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Importance of heat transfer in an anaerobic digestion plant in a continental climate context

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HIGHLIGHTS

- Unheated anaerobic digestion plants are highly sensitive to external temperature conditions.
- Heat transfer must be taken into account in the design of an anaerobic wastewater treatment plant.
- A simple steady-state heat transfer model is a useful tool to help forecast biogas production.

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ABSTRACT

Investigation on the sensivity to temperature variations has been achieved on a full-scale experimental dairy wastewater treatment plant including an unheated but insulated upflow anaerobic sludge blanket. A simple steady-state heat transfer model based on energy balance has been designed to forecast the biogas production depending on ambient air and dairy wastewater temperatures variations. Energy balance has been described for any part of the digestion plant. Calculated heat losses were in the same range than observed losses with an uncertainty of about 10%. From the equalization tank to the digester the average heat loss under cold period was close to 10 °C due to convection and conduction. Mesophilic conditions are not respected for couples of ambient air and wastewater temperatures ranging respectively from 8–35 to 35–29 °C. Technical solutions are suggested to increase the biogas production.

1. Introduction

In any organic wastewater treatment, e.g. wastewater from food industry, heating the influent prior to introduce it into a biogas reactor may reduce to null the energy balance of the all device. The relatively high temperature (>30 °C) of some effluents such as dairy wastewater could lead to avoid any heating of the effluent at the inlet of a mesophilic digester. But, increasing the reactor temperature increases the rate of anaerobic conversion and consequently the overall system efficiency (Zakkour et al., 2001; Manariotis and Grigoropoulos, 2006). Many digesters in the world are unheated but with large fluctuations in the biogas production (Jiang et al., 2011). So, to estimate the impact of heat transfer on the temperature's fluctuations in an anaerobic digestion facility using a simple model may help to answer this question.

The aim of this paper is to investigate the sensitivity to temperature changes of a full-scale experimental treatment plant including an unheated upflow anaerobic sludge blanket (UASB). The effluent treated in this plant is a dairy wastewater from a small size cheese factory located in a cold mountainous area in the French Alps. This plant is definitely a real, full-scale cheese factory, and the anaerobic digester being on-site. The unit has good pollutants removal efficiency as chemical oxygen demand (COD) but with an important consumption of sodium hydroxide. In winter 2009–2010, an inoculation of granular sludge had to be carried out due to process failure after a period of very large cold temperature (−20 °C) and the freezing of some pipes. It became obvious to understand the heat transfer's process within the whole process unit. The model suggested in this paper is a simplified one, designed to help a dairy plant's manager to supervise the wastewater treatment through an anaerobic digester.

Dairy wastewater is generated either from milk, cheese production industries or dairy farms. Dairy wastewater is generally characterized by its relatively high temperature (30–40 °C) and high strength with for example COD values in the range of few tens of grams per liter (Rajeshwari et al., 2000; Demirel et al., 2005; Latif et al., 2011). The dairy wastewater consists mainly of raw materials lost during handling processing and cleaning materials discharged to the processing water. The composition involves a substantial

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