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Review

Pretreatment technologies for advancing anaerobic digestion of pulp and paper biotreatment residues

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ABSTRACT

While anaerobic digestion is commonly practiced in the municipal sector, it has not gained popularity in the pulp and paper industry mainly because of its long sludge residence time requirement of 20–30 days. The construction of large digesters to provide such extended residence times is capital-intensive and thus the implementation of anaerobic digestion has remained economically prohibitive. A review of the literature suggests that recent developments in sludge preconditioning technologies have substantially reduced the sludge residence time requirement to the order of 7 days. Also, the preconditioned sludges have been reported to hold potential for higher methane recovery with reduced excess sludge production requiring disposal. Such advantages, coupled with escalating fuel prices and the introduction of carbon credits under the Kyoto Accord, have significantly improved the economics of anaerobic digestion. As the cost of sludge management varies from one mill to another, mill-specific economic assessment of anaerobic digestion could identify cost-saving opportunities.

Contents

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1. Introduction

While aerobic wastewater treatment (WWT) processes are commonly used in the Canadian pulp and paper industry, the use of anaerobic WWT technologies is limited to a few installations. There have been only four anaerobic treatment plants installed at Canadian pulp and paper mills, exclusively for the treatment of pulp and paper effluents. Of the four installations, two are currently in operation. The Lake Utopia, Irving mill has operated an anaerobic BIOPAQ© upflow anaerobic sludge blanket (UASB) reactor for effluent treatment for over a decade. Energy recovery (15,100 m^3/d of methane produced) represents a substantial cost saving for this mill (Smith et al., 1994). Tembec, Témiscaming has recently installed a similar UASB reactor for the treatment of two of its high-strength mill streams. Anaerobically treated wastewaters at Lake Utopia and Témiscaming are discharged to aerobic bioreactors for polishing before discharge to receiving waters. Similarly, the American Israeli Paper mill in Hadera, Israel, uses an UASB reactor for pretreating the entire mill effluent before discharging into an activated sludge system. The amount of excess sludge produced by the activated sludge system has been reported to be reduced by 75% due to BOD off-loading (Stahl et al., 2004). Anaerobic technology has also been used for treating a selected process stream within a pulp and paper mill. For example, an in-line application at the Zülpich mill, in Germany, successfully treats whitewater for its reuse within the mill (Habets and Knelissen, 1997).

In the municipal sector, anaerobic digestion of solid residues is commonly practiced to stabilize sludge, reduce volume, and, at least partially, disinfect solids prior to disposal. Many of these installations have the added benefit of energy recovery from the methane produced. However, to the best of our knowledge, there is no full-scale anaerobic digestion facility in the pulp and paper sector for the digestion of solid residues.

In the late 1980s and early 1990s, several investigations were conducted to explore the use of anaerobic digestion for treating pulp and paper solid residues (Kowalczyk and Martynelis, 1989; Poggi Varaldo et al., 1997; Puhakka et al., 1988; Puhakka, 1991). The studies were performed on both laboratory and pilot-scale systems. Generally, the results of these studies showed that anaerobic digestion of pulp and paper biosolids could reduce solid wastes by 30–70%, with the benefit of methane production. However, high operating and capital costs appeared to be the reasons for the lack of subsequent mill installations. An economic assessment of anaerobic digestion of waste activated sludge (WAS) was performed in 2002 at Paprican, Quebec, Canada (unpublished study, 2002) to determine its potential for implementation in the pulp and paper industry. Specifically, the assessment focused on cost and benefits of the anaerobic technology if installed at a selected thermomechanical pulp (TMP) mill in Quebec. A pilot-scale mesophilic anaerobic digester was operated to determine WAS reduction potential and dewatering properties of the digested sludge. The data were then used in conjunction with mill sludge management data to determine the economic feasibility of implementing anaerobic digestion at this mill. The payback period for the capital equipment was estimated to be over 9 years, which at the time made the technology cost prohibitive. Recent escalation of energy costs, the introduction of carbon credits under the Kyoto Accord, and technical advances in the anaerobic technology have subsequently made anaerobic digestion of WAS a more cost-effective alternative to disposal. Especially so, as technological advances hold potential for higher methane recuperation while using smaller reactors.

Generally, only approximately one half of the organic matter in WAS is susceptible to anaerobic biodegradation, resulting in the formation of biogas. The remaining non-digestible material is either inorganically bound carbon or slowly digestible organics. The majority of anaerobic digesters operating in the municipal sector use single-phase mesophilic reactors (Erdal et al., 2006). The use of thermophilic digesters has recently become more attractive due to their superior performance, better pathogen destruction, and higher digestion rates, which allow the anaerobic digestion facilities to operate at higher loading rates (Erdal et al., 2006) with smaller reactor volumes. Thermophilic digestion can reduce the amount of difficult-to-degrade organic materials, thus improving the overall removal efficiency of organics. Negative aspects of thermophilic digestion include increased operator attention, higher odor potential, higher susceptibility to process upsets, and poorer quality of dewatering filtrate (Erdal et al., 2006; Tchobanoglous et al., 2003). Two-stage digestive systems, which segregate the formation of volatile fatty acids from methanogenesis, have also been developed, improving the overall digester performance.

Another fairly recent technological advancement that potentially can make anaerobic digestion more feasible has been the development and establishment of pretreatment of sludge prior to anaerobic digestion to accelerate the hydrolysis of sludge. Pretreatment enhances sludge digestion and the rate and quantity of biogas generated, thereby reducing the retention time requirement from 15 to 25 days to approximately 7 days. Feasibilities of most of these pretreatment technologies have been demonstrated using municipal activated sludges. Table 1 provides a comparison of municipal and pulp and paper secondary sludge characteristics. Differences do exist, which could impact the effectiveness of pretreatment. For instance, the higher volatile fraction for the pulp and paper sludges could make them more amenable to pretreatment technologies. The following pages summarize most of the technologies that have been suggested as pretreatments.