Volatile Fatty Acids Production from Fermentation of Secondary Sewage Sludge

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By

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Abstract

Sludge fermentation is used worldwide as an economical means to produce volatile fatty acids (VFA), which can be used as readily available carbon in biological nutrient removal (BNR) systems. In this research, secondary sludge was tested for its potential to generate VFA. Fermentation of secondary sludge was carried out in a lab-scale sequencing batch reactor (SBR). The SBR was fed with secondary sludge of 1% total solids and run with hydraulic retention time (HRT) of 48 hours and 28 hours in phase 1 (40 days) and phase 2 (12 days) respectively. The SBR produced net VFA (expressed as acetic acid) of 365 ±62.5 mg VFA_{HAc}/l which was equivalent to a VFA yield of 0.28 ±0.05 mg VFA_{HAc}/mg VSS_{feed} during phase 1. A change in operating HRT from 48 hours to 28 hours led to a reduction in solids retention time (SRT) from 2.65 days to 2 days in phase 2. The reduction in SRT during phase 2 led to poor hydrolysis and hence could not support the fermentation. Net VFA generation decreased during phase 2 and reached 0 mg/l. Acetic acid was the main acid produced comprising 45% of total VFA content during the run with 48 hours HRT.

The effect of total solids (TS) concentration on secondary sludge fermentation was tested using batch experiments. The batch with 2.8% TS secondary sludge showed a maximum net VFA production of 60 mg VFA_{HAc}/l, which appeared to be superior to the 1% TS secondary sludge batch fermentation where no net VFA production observed throughout the test period. Primary sludge (3% TS) exhibited 1200 mg VFA_{HAc}/l in a batch fermentation, which was superior to the net VFA produced during secondary sludge (2.8% TS) batch fermentation. The effects of sonication on fermentability of primary and secondary sludges were tested. A sonic power application of 0.0017 Watt/ml/min density increased soluble content of primary and secondary sludges. In batch fermentations, sonicated secondary sludge improved fermentation over unsonicated secondary sludge. A maximum net VFA production of 130 mg VFA_{HAc}/l was observed in the secondary sludge batch fermentation.

In this research work, an investigation into inhibiting VFA degradation in secondary sludge batch fermentations was also carried out. The effects of a methanogenic bacteria inhibitor (bromoethane sulfonic acid) and low pH (range of 4.02-6.07) were considered. The addition of 1 mM bromoethane sulfonic acid (BES) in secondary sludge (1% TS) batch fermentation successfully inhibited VFA degradation. pH values as low as 4.02 showed an inhibitory effect on secondary sludge (1% TS) batch fermentation which led to poor hydrolysis and hence no net VFA generated during the test period. However, low pH values reduced the VFA degradation rate in the batch fermentations.

Secondary sludge used in the present research showed the potential to generate VFA. The amount of VFA produced in the present work showed the potential to improve the performance of a BNR system. Moreover, in batch fermentations, VFA generation was improved using various pre-treatments like sonication and BES addition.

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1 Introduction

1.1 General:

Growing urbanization and limited water resources demand advances in technology to preserve water quality. Over the last few decades, the influx of excess nutrients into water bodies has brought water quality into question. Excess quantities of nitrogen and phosphorus can result in eutrophication (enrichment of nutrients like nitrogen and phosphorus) of receiving water bodies, mainly lakes and slow moving rivers (Sundblad et al., 1994). Nutrients can be treated by various chemical treatments. However, biological treatments are preferred over chemical treatments for economical and environmental reasons. Therefore, biological nutrient removal (BNR) systems are increasingly being incorporated in wastewater treatment plants.

In BNR systems, micro-organisms require readily available carbon as an energy source to remove nitrogen and phosphorus. Therefore, external carbon sources are supplemented to facilitate nutrients removal in BNR processes. However, external carbon sources incur high costs and increase organic load. McDonald (1990) reported that methanol costs were 70% of the total operating and maintenance expenditure of a municipal wastewater treatment facility. An internal carbon source (wastewater or sludge or a mixture of both) can be employed as an economical alternative to external carbon supplementation. However, quite often internal carbon sources are not inherently rich enough in readily available carbon to support BNR systems. As a result, fermentation of sludge or wastewater is carried out to produce volatile fatty acids (VFA) which can be used as a readily consumable substrate for bacteria in BNR systems.

1.2 Prior research:

Over the past few years, a lot of research has been conducted to optimise sludge-fermentation processes. The effects of various operational and sludge parameters like pH, hydraulic retention time (HRT), solids retention time (SRT), solids concentration and temperature on fermentation have been studied significantly. Also, a few studies have demonstrated the effect of different reactor configurations on VFA production. Furthermore, a myriad number of studies have dealt with various sludge pre-treatments to enhance solubility in order to boost fermentation.

Most of the previous studies of sludge fermentation were carried out on primary sludge. Secondary sludge fermentation has been given very little attention. It was believed that secondary sludge is hard to digest due to its characteristics, and hence its suitability to generate VFA via fermentation is lesser than primary sludge. Secondary sludge is reported as troublesome to stabilise because of difficulty in dewatering and digestion (Hogan et al., 2004; Mao et al., 2004). However, secondary sludge may contain high levels of organic matter and could be used to produce VFA, by which reduction and stabilization of organic wastes can also be achieved. Few full scale reactor and batch studies were attempted which focused on secondary sludge fermentation (Min et al., 2002; Yuan et al., 2006a, b; Chen et al., 2006). The findings of these studies are discussed later in the thesis.

1.3 Thesis aims and objectives:

The main objective of this research was to assess the potential of secondary sludge fermentation to facilitate VFA production.

Specifically, the objectives of this research were:

1. To quantify VFA production resulting from fermentation of secondary sludge.

2. To assess the effect of pH and solids concentration on secondary sludge fermentation.
3. To examine the effect of sonic power application on secondary sludge in terms of enhancement of solubility, and to compare VFA production resulting from the fermentation of sonicated and unsonicated secondary sludges.

Throughout the study, results will be put into context through comparisons with data pertaining to primary sludge fermentation.