The effect of an initial anaerobic zone on the kinetics and stoichiometry of acetate removal during nutrient-limiting conditions

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Abstract

I studied the stoichiometry and kinetics of acetate removal on anaerobic/aerobic (AnA) and completely aerobic (CA) sequencing batch reactors under nutrient-limiting conditions. CA acetate removal rates were 20 to 40% higher than AnA acetate removal rates when both nitrogen and phosphorus (P) were sufficient. When P was deficient, the acetate removal rate of both sludges was 0.8 mg acetic acid/g VSS/min. Anaerobic stoichiometry indicated that polyphosphate-accumulating organisms were present at a low-level, and that glycogen-accumulating organisms were dominant. I also found that the AnA sludge synthesised 2 to 5 times more polyhydroxybutyrate-C than the CA sludge.

Keywords: nutrient deficiency, anaerobic/aerobic, acetate removal, microbial storage products

Nomenclature

AnA	-	anaerobic/aerobic
CA	-	completely aerobic
CH	-	carbohydrate
COD	-	chemical oxygen demand
GAO	-	glycogen-accumulating organism
GLY	-	glycogen
MCRT	-	mean cell residence time
N	-	nitrogen
P	-	phosphorus
PAO	-	polyphosphate-accumulating organism
PHA	-	polyhydroxyalkanoate
PHB	-	polyhydroxybutyrate
SBR	-	sequencing batch reactor

Introduction

It is common practice in biological treatment of nutrient-deficient wastewater to use completely aerobic (CA) activated sludge units. Recent laboratory-scale work has shown that the use of an anaerobic/aerobic (AnA) process may be a better alternative due to three key operating benefits. The first benefit is that the AnA process requires 20% less P to remove a given amount of influent chemical oxygen demand (COD) than a CA process because of the accumulation of glycogen (GLY) and polyhydroxyalkanoates (PHAs) (Harper and Jenkins, 2003). The second benefit is the suppression of viscous bulking, due to the accumulation of more intracellular carbohydrate (CH) (i.e. GLY) and less exocellular CH (Jobbagy et al., 2002). The third operating benefit is that the AnA process produces lower effluent P concentrations than the CA process, when both systems are subjected to variable influent organic loading (Harper and Jenkins, 2002).

These first two benefits are due mostly to glycogen-accumulating organisms (GAOs). These organisms synthesise and degrade storage products (PHB and GLY) as they are cycled between anaerobic and aerobic conditions. Under anaerobic conditions, GAOs remove soluble carbon and synthesise PHB, while degrading GLY. During the aerobic phase, they use a portion of the internal PHB pool to synthesise GLY, with the common result being net PHB and GLY accumulation in the biomass. GAOs are abundant in AnA systems operated at influent COD/P ratios > 60 (Liu et al.1997, Schuler 1998).

The third benefit is due to another group of storage product-accumulating organisms, polyphosphate-accumulating organisms (PAOs). Like GAOs, PAOs also synthesise and degrade PHB and GLY, but unlike GAOs, PAOs rely on a third storage product, polyphosphate. As carbon is removed during the anaerobic phase, PAOs produce energy by hydrolysing polyphosphate, resulting in P release into the wastewater. Under the following aerobic phase, PAOs remove P to synthesise polyphosphate, resulting in net P removal from wastewater. Harper and Jenkins, 2002 exploited this characteristic P release and uptake profile to show the third operating benefit. When an AnA and CA SBR are both treating a P-limited wastewater with variable influent organic loading, the AnA SBR produces lower effluent P concentrations because of the P release and uptake characteristics of polyphosphate metabolism. During low influent COD loading periods, aerobic polyphosphate synthesis removes P to low levels, while under high influent COD loading periods, anaerobic P release provides P and prevents P deficiency. The key to this benefit is to constantly add enough P to stimulate the P release and uptake characteristics of polyphosphate metabolism.

Realising all three of these benefits means operating an AnA system in a way that sustains both PAOs and GAOs under nutrient-limiting conditions. Evaluating coexistence of PAOs and GAOs can be done by investigating the anaerobic stoichiometry, which depends on the relative abundance of PAOs and GAOs (Liu et al.,1997; Schuler 1998). The ratio of P released/acetate-C removed is the key measure of PAO activity, while the ratio of CH-C degraded/acetate-C removed is the key measure of GAO activity.

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