WATER RESEARCH 65 (2014) 321–349

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Review

Anaerobic digestion of pulp and paper mill wastewater and sludge

Torsten Meyer[*], *Elizabeth A. Edwards*

Department of Chemical Engineering and Applied Chemistry, University of Toronto, 200 College St., ON, Canada M5S3E5

ARTICLE INFO

Article history:
Received 2 March 2014
Received in revised form
20 June 2014
Accepted 12 July 2014
Available online 24 July 2014

Keywords:
Anaerobic treatment
Anaerobic digestion
Pulp
Paper
Wastewater
Sludge

ABSTRACT

Pulp and paper mills generate large amounts of waste organic matter that may be converted to renewable energy in form of methane. The anaerobic treatment of mill wastewater is widely accepted however, usually only applied to few selected streams. Chemical oxygen demand (COD) removal rates in full-scale reactors range between 30 and 90%, and methane yields are 0.30–0.40 m^3 kg^{-1} COD removed. Highest COD removal rates are achieved with condensate streams from chemical pulping (75–90%) and paper mill effluents (60–80%).

Numerous laboratory and pilot-scale studies have shown that, contrary to common perception, most other mill effluents are also to some extent anaerobically treatable. Even for difficult-to-digest streams such as bleaching effluents COD removal rates range between 15 and 90%, depending on the extent of dilution prior to anaerobic treatment, and the applied experimental setting. Co-digestion of different streams containing diverse substrate can level out and diminish toxicity, and may lead to a more robust microbial community. Furthermore, the microbial population has the ability to become acclimated and adapted to adverse conditions. Stress situations such as toxic shock loads or temporary organic overloading may be tolerated by an adapted community, whereas they could lead to process disturbance with an un-adapted community. Therefore, anaerobic treatment of wastewater containing elevated levels of inhibitors or toxicants should be initiated by an acclimation/adaptation period that can last between a few weeks and several months. In order to gain more insight into the underlying processes of microbial acclimation/adaptation and co-digestion, future research should focus on the relationship between wastewater composition, reactor operation and microbial community dynamics. The potential for engineering and managing the microbial resource is still largely untapped.

Unlike in wastewater treatment, anaerobic digestion of mill biosludge (waste activated sludge) and primary sludge is still in its infancy. Current research is mainly focused on developing efficient pretreatment methods that enable fast hydrolysis of complex organic matter, shorter sludge residence times and as a consequence, smaller sludge digesters.

Previous experimental studies indicate that the anaerobic digestibility of non-pretreated biosludge from pulp and paper mills varies widely, with volatile solids (VS) removal rates of 21–55% and specific methane yields ranging between 40 and 200 mL g^{-1}

* *Corresponding author*. 200 College St. Toronto, ON, Canada M5S 3E5. Tel.: +1 416 946 3690.
E-mail address: torsten.meyer@utoronto.ca (T. Meyer).
http://dx.doi.org/10.1016/j.watres.2014.07.022

VS fed. Pretreatment can increase the digestibility to some extent, however in almost all reported cases, the specific methane yield of pretreated biosludge did not exceed 200 mL g^{-1} VS fed. Increases in specific methane yield mostly range between 0 and 90% compared to non-pretreated biosludge, whereas larger improvements were usually achieved with more difficult-to-digest biosludge. Thermal treatment and microwave treatment are two of the more effective methods. The heat required for the elevated temperatures applied in both methods may be provided from surplus heat that is often available at pulp and paper mills. Given the large variability in specific methane yield of non-pretreated biosludge, future research should focus on the links between anaerobic digestibility and sludge properties. Research should also involve mill-derived primary sludge. Although biosludge has been the main target in previous studies, primary sludge often constitutes the bulk of mill-generated sludge, and co-digestion of a mixture between both types of sludge may become practical. The few laboratory studies that have included mill primary sludge indicate that, similar to biosludge, the digestibility can range widely. Long-term studies should be conducted to explore the potential of microbial adaptation to lignocellulosic material which can constitute more than half of the organic matter in pulp and paper mill sludge.

Contents