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High rate immobilized anaerobic system treating wastewater-evaluation and simulation at a pilot-scale system

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Abstract

An evaluation and simulation of an Advanced high rate Anaerobic Treatment technology (AAT) system applied at demo-scale with focus on methane production was performed in Karmiel (Israel) WWTP. The reactor is composed of an impregnated active biomass foam matrix to guarantee process stability and increase biogas production efficiency while reducing OLR shocks. Two different scenarios were investigated,1st scenario: AAT preceded by a primary clarifier and; 2nd scenario: AAT received raw sewage. Average removal efficiencies were higher during the 2nd scenario, with biogas production at1.3and6.7 $m^3.d^{-1}$during scenario1 and 2, respectively. The ADM1 showed applicability for the AAT (COD and gas flow).

Keywords: Advanced anaerobic treatment; municipal wastewater; biogas; ADM1.

Introduction

Anaerobic treatment of wastewater is more energy-efficient than aerobic processes because of the reduced oxygen consumption and the added value of biogas production. In addition, less biomass is produced and higher organic loads are handled in comparison to aerobic processes (Lettinga, 1996). However, operational stability obstacles still limit wide application of anaerobic technologies for wastewater treatment (Dupla et al., 2004). Moreover, anaerobic processes are highly vulnerable to organic and hydraulic load fluctuation, suffer active biomass washout, are sensitive to inhibitors, and require lengthy periods of acclimation (Chen et al., 2008; Dereli et al., 2012). To overcome these limitations a unique immobilization technique using hydrophilic polyurethane foam was applied. This advanced anaerobic technology (AAT) is a modified high rate up flow anaerobic biofilter, composed of a primary clarifier for sedimentation and biomass impregnated in the polymer-based matrix (Massalha et al, 2015, Sabbah et al., 2016).

This study is aimed at implementing the AAT at a demo-scale receiving real municipal wastewater for two scenarios over more than one year, i.e., preceded by a primary clarifier and no primary clarifier. The Anaerobic Digestion Model nº1 (ADM1) (Batstone et al., 2002) was used to characterise and predict expected results for different scenarios, as well as demonstrate its robustness in fitting with different anaerobic treatment units.

Methods

The wastewater treatment plant (WWTP) serves the city of Karmiel (Israel) and consists of a conventional Activated Sludge system. The pilot AAT system was operated for over a year on the premises. The immobilized biomass (within the matrix) was inserted in the 25 m^3 cylindrical-shaped reactor. The reactor is composed of a sedimentation zone (lower part) and immobilized anaerobic bio-matrix (upper part). The bio-matrix occupies 1.875m^3 of the total volume, resulting in a useful reactor volume of 23.125 m^3. Two scenarios were evaluated during the operation period (flow rate 48–120 $m^3.d^{-1}$): Scenario 1: raw sewage flowed first to the primary clarifier (PC) before flowing into the AAT. Scenario 2: raw sewage flowed directly into the AAT.

Results and conclusions

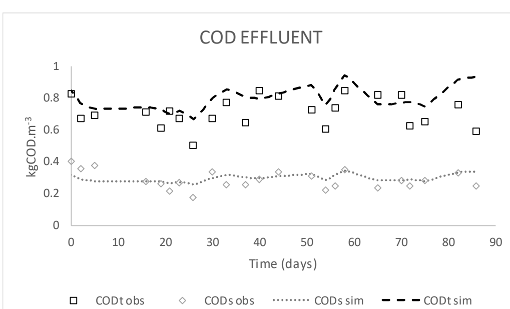
Overall, total COD and TSS removal efficiency was higher during the 2nd scenario (Table 1) due to the better established bacterial consortium, higher influent concentration and supported by the higher biogas production. Removal efficiencies are comparable to typical UASB reactors operating in tropical countries, however higher OLR and lower HRTs were applied for the current research (Table 1).

A small modification was performed to the ADM1 by considering the system as three compartments in series: Immobilized matrix compartment (infinite SRT), normal anaerobic reactor (with SRT similar to UASB) and headspace for biogas. This assures the assumption that biomass in the first compartment does not leave in the effluent because of the characteristics of the reactor. The data adjusted well to the ADM1 (Figure 1 – 2nd scenario), therefore proving its robustness. 3 biochemical parameters were estimated to fit total and soluble COD concentrations in the final effluent.

Table 1 - Removal efficiencies for both scenarios andtypical removal efficiencies from UASB reactors in the literature.

Removal efficiencies for the different scenarios (mean/median/*max*(SD))				
Variable	**1st scenario PC + AAT**	**2nd scenario AAT**	**UASBoperating in Brazil (Dias et al., 2018)**	**Typical UASB (Chernicharo 2007)**
Volume (m^3)	PC+23.125	23.125	14.2	-
OLR ($kgCOD.m^{-3}.d^{-1}$)	2.5/2.3/*4.5*(1.06)	6.3/6.2/*11.7*(1.66)	0.87/0.87/-	-
HRT (d)	0.3/0.3/*0.5*(0.09)	0.2/0.2/*0.2*(0)	0.43/-/-	-
Total COD	17.5/19/*29.1*(6.8)	47.7/50.1/*74*(13.1)	-/62.8/-	65 to 75%
Filtered COD	12.6/10.8/*35.2*(7.8)	25.3/25/*45.2*(11.4)	-/64.5/-	-
Particulate COD	22.6/22/*53.9*(12.2)	56.6/59.9/*80.4*(15.8)	-/59.1/-	-
TSS	29.7/30.8/*68.3*(17.2)	54/56.1/*87*(18.8)	-/85.1/-	-
Biogas production ($m^3.d^{-1}$)	1.3/1.2/*1.7*(0.31)	4.5/4.9/*6.8*(1.9)	-	-

All variables are in %, except: OLR in $kgCOD.m^{-3}.d^{-1}$;HRT in d and only in respect to the AAT;



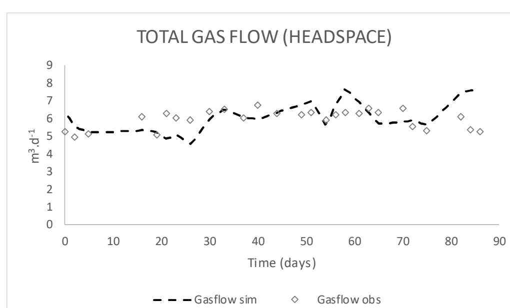


Figure 1 - Simulation for 2nd scenario at steady state.

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