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# Restart of anaerobic filters treating low-strength wastewater

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**Abstract**

The anaerobic filter (AF) technology offers an alternative method for the direct treatment of low-strength wastewater and the study was undertaken to access AF-biomass reactivation after prolonged nonfeeding periods, an important characteristic making the process suitable for handling variable or intermittent pollution loads. Four upflow AF (three 12.5-L and one 3.9-L, each with different packing), which had treated municipal-type wastewaters (natural, amended or synthetic) for 34 months at 25 or 16 °C and varying hydraulic loads and had remained inactive for 24 months, were used. All units were fed synthetic wastewater [mean chemical oxygen demand (COD) 323 mg/L, total suspended solids (TSS) 47 mg/L] and operated at 27 °C for 2.5 months (phase 1); and following a 6-month idle period, the smaller filter treated municipal wastewater (mean COD and TSS 820 and 448 mg/L) at 16 °C for an additional 2.5 months (phase 2). The larger units operated at a 2.0-d hydraulic retention time and the smaller at 1.0–0.33-d in phase 1 and 2.0 or 1.0-d in phase 2. Reactivation was quick and yielded efficient treatment. Restart was affected by the AF history and packing morphology, the types of wastewater previously handled, and the duration of the nonfeeding period.
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*Keywords:* Biological wastewater treatment; Anaerobic process; Anaerobic filter; Low-strength wastewater; Reactor restart

## 1. Introduction

The anaerobic filter (AF) reactor has been studied over the past 40 years (Witherow et al., 1958; Plummer et al., 1968; Genung et al., 1982; Kobayashi et al., 1983), and is recently gaining increased attention as an alternative means for the direct anaerobic treatment of municipal and other low-strength wastewaters at ambient conditions, especially in small decentralized facilities located in regions of moderate climate (Viraraghavan and Dickenson, 1991; Wilson et al., 1998; Bodik et al., 2002; Elmitwalli et al., 2002; Manariotis and Grigoropoulos, 2006a). Compared to conventional aerobic systems, anaerobic systems have been reported (Verstraete and Vandevivere, 1999) to require lower capital and operational costs, even if accompanied by a low-tech aerobic posttreatment step to achieve the desired effluent quality, and the AF constitutes a significant technological development for raw domestic or municipal wastewater treatment. An important consideration for seasonally operated facilities would additionally be the ability of the anaerobic process to withstand long idle periods and return to effective operation soon after feeding has been resumed; however, limited information relative to the restart behavior of AF and other anaerobic reactors has been found in the literature.

Short-term nonfeeding intervals do not negatively impact the quick response of AF reactors. Young (1980) over 25 years ago observed that periods up to 3 d did not affect the chemical oxygen demand (COD) removal or methane ($CH_4$) production, while after 14 d COD removal and biogas production levels were restored within 3–4 d. Manariotis and Grigoropoulos (2006a) recently reported that a 1-month nonfeeeding period did not significantly affect the performance of an AF unit treating at 23 °C municipal wastewater with a mean COD and total suspended solids (TSS) content of 442 and 247 mg/L, respectively; effluent COD and TSS averaged 262 and 109 mg/L

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before and 215 and 49 mg/L after feeding stopped (loading was higher during the earlier period), and organic material continued to be stabilized during the inactive time. Longer periods, however, may considerably influence the reactor viability and restart effluent quality. Young (1980) has reported that after a 6-month idle period, a laboratory-scale AF treating a milk-based synthetic wastewater with an ultimate biochemical oxygen demand ($BOD_L$) of 2740 mg/L at an organic loading rate (OLR) of 0.77 kg COD/m$^3$ d, yielded an immediate $BOD_L$ removal of 50%, which after 16 and 24 d of operation increased to 90 and 95%, respectively.

Sanz and Fdz-Polanco (1989) have compared the restart behavior of laboratory anaerobic fluidized bed (AFB) and upflow anaerobic sludge bed (UASB) reactors treating municipal wastewater at 20 and 18.5 °C following a 6-month nonfeeding period, and noted that during this time the sludge blanket height in the UASB reactor had decreased by 8% due to compaction. After 25 d of operation, the influent COD concentration of 475 mg/L was reduced to below 100 mg/L in the AFB reactor effluent, however, the level in the UASB effluent never fell below 130 mg/L. The initial hydraulic retention times (HRT) employed during the restart period were 15.3 and 8.9 h in the AFB and UASB reactors, respectively, and were further reduced when COD removal was higher than 70%. The AFB reactor had fewer problems during restart and exhibited better performance in terms of the removal of organics and solids than the UASB reactor. The impact of starvation on UASB reactors has also been studied at high operational temperatures. Lepisto and Rintala (1995) have reported that short-term starvation (1–6 d) of a UASB unit treating acetate at 70 °C had little effect on the specific methane production rate, however, longer periods (up to 15 d) caused an increase in the lag phase and a decrease in the specific methane production rate. Ohtsuki et al. (1992) have also noted that the methanogenic activity at 55 °C in a UASB reactor after 7 and 68 d without feeding was decreased by 30% and 90%, respectively, although no change was observed at 30 °C.

Manariotis and Grigoropoulos (2002) have studied the restart after a 2 year inactive period of a laboratory anaerobic baffled reactor (ABR) treating low-strength synthetic wastewater (COD 300–400 mg/L) at 26 °C. The HRT was dropped within 10 d from 12.5 to 2.0 d and thereafter the reactor operated at HRT levels of 2.0 and 1.0 d, yielding OLR of 0.31–0.66 kg COD/m$^3$ d. The reactor responded to reactivation rapidly. Effluent COD remained below 70 mg/L, ranging from 16 to 66 mg/L after the initial 10-d period, and COD removal averaged 92% and 83% at HRT levels of 2.0 and 1.0 d; biogas release was low during the initial 10 d, but gradually increased reaching a peak value after approximately 20 d. The ABR reactor could be easily reactivated after the extended period without feeding and performed satisfactorily soon thereafter.

Bae et al. (1995) have tested anaerobic granules from UASB reactors treating a glucose-based synthetic wastewater and found that they recovered quickly after they had been held for 10 months at 10–26 °C and at 4 °C without feeding. By the end of this period, the specific acidogenic activity of the granules had decreased to 30% of its original value, regardless of the incubation temperature, and the specific methanogenic activity had decreased to 60% and 80%, depending on the temperature used (10–26 °C and 4 °C). Granules stored at 10–26 °C had better reactivation characteristics and greater recovery of the specific methanogenic activity (95% as compared to 64% when storage was at 4 °C). Recently, Thomsson et al. (2003) studied the impact of short-term starvation on different strains of *Saccharomyces cerevisiae* and reported that the fermentative capacity was completely lost after 24 h of carbon starvation and was reduced by 70–95% under nitrogen starvation. The inactivity of the carbon-starved cells was attributed to energy deprivation, and the addition of small amounts of glucose during the initiation of the starvation phase enabled the cells to preserve their fermentative capacity.

The objective of this paper is to present the findings of a laboratory restart study which investigated the return of AF biomass to active condition after prolonged periods without feeding and the time needed to achieve steady-state under different operating conditions (including HRT, type of substrate, and temperature). Four upflow AF reactors with different packing materials, which had remained inactive for periods up to 2 years, were used for this purpose. The four reactors had been initially used in a comprehensive 3-year investigation of the direct AF treatment of raw municipal and other low-strength wastewaters, with emphasis on the efficacy and sustainability of the process over the long period of operation, the effect of packing height on AF performance, the accumulation and characteristics of biosolids within the columns, and their contribution to treatment (Manariotis and Grigoropoulos, 2003, 2006a, 2006b). The AF process offers a low-cost system for the direct treatment of low-strength wastewater, and the findings of the present study should facilitate its application to decentralized areas experiencing significant population load increases and widely divergent flows during the tourist season or to seasonally operated agroindustrial facilities.

## 2. Methods

### 2.1. Test system

Four laboratory upflow AF reactors, units 1, 2, 3, and 4, were employed and were packed with ceramic saddles, smooth plastic rings, crushed stone, and corrugated plastic rings, respectively. These materials had specific surface areas of 308, 186, 186, and 308 m$^2$/m$^3$ and void ratios of 0.59, 0.67, 0.46, and 0.90, respectively. Units 1, 2, and 3 had a 12.5-L packed-bed volume and 0.8-m height, while unit 4 had a 3.9-L volume and 0.7-m height. Sampling ports, placed at 20-cm intervals, enabled profile sampling

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