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Enzymatic treatment effects on dewaterability of anaerobically digested biosolids-I: performance evaluations

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Abstract

This paper reports on the ability of an enzymatic pre-treatment to significantly improve the conditioning of wastewater sludges (biosolids) significantly using by a polymeric flocculant. Experiments used anaerobically digested biosolids samples from two different municipal wastewater treatment facilities, and a formulation containing several different hydrolytic enzymes. Samples were incubated at 35 °C for 16 h then conditioned with the cationic polymer solution. A laboratory scale mechanical dewatering unit, which simulates full-scale belt filter presses, was used in dewatering of the biosolids. Dewaterability was evaluated using capillary suction time (CST), solid content of final cake product, filtrate turbidity, and suspended solids analysis. The enzyme additions enhanced dewaterability of the polymer conditioned samples in terms of CST and solids content of final product, demonstrating the possibility of significant volume reductions using enzymatic treatment at full-scale. The biosolids structures with the additions of enzyme, polymer, and both additives were determined using field emission scanning electron microscopy.

Keywords: Biosolids; Anaerobic digestion; Dewaterability; Enzymes; Drainability; Filterability; SEM

1. Introduction

Anaerobic digestion is one of the more commonly used stabilization processes in sludge management, providing effective pathogen destruction, reduction of volatile solids and odour potential and an energy source in the form of biogas. Although, it has these advantages, the stabilization process may lead to poorer dewatering characteristics, which means higher chemical requirements in biosolids conditioning, lower quality of final processed biosolids, and higher operation and disposal costs.

Microorganisms and microbial-environment conditions are crucial in this process as in other biological treatment processes. During the anaerobic digestion of biosolids, the first stage in the degradation of particulate organic matter is the solubilization and enhanced hydrolysis of complex polymeric organic carbon structures.

Bacteria are usually contained within a flocculated matrix of exopolymeric substances. When biopolymers are released from this floc structure as biocolloids, their properties hinder effective dewatering of the biosolids and are responsible for a significant portion of the polymer demand in the chemical conditioning prior to dewatering processes [1].

The exopolymeric substances also act as a network that confines extracellular enzymes exhibiting hydrolytic activity [2]. Jain et al. [3] showed that both the concentration of hydrolytic enzymes and the contact between these enzymes and their substrates, were very important in their modeling studies of anaerobic digestion of complex particulate substrates.

Novak et al. [1] studied the mechanisms of floc destruction during anaerobic and aerobic digestion and their effects on conditioning and dewatering of biosolids in laboratory scale studies. They showed that enzyme activity declines during both anaerobic and aerobic digestion. For aerobic digestion, glucosidase activity, indicating polysaccharide degradation potential, decreased to zero by day 10 of digestion time. The loss of the activity explained why polysaccharide accumulates during aerobic digestion, while most of the protein is degraded. Under anaerobic conditions,

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enzymatic activity for both protein and polysaccharide degradation declined, but remained higher than during aerobic digestion.

Given the above observations, it would seem logical to supplement the active enzymatic systems in these biosolids. If this serves to enhance the degradation of extracellular polymeric substances, then the resistance to dewatering might be lessened and the amount of polymer required for conditioning might be reduced.

An enzymic supplement for this purpose would not necessarily require an expensive, purified product. Although relatively pure enzyme extracts are required for some applications (such as in clinical diagnosis and in food processing), many useful industrial enzyme preparations are not highly purified. Such enzyme mixtures may include a variety of enzymes capable of numerous catalytic functions, and thus, are useful for very heterogeneous substrates in many industrial applications [4].

This possibility has been explored in one previous study. Thomas et al. [5] added an enzyme product (Degomma 7083®, containing carbohydrase, lipase and proteinase activities) to digested biosolids, which were then incubated approximately 16 h. Laboratory tests showed improved dewaterability, as indicated by CST reductions of 50%. These results are somewhat uncertain because the control sample (with no enzyme addition) was also fairly dewaterable, with a CST of 29 s. However, drainage volumes from sieving tests were increased by up to 43%. Full-scale tests with dewatering by belt filter press showed cake solids improvements of +2.2 to +4.3%, representing potential decreases in sludge mass of 8.4–13.3%. This paper mentioned that polymer was required following the enzyme treatment, and also that comparable results were obtained with primary sludge and waste activated sludge. However, no subsequent reports from these authors could be located, and the use of enzymes for improved dewatering is not known to have been proven in any subsequent studies.

In addition, there have been no reports on whether enzymatic pre-treatment alters the requirement for flocculant polymer. In evaluating the feasibility of using an enzyme, this is likely to be an important cost consideration.

2. Objectives

The objectives of the study were therefore:

- to determine whether previously reported enzymic treatment effects could be reproduced or improved, based on both the standard laboratory tests of dewaterability and on the performance of a bench-scale dewatering process;
- to determine whether enzyme pre-treatment changes the amount of polymer required for conditioning, and if so, how the combined used of enzymes and polymer can be optimized;
- to determine whether enzymatic treatment changes the physical or chemical properties of conditioned biosolids; and
- to determine whether enzyme pre-treatment can be optimized with polymer dosage to provide a feasible means of improving biosolids dewatering.

The overall objective of this project was to determine the feasibility of combining enzyme use with polymer conditioning, based on possible improvements in the cost and performance of biosolids dewatering. A companion paper reports on additional work required to complete this determination.

3. Materials and methods

3.1. Materials

Anaerobically digested biosolids were collected from two municipal wastewater treatment facilities, the Newtown Creek Wastewater Treatment Facility in New York City, NY and the Wilmington Wastewater Treatment Facility in Wilmington, DE. These are designated as NYC and WIL samples, respectively.

Polymer conditioning tests were conducted using Percol 757, a high molecular weight, cationic copolymer consisting of 65% AMD (acrylamide monomer) and 35% AETAC (acryloyloxyethyl trimethylammonium chloride) by mole percent, with the monomer structures shown in Fig. 1. Polymer stock solutions were prepared at a 0.5% w/v concentration according to Dentel et al. [6].

A commercial product (Enviro-Zyme 216, Winston Company, Inc., Tulsa, USA) was used for enzymic pre-treatment, which contains protease, lipidase, anaerobic bacteria, *Aspergillus oryzae*, and an enzyme complex mixture (other hydrolytic enzymes). This is a dry powder product. Enzyme stock solution (2%, w/v) was prepared using warm water.

3.2. Experimental procedures

The dry solid contents of NYC and WIL biosolids were found to be 3.2 and 2.6%, respectively. The samples without enzyme and with different enzyme concentrations were first incubated at 35 °C for 16 h. For full-scale application, this could be accomplished using either a secondary digester or a post-settler.

These samples were then conditioned using different volumes of Percol 757 polymer stock solution. The polymer was added to 500 mL volumes of the biosolids samples contained in standard 1 L beakers. Intensive mixing was provided with a household-blending mixer (Braun Multipractic) for 15 s.

To evaluate the filterability of these samples, capillary suction time (CST) analyses were then performed using a