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The role of anaerobic sludge recycle in improving anaerobic digester performance

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HIGHLIGHTS

- ▶ A pilot WWTP is operated with and without anaerobic digester sludge recycle.
- ▶ Anaerobic digester sludge recycling in traditional WWTPs increases CH_4 production.
- ▶ Anaerobic digester sludge recycling decreases net solids yield.
- ▶ More consistent *Archaea* concentrations occurred system wide with sludge recycling.

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ABSTRACT

Solids retention time (SRT) is a critical parameter for the performance of anaerobic digesters (AD) in wastewater treatment plants. AD SRT should increase when active biomass is input to the AD by recycling anaerobic sludge via the wastewater-treatment tanks, creating a hybrid aerobic/anaerobic system. When 85% of the flow through the AD was recycled in pilot-scale hybrid systems, the AD SRT increased by as much as 9-fold, compared to a parallel system without anaerobic-sludge recycle. Longer AD SRTs resulted in increased hydrolysis and methanogenesis in the AD: net solids yield decreased by 39–96% for overall and 23–94% in the AD alone, and AD methane yield increased 1.5- to 5.5-fold. Microbial community assays demonstrated higher, more consistent *Archaea* concentrations in all tanks in the wastewater-treatment system with anaerobic-sludge recycle. Thus, multiple lines of evidence support that AD-sludge recycle increased AD SRT, solids hydrolysis, and methane generation.

1. Introduction

While treatment of municipal and industrial wastewater is essential in the preservation of water environments, conventional wastewater treatment plants (WWTPs) are not necessarily sustainable. It is estimated that up to 1% of the annual United States electricity consumption is applied to wastewater treatment and that energy consumption by WWTPs will increase 20% over the next fifteen years (Carns, 2005). In addition, WWTPs produce 8 million dry tons per year of biosolids (Center for Sustainable Systems, 2009), which must be disposed of, and release 28 million tons of CO_2 equivalents to the atmosphere (U.S. Energy Information Administration, 2010).

Anaerobic digestion is a well-established technology that has potential for helping WWTPs become more sustainable. Anaerobic digestion involves three mechanisms (Lawrence and McCarty, 1969; Parkin and Owen, 1986; Rittmann and McCarty, 2001): hydrolysis of particulate and polymeric organic compounds, fermentation of the solubilized, but complex organic substrates to short chain fatty acids including acetate and hydrogen gas (H_2), and methanogenesis of the acetate and H_2 to methane (CH_4). Major benefits from anaerobic digestion are capturing energy in CH_4 and stabilizing and destroying biosolids.

Hydrolysis of microbial biomass and particulate organic compounds is usually considered the rate-limiting step during anaerobic digestion and is generally modeled with first-order kinetics (Eastman and Ferguson, 1981; Lee et al., 2011; Miron et al., 2000; Rittmann and McCarty, 2001). The extent of hydrolysis increases with increasing solids retention time (SRT) in the anaerobic digester (AD), and this generates additional soluble organic matter for fermentation and methanogenesis. A long-enough SRT also is critical for ensuring that the slow-growing methanogenic microorganisms are stably maintained in the digester (Parkin and Owen, 1986; Rittmann and McCarty, 2001). In a conventional AD, SRT equals the hydraulic retention time (HRT).

SRT, the reciprocal of the net specific growth rate of active biomass in a system, is computed as the ratio of active biomass in the system divided by the production rate of active biomass (Rittmann

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