for the optimal polymer dosage and mixing time requirement for conditioning wastewater sludge with the polymer. The relationship between viscosity and electrical conductivity of centrate was established in this study; therefore, the electrical conductivity of centrate could be used to identify the optimal dosage of polymer. The optimal dose polymer identified by the centrate electrical conductivity is consistent with the one obtained by the centrate viscosity which is 4 kg polymer/ton dry solids in this study. In addition, the in-situ measurements of electrical conductivity in the mixtures of sludge and polymer could indicate the mixing time requirement. The electrical conductivity of the mixture between polymer and sludge will stabilize with sufficient mixing time resulting in the homogenous mixture; therefore, the optimal dosage of polymer for sludge conditioning can clearly be identified. The experimental results indicate that the mixing time requirement in this study be 55 minutes.

It was the first attempt to use the electrical conductivity as an indicator for the optimal dosage and mixing time requirement in the field of sludge conditioning. A further attempt will be made to determine the factors contributing to the validity of using the electrical conductivity including operating conditions, biological wastewater treatment plant performances, sludge characteristics, and polymer types.

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