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Influence of microwave pre-treatment on sludge solubilization and pilot scale semi-continuous anaerobic digestion

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HIGHLIGHTS

- The effects of a microwave pre-treatment on anaerobic digestion were studied.
- The microwave treatment resulted in a significant solubilization of organic matter.
- Volatile fatty acid concentration increased during the treatment.
- A 50% increase in biogas production was observed for a retention time of 20 days.

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ABSTRACT

Anaerobic digestion is widely applied for the recovery of energy from waste activated sludge. Pre-treatment methods are of high interest to increase the biodegradability of the sludge and to enhance the digestion efficiency. This paper studies the application of a microwave pre-treatment. An experimental set-up of two pilot scale semi-continuous digesters was used. During a long term experiment, one of the reactors was fed with untreated sludge, while microwave pre-treated sludge (336 kJ/kg sludge) was introduced in the second one. A solid retention time of 20 days was kept during the experiments. (Organic) dry solids, carbohydrates, proteins and volatile fatty acids were monitored during digestion. It was seen that the microwave pre-treatment resulted in an effective solubilization of the organic matter in the sludge. The changes to the sludge composition resulted in an increase in biogas production by 50%, while the methane concentration in both reactors remained stable.

1. Introduction

The huge amounts of waste sludge that are annually generated in biological wastewater treatment plants represent a problem of growing importance. The production of excess sludge is an inevitable drawback inherent to the waste activated sludge system, and the expansion of the wastewater treatment infrastructure will lead to a further increase in sludge production in the future. Anaerobic digestion is generally recognized as a valuable step in the treatment of waste sludge, mainly because of the production of an energy rich biogas (55–70% CH_4), which can be valorized energetically (Appels et al., 2008). Other beneficial properties include the ability to reduce the overall load of sludge to be disposed, the stabilization of the sludge, the improvement of sludge dewaterability and the reduction of pathogens (Appels et al., 2011).

One of the main drawbacks of anaerobic digestion, however, is the rather slow degradation of the particulate organic matter, which leads to long residence times and/or low degradation efficiencies. This is mainly attributed to the hydrolytic stage of the anaerobic digestion, which is considered to be rate limiting (Abelleira et al., 2012). In this sense, a lot of research attention has been paid to pre-treatment methods that cause a disintegration of the sludge (accompanied by the solubilization of organic material) and hence succeed in partially bypassing the hydrolytic stage and leading to a higher biogas production. Different techniques have been studied, including chemical (Dewil et al., 2007), mechanical (Zhang et al., 2012), ultrasonic (Bougrier et al., 2005), enzymatic (Barjenbruch and Kopplow, 2003) and thermal (Val del Río et al., 2011) treatments.

Microwave (MW) pre-treatment is an alternative method to conventional thermal pre-treatment and its potential has been well recognized in sludge treatment (Mudhoo and Sharma, 2011). Microwave irradiation is electromagnetic radiation with a wavelength between 1 mm and 1 m, corresponding to an oscillation frequency of 300–0.3 GHz (Eskicioglu et al., 2007a). Domestic "kitchen" microwave ovens and industrial microwave generators are generally operating at a frequency of 2.45 GHz with a corresponding wavelength of 12.24 cm and energy of 1.02×10^{-5} eV (Jones et al., 2002; Eskicioglu et al., 2007a; Tang et al., 2010).

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