Evaluation and Installation of a Thermochemical Hydrolysis Process at the Kenosha Wastewater Treatment Plant

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Sludge hydrolysis pretreatment for anaerobic digestion increases biogas production, enhances volatile solids reduction, and improves dewaterability of digested sludge (Abelleira-Pereira et al., 2015; Ruiz-Hernando et al., 2013; Schieder et al.; 2000). Conventional thermal hydrolysis treatment applies high temperature and high pressure to achieve an adequate hydrolyzing effect of treated sludge (Feng et al., 2014; Schieder et al., 2000).

Thermochemical hydrolysis process (TCHP) combines both thermal treatment and chemical treatment for sludge hydrolysis. The TCHP can be achieved below boiling temperature and could be applied at small to mid-sized utilities. Both sodium hydroxide (Neyens et al., 2003; Zhang et al., 2015) and hydrogen peroxide (Abelleira-Pereira et al., 2015) have been applied for thermal chemical treatment. The PONDUS TCHP utilizes heat (60°C-70°C) and sodium hydroxide. Though six full-scale PONDUS TCHP installations are in operation, the TCHP is still at the early stages of technology adaptation.

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Dewaterability of sludge is an important economic driver of implementing sludge hydrolysis technologies. Maximizing sludge dewaterability is especially important when wastewater treatment plants (WWTPs) are facing high sludge disposal costs (Aichinger et al., 2015; Takaoka et al., 2014). Thermal hydrolysis pretreatment of sludge for anaerobic digestion is reported to improve sludge dewaterability in relation to dry cake solids and polymer dosage (Neyens and Baeyens, 2003). This study evaluated the impact of TCHP on the dewaterability of anaerobically digested sludge.

Improvement of sludge rheology for better sludge transfer and mixing is another benefit of the sludge hydrolysis process (Higgins et al., 2017; Urrea et al., 2015). Thermal hydrolysis pre-

Figure 1. Thermochemical hydrolysis process (TCHP) installation at the Kenosha Wastewater Treatment Plant.

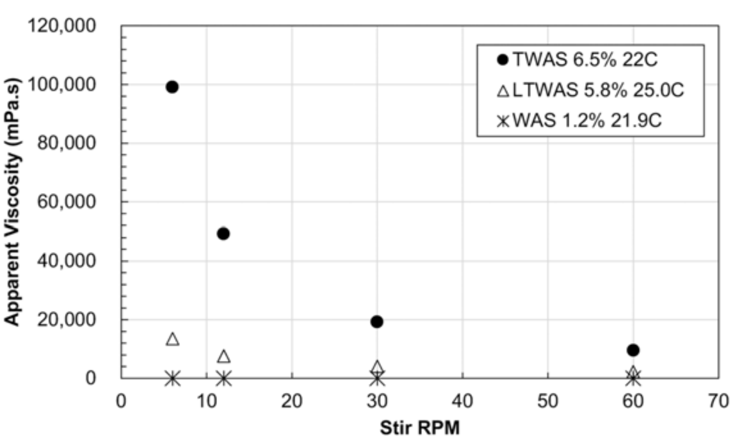

Figure 2. Dynamic viscosities of waste activated sludge, thickened waste activated sludge, and lysed thickened waste activated sludge near room temperature.

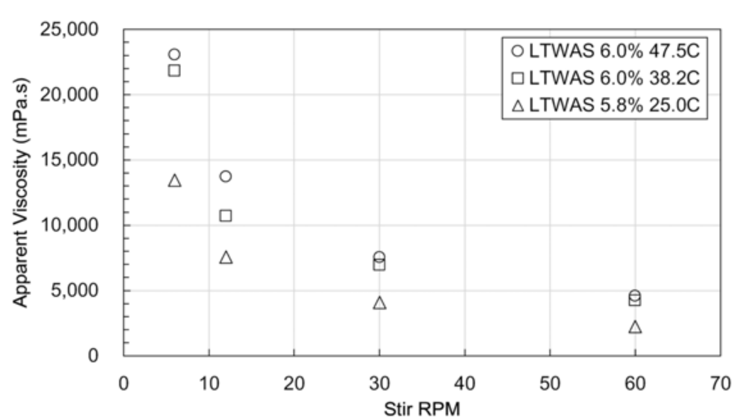

Figure 3. Dynamic viscosities of lysed thickened waste activated sludge during the cooling test.

treatment significantly decreases sludge viscosity (Bougrier et al., 2008; Feng et al., 2015) and enables better mixing in anaerobic digesters (Baudez et al., 2011). Sludge viscosity reduction allows better mixing and higher solids loading in anaerobic digesters in the Kenosha WWTP. On average, the TCHP achieves 80 percent reduction of thickened waste activated sludge (TWAS) viscosity. The implementation of the TCHP enables the plant to reduce six operating mesophilic digesters to three, realizing significant savings of digester heating, pump maintenance, and laboratory monitoring costs.

The objective of this study was to evaluate the impact of a TCHP process on the rheology of TWAS, the biogas production, and the dewaterability of anaerobically digested sludge. Dynamic viscosities of TWAS and lysed TWAS (LTWAS) were monitored. Cell lysis of TWAS was confirmed by microscope examination and biogas production; volatile solids reduction (VSR) and volatile solids volumetric loading were also evaluated. The results of this study may provide reference information for technology evaluation.

Materials and Methods

The Kenosha WWTP, with a current average wastewater flow of 22 mil gal per day (mgd), implemented a PONDUS TCHP in 2015 as a key upgrade of its energy-optimized resource recovery project. The TCHP was commissioned in March 2016 and occupies part of a basement with a 40-ft by 30-ft footprint at the plant (Figure 1). The TCHP includes a hydrolysis reactor, a heat exchanger, a recirculation pump, and temperature and pressure sensors. The TCHP operates with atmospheric pressure and low-grade hot water (80°C-90°C), ensuring a safe working environment requiring no specialized certification. Operation costs mainly consist of sodium hydroxide (NaOH) consumption (20-lb NaOH/dry-ton sludge). Hot water is supplied from the exhaust heat of two combined heat and power units. Required operator time is less than 0.5 hours/day based on more than two years of operation experience.

Kenosha Water Utility (KWU) partnered with Centrisys/CNP for a performance evaluation of the implemented TCHP. Total solids (TS), volatile solids, biogas production, sludge flow rate, and solids loading rate were provided by the laboratory at KWU. Centrisys/CNP conducted dynamic viscosity test of waste activated sludge (WAS), TWAS, LTWAS, and digested sludge using a rotational viscometer (Thermo Fisher Scientific, Calif.). The changes of dynamic viscosities of LTWAS during the cooling process were evaluated at 47.5°C, 38.2°C, and 25°C. Floc

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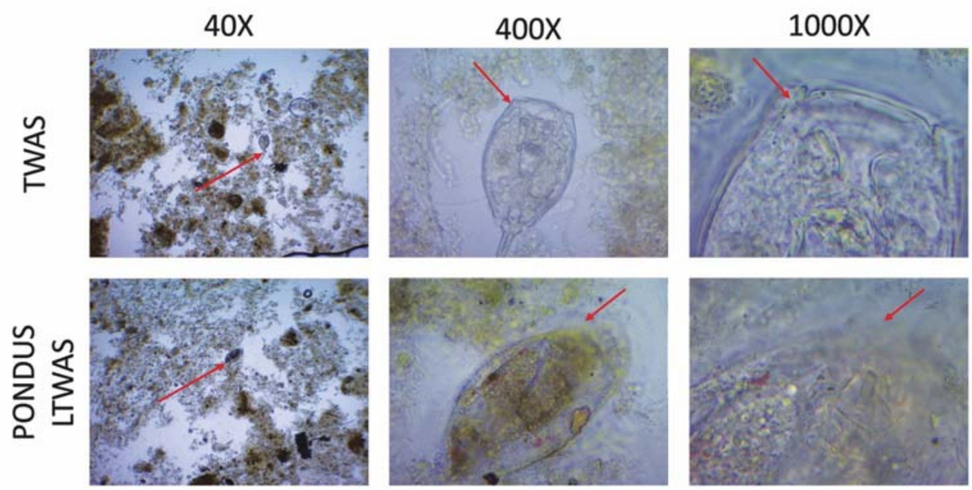

Figure 4. Floc morphology of thickened waste activated sludge and lysed thickened waste activated sludge before and after thermochemical hydrolysis process treatment.

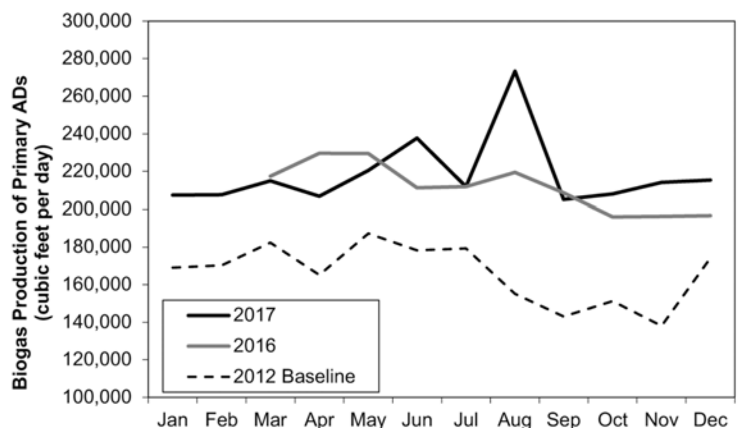

Figure 5. Biogas production from primary anaerobic digesters of baseline year (2012) and project year (2016-2017). A peak biogas production was observed in August 2018 during a grease codigestion test.

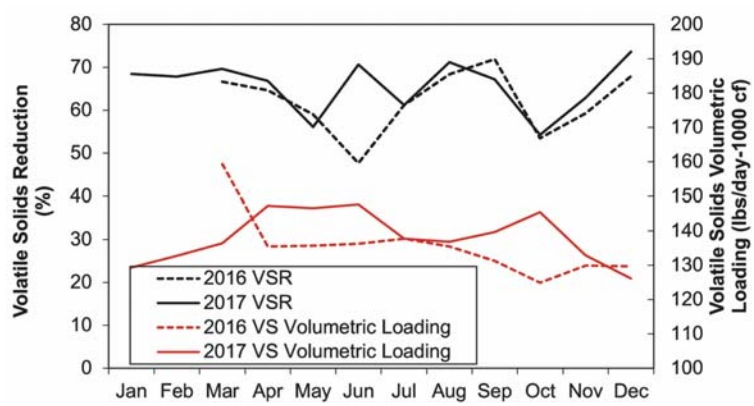

Figure 6. Volatile solids reduction and volatile solids volumetric loading after implementing the thermochemical hydrolysis process.

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morphology of TWAS and LTWAS was evaluated under a microscope (AmScope, Ill.) at 40x, 400x, and 1000x magnifications. Floc images were captured by a charge-coupled device (CCD) camera installed on the microscope.

The VSR was evaluated with care. The KWU implemented a fine screen (FSM Filterscreen®) at the plant headwork and hydraulic mixing system (Vaughan Rotamix®) in anaerobic digesters as part of the upgrade project. In general, the Kenosha WWTP achieved satisfactory grit removal at the plant headwork and provided high-efficacy digester mixing. It was assumed that minimal grit accumulation would occur in the anaerobic digesters; therefore, the Van Kleeck method was selected for calculating VSR (Brobst, 2011).

Results

Change of Thickened Waste Activated Sludge Rheology

In order to increase the capacity of the anaerobic digester, WAS was thickened to 6 to 7 percent TS at the Kenosha WWTP. Near 80 percent reduction of dynamic viscosity was observed after TWAS went through PONDUS treatment, as shown in Figure 2. Both TWAS and LTWAS were non-Newtonian fluid; however, the change of dynamic viscosity of LTWAS at different shear rates was less significant, compared with that of TWAS.

Figure 3 evaluates the dynamic viscosity of LTWAS under different temperatures. No significant change of the dynamic viscosity of the TLWAS was observed during the sludge cooling test. This observation was beneficial since the data suggested that LTWAS could be held for a longer time or be transported long distances at a lower temperature.

Floc morphology of TWAS and LTWAS are compared in Figure 4, with a rotifer selected as a target microorganism for comparison. Floc images at 1000x magnification clearly indicated the damage of cell structure on the rotifer. The combined effects of thermal treatment and chemical treatment on microorganisms could facilitate release of inner cellular organics. This observation was in agreement with other studies focusing on thermal hydrolysis (Bougrier et al., 2008; Feng et al., 2015).

Biogas Production and Volatile Solids Reduction

The TCHP improved the biogas production of the anaerobic digestion process. Figure 5 indicates 20 percent more biogas production after the implementation of the TCHP, compared to the baseline year of 2012. A peak biogas production month was observed in August 2017 when the KWU tested grease codigestion in one of the primary digesters. The VSR remained around 63 to 70 percent despite an occasionally low value of 55 percent due to the receiving of aluminum sludge from the Kenosha Drinking Water Treatment Plant (Figure 6). The volumetric loading of volatile solids varied between 130-160 lb/1000 cu ft (ft^3), which was doubled from the <80 lb/1000 ft^3 before TCHP implementation.

Dewaterability of Anaerobically Digested Sludge

The cake solids of dewatered anaerobically digested sludge were reported under the same polymer dosing condition (Figure 7). Before the TCHP was adopted, the average cake solids value was at around 26 percent. The cake solids improved gradually during the TCHP start-up phase, and stabilized around 28 to 31 percent. It's worthwhile to note that KWU did not intend to maximize cake solids due to sludge cake pumping at the subsequent sludge dryer.

Figure 8 evaluates the dewatering polymer curve before and after TCHP implementation, within the temperature range of 28°C and 30°C. The optimum polymer dosage reduced from higher than 43 active lb/dry-ton to about 35 active lb/dry-ton. Within the optimum dosing range for treated sludge, a constant 3.5 to 4 percent increase in cake dryness was observed.

Conclusion

The impacts of the TCHP on sludge viscosity, floc morphology, biogas production, and dewaterability were evaluated at the Kenosha WWTP. The TCHP reactor effectively hydrolyzed TWAS, with total solids around 7 percent, and biogas production was increased by higher than 20 percent. The VSR was maintained around 63 to 70 percent, with VS volumetric loading of 130-160 lb/1000 ft^3. Implementation of thermochemical hydrolysis improved the dewaterability of anaerobically digested sludge by >3.5 percent, with maximum cake dryness of 31 percent.

The results of this study suggest that the thermochemical hydrolysis can effectively reduce sludge viscosity, enhance biogas production, and improve sludge dewaterability.

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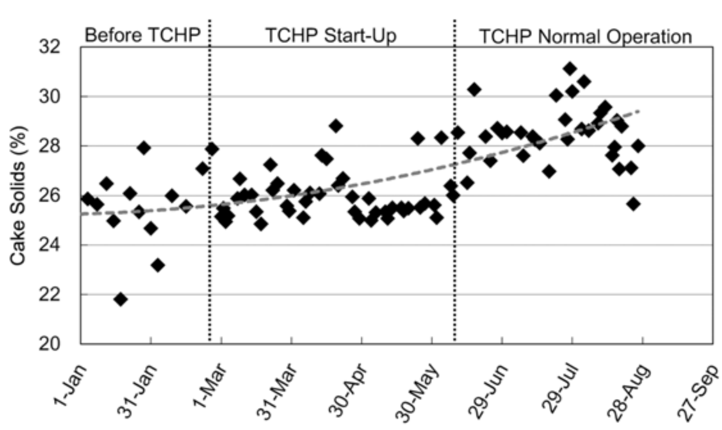

Figure 7. Change of dewatering cake solids of anaerobically digested sludge during the start-up of the thermochemical hydrolysis process.

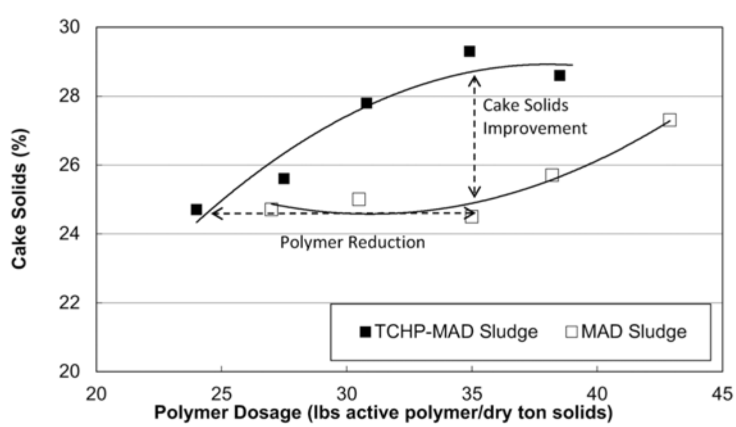

Figure 8. Polymer curves of dewatering anaerobically digested sludge with and without thermochemical hydrolysis process pretreatment of thickened waste activated sludge.

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