Bioresource Technology 245 (2017) 207–215

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

A modelling approach to study the fouling of an anaerobic membrane bioreactor for industrial wastewater treatment

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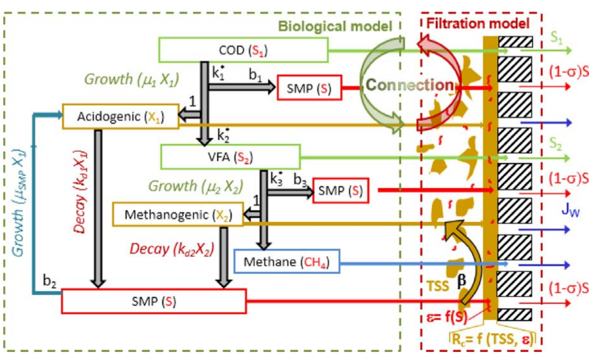
GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Anaerobic membrane bioreactor
Modelling
Membrane fouling
Biogas production
Deposit analysis

ABSTRACT

An Anaerobic Membrane BioReactors (AnMBR) model is presented in this paper based on the combination of a simple fouling model and the Anaerobic Model 2b (AM2b) to describe biological and membrane dynamic responses in an AnMBR. In order to enhance the model calibration and validation, Trans-Membrane Pressure (TMP), Total Suspended Solid (TSS), COD, Volatile Fatty Acid (VFA) and methane production were measured. The model shows a satisfactory description of the experimental data with $R^2 \approx 0.9$ for TMP data and $R^2 \approx 0.99$ for biological parameters. This new model is also proposed as a numerical tool to predict the deposit mass composition of suspended solid and Soluble Microbial Products (SMP) on the membrane surface. The effect of SMP deposit on the TMP jump phenomenon is highlighted. This new approach offers interesting perspectives for fouling prediction and the on-line control of an AnMBR process.

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http://dx.doi.org/10.1016/j.biortech.2017.08.003
Received 5 June 2017; Received in revised form 31 July 2017; Accepted 2 August 2017
Available online 14 August 2017

Nomenclature

A	membrane surface area (m^2)
b	S_2 yield from SMP (–)
b_1	SMP yield from S_1 (–)
b_2	SMP degradation by X_1 (–)
b_3	SMP yield from S_2 (–)
d	cake particle diameter (m)
k_1^*	yield for S_1 degradation (–)
k_2^*	yield for S_2 production (–)
k_3^*	yield for S_2 consumption (–)
k_4^*	yield for CO_2 production (L/g_{COD})
k_5^*	yield for CO_2 production (L/g_{COD})
k_6^*	yield for CH_4 production (L/g_{COD})
K1	half saturation constant ($kg \cdot m^{-3}$)
K2	half saturation constant ($kg \cdot m^{-3}$)
Ki	inhibition constant ($kg \cdot m^{-3}$)
K	half saturation constant ($kg \cdot m^{-3}$)
k_{d1}	acidogens decay rate (d^{-1})
k_{d2}	methanogens decay rate (d^{-1})
k_ε	coefficient of cake porosity decrease
m_c	Cake mass (kg)
m_X	Specific mass of suspended solids within the cake (kg/m^2)
m_s	Specific mass of SMP within the cake (kg/m^2)
n	empirical constant
Q_w	withdraw flow rate ($m^3 \cdot s^{-1}$)
Q_{in}	feed flowrate ($m^3 \cdot s^{-1}$)
Q_{out}	permeate flow rate ($m^3 \cdot s^{-1}$)
R_c	cake resistance (m^{-1})
R_0	intrinsic membrane resistance (m^{-1})
S_1	COD concentration ($kgCOD \cdot m^{-3}$)
S_2	VFA concentration ($kg_{equivalent\ acetate} \cdot m^{-3}$)
S	SMP concentration ($kg \cdot m^{-3}$)
TMP	transmembrane pressure (Pa)
V_R	reactor volume (m^3)
V_c	cake volume (m^3)
V_s	volume of SMP trapped in cake (m^3)
X_1	Acidogens concentration ($kg \cdot m^{-3}$)
X_2	Methanogens concentration ($kg \cdot m^{-3}$)
X_{TSS}	Total Suspended Solid ($kg \cdot m^{-3}$)
α	specific cake resistance ($m \cdot kg^{-1}$)
β	shear parameter (kg^{-1})
ε	cake porosity
ε_0	initial cake porosity
ρ_c	cake density ($kg \cdot m^{-3}$)
ρ_{smp}	SMP density ($kg \cdot m^{-3}$)
μ_p	permeate viscosity (Pa·s)
μ_1	growth rate of acidogens by consuming organic matter (d^{-1})
μ_2	growth rate of methanogens by consuming VFA (d^{-1})
μ_{smp}	growth rate of acidogens by consuming SMP (d^{-1})
μ_{max1}	maximum growth rate of acidogens by consuming COD (d^{-1})
μ_{max2}	maximum growth rate of methanogens by consuming VFA (d^{-1})
μ_{max3}	maximum growth rate of acidogens by consuming SMP (d^{-1})
σ	SMP fraction rejected by the membrane (–)
φ_{CH4}	Methane flowrate ($mol_{CH4} \cdot L^{-1} \cdot day^{-1}$)

1. Introduction

The Anaerobic Membrane BioReactor (AnMBR) has been proven to be an efficient waste water treatment technology which allows energy recovery from influent (Wang et al., 2013; Xia et al., 2016; Aslam et al., 2017a,b). An AnMBR associates the advantages of the anaerobic reactor able to treat the majority of organic pollutants, and those of the porous membrane bioreactor processes able to dissociate the Sludge Retention Time (SRT) and the Hydraulic Retention Time (HRT). An AnMBR leads, indeed, to a more efficient biological treatment where the totality of the suspended solids are retained in the reactor allowing a lower HRT which increases both process intensification and effluent water quality (Smith et al., 2012). Nevertheless one major drawback still hinders AnMBR performance, which is membrane fouling (Aslam et al., 2014;

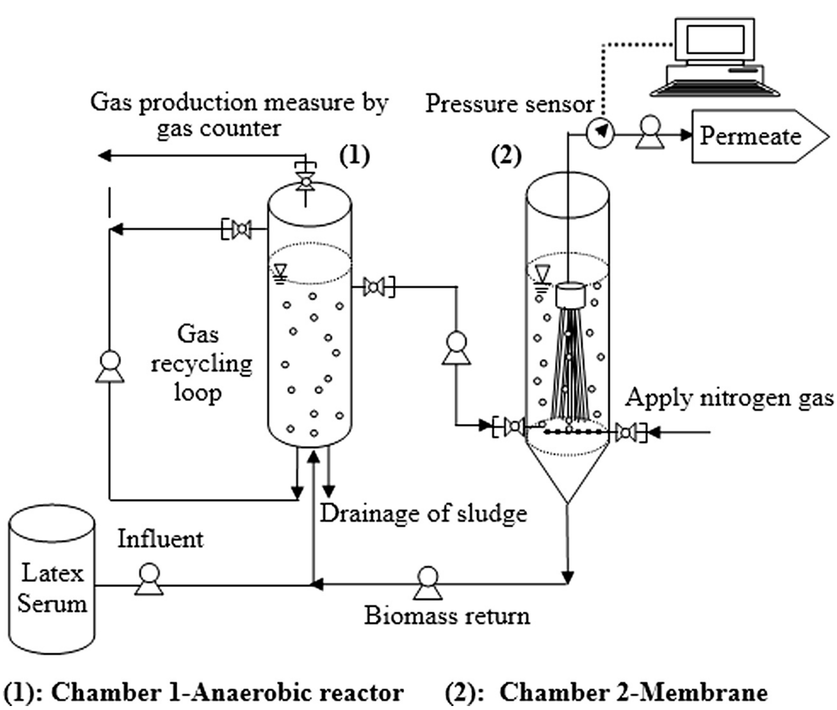

Fig. 1. Schematic diagram of AnMBR set-up.