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Enhancing pulp and paper mill biosludge dewaterability using enzymes

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ABSTRACT

There have been limited studies on the potential use of enzymes for enhancing the dewaterability of biosludge. The mechanisms for such enhancement have not been investigated despite the environmental advantages of using enzymes over synthetic polymers for biosludge conditioning. In order to find enzymes with this potential, a screening of commercially available enzymes was carried out using capillary suction time to assess biosludge dewaterability. The only enzyme that showed dewatering improvements in the screening tests was a lysozyme which reduced the capillary suction time by 36% and increased the cake solids content from 5.6 to 8.9 DS%. Lysozyme aided in the flocculation of particles reducing the polymer demand from 11% to 6%. Active and inactive lysozyme exhibited a similar ability for enhancing sludge dewatering, indicating that the conditioning mechanism of lysozyme is similar to that of a flocculant.

1. Introduction

Biosludge, also known as waste activated sludge (WAS), is the most difficult to dewater among the sludges produced in wastewater treatment plants in pulp and paper mills (Goodwin and Forster, 1985; Mahmood and Elliott, 2006). To improve dewaterability, biosludge is commonly combined with primary sludge (Dorica et al., 1999). However, this practice will become problematic given an industry-wide tendency to reduce primary sludge production as pulping processes become more efficient, and to produce a larger amount of waste activated sludge as regulations become more stringent (Mahmood and Elliott, 2006). Moreover, sludge management represents a significant portion of the total cost of wastewater treatment, with the liquid–solid separation efficiency during sludge dewatering defining the energy and overall costs associated with sludge management and disposal (Ayol and Dentel, 2005; Ayol, 2005; Benítez et al., 1994; Vaxelaire and Cézac, 2004; Wood et al., 2009). Thus, there is interest in finding new approaches for improving biosludge dewaterability.

The high moisture content of sludge affects its downstream processing and disposal and reduces the possibility of recovering energy or chemicals from biosludge. In pulp and paper mills, incineration is considered to be the last resort for sludge disposal (Dorica et al., 1999). While biosludge incineration can be carried out in existing boilers, eliminating the costs of transportation, it is not cost-effective due to the high energy cost with drying a large amount of water in the

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Nomenclature

WAS	Waste Activated Sludge – Biosludge
TSS	Total Suspended Solids
TS	Total Solids
EPS	Extracellular Polymeric Substances
CST	Capillary Suction Time
pI	Isoelectric Point

biosludge. Biosludge is increasingly acknowledged as valuable in terms of energy and chemical recovery. Overall, any improvement in biosludge dewatering would lower the disposal cost and increase energy recovery.

Chemicals can be used to improve the solid–liquid separation of biosludge; however, the use of chemicals has some disadvantages. For example, the addition of inorganic chemicals increases the final sludge mass and reduces its heating value; thus, it is not a good option when sludge is to be incinerated (Albertson et al., 1987; Bolto, 2006). Alternatively, synthetic organic polymers (polyelectrolytes) are required in lower doses and do not reduce the heating value of biosludge. However, these polymers represent a significant cost and are sensitive to dose rate. If the optimum dose is surpassed, sludge dewatering becomes even more difficult, especially when considering the variable nature of sludge (Bolto, 2006). Moreover, there are environmental concerns related to the use of synthetic polymers, as some of these have been reported to be toxic to aquatic organisms (Bolto, 2006; Bolto and Gregory, 2007). The combination of chemical conditioning treatments and mechanical aids helps dewater biosludge up to 40% dry solids.

Biosludge is a complex mixture of microorganisms, organic and inorganic matter (Keiding et al., 2001; Sheng et al., 2010; Yang and Li, 2009). It has a gel-like structure due to the presence of extracellular polymeric substances (EPS) that are produced by bacteria. The EPS assist in the aggregation of particles in biosludge producing aggregates called flocs (Legrand et al., 1998). Flocs in biosludge are known to carry a net negative charge making biosludge a stable suspension and hence impeding a natural solid–liquid separation. Changing the structure of flocs could potentially improve biosludge dewatering properties. This may include releasing the water trapped inside the flocs (Vaxelaire and Cézac, 2004) and/or increasing the particle size of flocs to reduce the surface area available for binding of water molecules. Although floc properties and their impact on biosludge dewaterability have been studied previously, the key properties and the degree of their impact on dewaterability are still not well understood (Jarvis et al., 2005a, 2005b; Park, 2002; Wu et al., 1998).

Enzymes are proteins with a catalytic activity and have been previously reported as conditioners for improved sludge dewaterability. Enzymes can break EPS releasing water trapped in flocs (Ayol, 2005; Dursun et al., 2006; Thomas et al., 1993). Poor dewatering properties in biosludge have been attributed to the lack of enzymatic activity after sludge digestion resulting in excess EPS which can trap water in their gel-like structure (Ayol, 2005; Novak et al., 2003). Thomas et al. (1993) used a product with carbohydrase, lipase and protease activities on digested sludge. Their study suggested that water-binding molecules were hydrolyzed resulting in better dewaterability. The effectiveness of another enzymatic product which contained protease, lipidase, anaerobic bacteria, *Aspergillus oryzae* and other hydrolytic enzymes was evaluated in two companion papers (Ayol and Dentel, 2005; Ayol, 2005). A reduction of proteins and polysaccharides in sludge was also noted after enzymatic treatment. Laboratory and pilot scale experiments have been carried out by Dursun et al. (2006) using enzymes on anaerobically digested sludge. They found dewatering improvements in lab-scale experiments but not in pilot experiments.

The previous studies illustrate the potential of using enzymes for improving dewatering, however, an understanding of how enzymes change sludge structure and properties is lacking in the literature. Enzymatic conditioners have been studied as mixtures and although these “cocktails” are promising, their use hinders the understanding of the mechanisms involved since it is difficult to identify which of the enzymes(s) in the mixture is contributing to a given effect. Research to date has mostly been focused in enzymatic conditioners for improved dewaterability of anaerobically digested sludge. Little has been studied for the use of enzymes on waste activated sludge. Moreover, the effect of conditions such as temperature, time and mixing on the effectiveness of these conditioners has not been explored. A better understanding of the changes in the physical and chemical properties of sludge during enzymatic treatment and the associated mechanisms is important to identify key properties for improving dewatering.

The objectives of this study were:

- To carry out an enzymatic screening to identify enzymes with potential for improving biosludge dewatering;
- To determine the effect of enzyme treatment conditions such as concentration, time, temperature and mixing conditions on improving biosludge dewaterability; and
- To characterize dewaterability improvements when using enzymes for biosludge conditioning.

2. Materials and methods

A series of screening tests was performed to identify enzymes that have a positive effect on biosludge dewaterability using Capillary Suction Time (CST) as the dewatering assessment method. Of all the enzymes tested, lysozyme, was the only enzyme that showed a positive effect on biosludge dewaterability. Different concentrations of lysozyme, mixing intensities and temperatures were evaluated to identify the optimal conditions to achieve maximal biosludge dewatering. The effect of enzymes on sludge dewaterability was further evaluated with a bench-scale belt press and compared with the CST results. The effect of enzymes on reducing the demand of synthetic polymer used to enhance dewatering was also measured. Turbidity and particle size distribution were measured to investigate structural changes in flocs due to enzymatic treatment.