Electrokinetic disintegration for an improvement in sludge digestion yield

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Abstract: Thickened waste activated sludge (TWAS) was electrokinetically pre-treated to improve its biodegradability, before being fed to parallel small pilot scale semi-continuous anaerobic digesters. Different specific energies (from 0.040, 0.053, 0.066 and 0.091 kJ/kg sludge) were applied, hence enabling to compare the effectiveness of the pre-treatment methods towards sludge solubilization and biogas production enhancement. It was seen that 0.091 kJ/kg sludge was most effective in COD solubilization. In terms of biogas and energy production, the best results were obtained with the TWAS treated with 0.053 kJ/kg sludge: 24% extra biogas was produced compared to the control reactor and a net energy gain of 9.06 kWh/ton TWAS was obtained.

Keywords: anaerobic digestion, pre-treatment, electrokinetic disintegration

Introduction

Anaerobic digestion as a sludge treatment step is widely known. Organic matter in the thickened waste activated sludge (TWAS) is transformed into an energy-rich biogas (55-70 % methane), which results in a reduction of the volume of biosolids that needs to be disposed. Biogas production via anaerobic digestion is often limited by the slow hydrolysis rate and can be improved by pre-treating the WAS before introduction into the anaerobic digesters. Various sludge pre-treatment methods including thermal, chemical, biological, ultrasonic, and mechanical methods have been investigated and further developed to enhance the hydrolysis rate (Houtmeyers et al., 2014; Appels et al., 2013; Tyagi et al., 2014)

In the present paper, an electrokinetic disintegration technique is applied as an innovative TWAS pre-treatment method. A strong electrical field across a porous medium (in this case WAS) induces the movement of the electrolyte solution and the transport of the soluble contaminants towards the electrodes. The high voltage creates pore openings (electroporation) in the cell walls and intracellular material will be released into the soluble phase and will be readily available for anaerobic microorganisms (Kim et al., 2002; Yu et al., 2014; Yuan et al., 2006).

Material and Methods

The digestion experiments were performed using three parallel completely mixed pilot-scale digesters (50 L volume), maintained at 37 °C via a heating mantle. The experiments were run for several months, with a hydraulic retention time of 20 days. One digester was fed with untreated (i.e., reference reactor) TWAS and the other digesters with electrokinetic pre-treated TWAS.

The electrokinetic disintegration unit consists of 2 BioCrack® modules (each with a power requirement of 35W) with an internal electrode, through which the TWAS was pumped back and forth under constant flow. The effect of circulating the TWAS through 4, 8 and 16 modules was investigated. Large components within the TWAS were removed with a
macerator before it entered the disintegration unit in order to protect the equipment. Main sludge parameters including total solids (TS) and volatile solids (VS) content, total and soluble COD concentration and carbohydrate concentration were measured throughout the experiments. The biogas production was monitored on a daily basis.

Results and Conclusions

The effect of the macerator itself and of a variable-module pre-treatment was investigated. One long-term experiment was performed: the first 72 days (i.e. phase 1) the effect of the macerator (0.040 kJ/kg sludge) and a 4-module (0.053 kJ/kg sludge) pre-treatment was investigated. In the following 57 days (i.e. phase 2), the effect of 8 (0.066 kJ/kg sludge) and 16 modules (0.091 kJ/kg sludge) was investigated.

It is observed that the electrokinetic treatment is able to significantly solubilise the organic matter present in the TWAS, represented here by the concentrations of soluble COD and soluble carbohydrates. The soluble COD concentration (carbohydrates concentration) in the TWAS treated with 0.053, 0.066 and 0.091 kJ/kg sludge increased with 179 % (273 %), 206 % (96 %) and 453 % (152 %) respectively.

Secondly, the effect on biogas yield is quantified (Figure 1). At the end of phase 1, a significant increase in biogas production for both pre-treatments was observed: 6.3% and 24% respectively. This corresponds to a production of 0.200 and 0.234 L/g VS compared to a 0.188L/g VS production of the control. For a further increase of the treatment intensity (i.e. phase 2), again a significant increase by 15.2 % was observed for the pre-treatment with 0.091 kJ/kg sludge (0.221 L/g VS) compared to the control (0.192 L/g VS). Contrastingly, it appeared that the pre-treatment with 0.066 kJ/kg sludge could not lead to a significant increase in biogas production compared to the control. Although, solubilisation of the organic matter was achieved by the electrokinetic pre-treatment, it could not be linked to the achieved biogas yield. From day 52 onward, a steady progress of the produced biogas was noticed for the following 20 days. At day 72, the treatment changed from 0.040 kJ/kg sludge to 0.066 kJ/kg sludge and from 0.053 kJ/kg sludge to 0.091 kJ/kg sludge. After 11 days, the biogas production curves returned to their stable trend. The methane concentration of the biogas produced remained stable at 64 %, regardless of the treatment applied.

In terms of energy production/consumption, the 4 modules-treatment achieved the most favourable results: a net energy gain of 9.06 kWh/ton TWAS (compared to -0.10 and 5.83 kWh/ton TWAS for 8 and 16 modules respectively) was obtained.
Figure 1. Daily biogas production (L/g VS) in the control and electrokinetic treated sludge digester
References