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Shear sensitivity of digested sludge: Comparison of methods and application in conditioning and dewatering

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ARTICLE INFO

Article history:
Received 26 March 2009
Received in revised form 13 June 2009
Accepted 10 July 2009
Published online 18 July 2009

Keywords:
Conditioning
Dewatering
Rheology
Shear sensitivity
Yield stress
Enzyme

ABSTRACT

Shear sensitivity of digested sludge was evaluated by two methods: a CST shear test and a strain sweep rheological method of measuring yield stress. Sludge pretreatment by an enzyme formulation was used to alter the sludge's response to shear and, potentially, to improve dewaterability. Also varied were the polymer conditioning dose and the amount of shear applied by mixing. A bench-scale device was then used to simulate dewatering by belt press in order to assess the CST shear tests and the rheological test. CST-based shear tests showed that the optimum chemical conditioner doses with low shear levels became sub-optimal with increasing mixing times. For all three polymer conditioners, longer shear times increased the dose requirements. When the polymer dose was held constant, and the extent of mixing varied, the CST test was a poor indicator of effects on dewaterability. The benefits of enzyme treatment, apparent by actual dewatering, were not predicted by the CST results. In contrast, yield stress values were significantly correlated with cake solids values, and inversely correlated with filtrate solids. Yield stress is not adequate by itself to predict final cake solids after dewatering, because enzyme pretreatment gave higher solids concentrations when both shear extent and initial yield stress were held constant.

1. Introduction

1.1. *Background*

The efficient dewatering of wastewater sludges is an important cost and operational concern. In mechanical dewatering processes, it has long been known that shear, and a sludge's response to shear, are critical properties. The development of more successful dewatering devices—evolving from vacuum filters to belt presses to centrifuges—has shown that the application of greater shear can lead to higher solids concentrations if the applied conditioning chemical can impart the needed resilience. Other types of mechanical equipment (particularly filter presses) apply greater normal forces and less shear, but still rely on the material porosity being maintained in a stress field that includes a shear component.

An improved description of shear in dewatering was the objective of this research. The topic is more than an academic exercise. An important practical concern is that final cake solids to be obtained at full scale still cannot be predicted to date with simple bench-scale procedures. Even the relative effects of shear have not been reliably correlated between lab tests and dewatering processes. Consequently, it is impossible to optimize design or operation of the costly processes of conditioning, dewatering, transportation, and reuse or disposal except by full-scale trial and error.

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0043-1354/$ – see front matter
doi:10.1016/j.watres.2009.07.015

1.2. Methods for determining sludge response to shear

1.2.1. CST-based floc strength test

The most common means of comparing dewatering properties of sludges in laboratory tests is the capillary suction time (CST) test. Although the CST test itself does not apply significant shear, a standard shearing procedure has been established in the European Community for use immediately prior to the CST test. Fig. 1 shows the geometry employed (Spinosa, 1985); the system is also available commercially (Triton Electronics, Essex, UK). For the "floc strength test," flocculated sample are withdrawn after specified periods of mixing, and tested for CST. A large rise in CST with greater mixing time indicates a weak floc, while a small rise is indicative of strong floc (Baskerville et al., 1978; Spinosa, 1985). Although this method has intuitive appeal, there is little evidence that it actually indicates a sludge's overall structural resilience during an actual dewatering process.

1.2.2. Rheological methods

A more appropriate way to quantify a sludge's structural resilience would appear to be by the use of rheological measurements. The entire sample is characterized, without defining or measuring particle or floc properties. This can be done by fairly empirical methods with evident success (Örmeci, 2007). To determine more fundamental rheological properties, new methods such as dynamic rheology and immobilization cell rheometry are available. This is crucial when characterizing conditioned or flocculated solids which behave as paste-like materials (Chaari et al., 2003) and exhibit behaviors that classical rheological models cannot describe (Dentel et al., 2005).

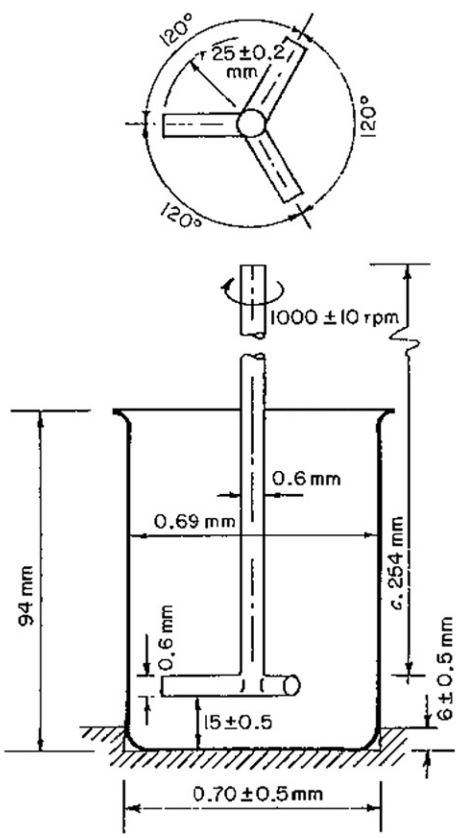

Fig. 1 – Mixing configuration for the EC Standard Shear Test. The system uses a 100 mL sample of conditioned sludge, subjected to stirring at 1000 rpm in a 250 mL beaker.

1.2.3. Other methods

To examine the second type of response to shear (erosion or structural disruption), a number of approaches are available (e.g. Jarvis et al., 2005). Most of these methods are related to settleability and thickening rather than dewatering. For example, Mikkelsen and Keiding (2002) have suggested a floc strength test for activated sludge that defined the primary particle concentration in terms of turbidity. Seka and Verstraete (2003) presented a similar test method although concerns have been raised with the approach (Dentel, 2005). Both methods assess particle release from the solids matrix, but this property has not been related to dewaterability in terms of final solids concentrations.

Researchers have also measured particle or floc size in conditioned biosolids, using various methods such as light scattering (Spicer et al., 1998) or image analysis (Wu et al., 2003) with a controlled amount of applied shear. The size of particles or flocs is then considered to be a relative index of floc strength, with the greater the applied shear, the smaller the particle size. But typically, this information is used neither to indicate the amount of free particulate material that will be released, nor the physical structure of the biosolids during the dewatering processes.

1.3. Experimental design

1.3.1. Test methods

For this research, the CST-based floc strength test was chosen for evaluation, along with a rheological method that uses a dynamic method to determine the sludge's yield strength. Both methods focus on properties of concentrated sludges prior to dewatering, rather than more dilute suspensions such as activated sludge. The yield strength method was preferred over other rheological tests because it measures a fundamental physical parameter prior to disruption of the sludge structure (Ayol et al., 2006).

1.3.2. Use of enzymes

Research on sludge conditioning and dewatering often examines the effects of varying polymer type or dosage. In this research, sludge structure was also varied by the use of enzyme pretreatment prior to polymer conditioning. Enzymatic pretreatment has led to significant improvements in dewatering under some circumstances, as reported elsewhere (Dursun et al., 2006). However, the enzyme also appeared to alter the sludge's resistance to shear, warranting further investigation.

In examining the effects of shear on sludge structure and on dewaterability, several procedural approaches are available, but experimental work comparing these methods with actual dewaterability has been sparse. The enzyme pretreatment was viewed as providing a method of deliberately changing the floc size and strength prior to use of these test methods. Dewaterability was then measured by a bench-scale