Improved waste-activated sludge dewatering using sludge/oil emulsion, ultrasonic and microwave technologies

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ABSTRACT

Conventional dewatering technologies, such as centrifuges, belt filter presses, and rotary vacuum filters, are not effective methods for treating sewage sludge with high water content. This study evaluated the field-scale feasibility of new technologies that use emulsion, ultrasonication, and microwaves to dewater sludge. Emulsion technology lowered the water content in sludge to 60%, but the overall process was too complex to incorporate into the design of commercial plants due to the requirement for oil- and methanol-recovery facilities. Ultrasonication had low dewatering and energy efficiency with long irradiation times, indicating that it would be difficult to implement in a field plant. The water content of sludge was reduced to 60% within 120 s using microwaves, but dewatering efficiency depended on the thickness and volume of the sludge. In a pilot-scale test, the average energy consumption was 0.54 kWh/kg of water removed, and the final water content of the sludge cake reached 60% within 30 min.

Keywords: emulsion, energy efficiency, microwave, sludge dewatering, ultrasonication

INTRODUCTION

In recent years, the production of waste-activated sludge in municipal wastewater treatment plants has increased significantly. Treatment and disposal methods for municipal wastewater sludge include landfilling, ocean disposal, incineration, and composting, but direct landfills have been banned since July 2003 (MOE, 2003), and ocean disposal was outlawed in January 2012 (MOF, 2009). Thus, the recycling of sludge has been encouraged (e.g., composting, raw material for cement, and cover soil for landfilling), which is a prerequisite for reducing sludge volume and weight.

Sludge dewatering is a fundamental step in sludge processing because it decreases sludge volume and consequently the cost of transporting the sludge to its final disposal site. However, the high water content and biological gel-like structure of sludge render it difficult to dewater. Thus, suitable sludge conditioning processes should be performed before sludge dewatering. The moisture content of municipal wastewater sludge must be reduced significantly before its incineration and composting. Except for the drying method, however, existing technologies have technical limitations. The water content of activated sludge can be decreased to approximately 80% with existing mechanical dewatering technologies. To this end, various methods have been proposed to improve sludge dewaterability, such as the addition of acids and surfactants, Fenton's reagent pre-treatment, fungal treatment, ultrasonication, and microwave irradiation (Chen et al., 2001; Eskicioglu et al., 2007; Fakhru'l-Razi and Molla, 2007; Tony et al., 2008; Feng et al., 2009a; 2009b; Yu et al., 2009).

Chemical conditioning is a tactic that improves mechanical dewatering, flocculating the sludge with conditioners, such as calcium oxide, ferric chloride, and polyacrylamide (Chen et al., 2001). Also, thermal and thermochemical processes and chemical oxidation using hydrogen peroxide can enhance cake dewaterability in two ways: (i) they degrade extracellular polymeric substances (EPS) proteins and polysaccharides reducing the water retention properties; and (ii) they promote flocculation which reduces the amount of fine flocs (Neyens et al., 2004). However, the operating cost for sludge dewatering by these methods is relatively expensive compared to that for conventional transportation and disposal (Chitikela and Dentel, 1998; Lee and Liu, 2001; Dentel, 2010).

Alternatively, dewatering technologies using ultrasonic, electro-osmotic, and microwave treatments have been examined (Raats et al., 2002; Dewil et al., 2006; Na et al., 2007; Huan et al., 2009; Feng et al., 2009a). Na et al. (2007) observed that ultrasonic treatment of waste-activated sludge improved the dewaterability, as evidenced by decreases in capillary suction time (CST) with increasing ultrasonic energy dosages. Feng et al. (2009a) reported that low-energy dosage slightly enhanced sludge dewaterability, while high-energy dosage significantly decreased sludge dewaterability in ultrasonic treatment; the optimal energy dosage generated sludge with optimal EPS concentration and particle size distribution. Also, Dewil et al. (2006) reported that the dewaterability decreases with increasing specific energy. The rate of dewatering also decreases, as evidenced by a higher CST.

Industrial use of microwave heating as an alternative to conventional heating methods in chemical reactions is becoming popular, primarily due to its dramatic reactions and reaction times (Eskicioglu et al., 2007). Many studies have analysed the effects of microwave irradiation on biological and chemical systems using various microwave and conventional heating units and experimental techniques and approaches. In particular, Eskicioglu et al. (2007) observed that a thermal microwave

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