processes

Article

Supplementary data

Optimization of In-situ Backwashing Frequency for Stable Operation of Anaerobic Ceramic Membrane Bioreactor

Rathmalgodage Thejani Nilusha [1,2,3], Tou Wang [1,2,3], Honyan Wang [1,2,3], Dawei Yu [1,2,3], Junya Zhang [1,2,3] and Yuansong Wei [1,2,3,4,*]

1 State Key Joint Laboratory of Environmental Simulation and Pollution Control, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China; nthejani@yahoo.com (R.T.N.); wangtuo17@mails.ucas.edu.cn (T.W.); hywang_st@rcees.ac.cn (H.W.); dwyu@rcees.ac.cn (D.W.); jyzhang@rcees.ac.cn (J.Z.)
2 Department of Water Pollution Control Technology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China
3 University of Chinese Academy of Sciences, Beijing 100049, China
4 Institute of Energy, Jiangxi Academy of Sciences, Nanchang 330029, China

* Correspondence: yswei@rcees.ac.cn; Tel.: +86-10-6284-9690

S1: Composition of Synthetic Wastewater

Synthetic wastewater was designed to simulate domestic wastewater. This synthetic wastewater contained (per liter) D (+) – Glucose monohydrate (200 g/L), Triptone (15 g/L), Calcium chloride dehydrate $CaCl_2 \cdot 2H_2O$ (25 g/L), Pottasium dihydrogen phosphate KH_2PO_4 (17.5 g/L), Sodium hydrogen Carbonate $NaHCO_3$ (137.5 g/L), Ammonium Chloride (NH_4Cl) 95.5 g/L, Sodium acetate ($C_2H_3NaO_2$)(100 g/L), Sodium acetate ($C_2H_3NaO_2$) (100 g/L), Magnesium sulfate ($MgSO_4 \cdot 7H_2O$) (50 g/L). All were analytical grade chemicals purchased from Sinopharm, China). In addition, trace element solution was also added based on Zhang et al, 2018.

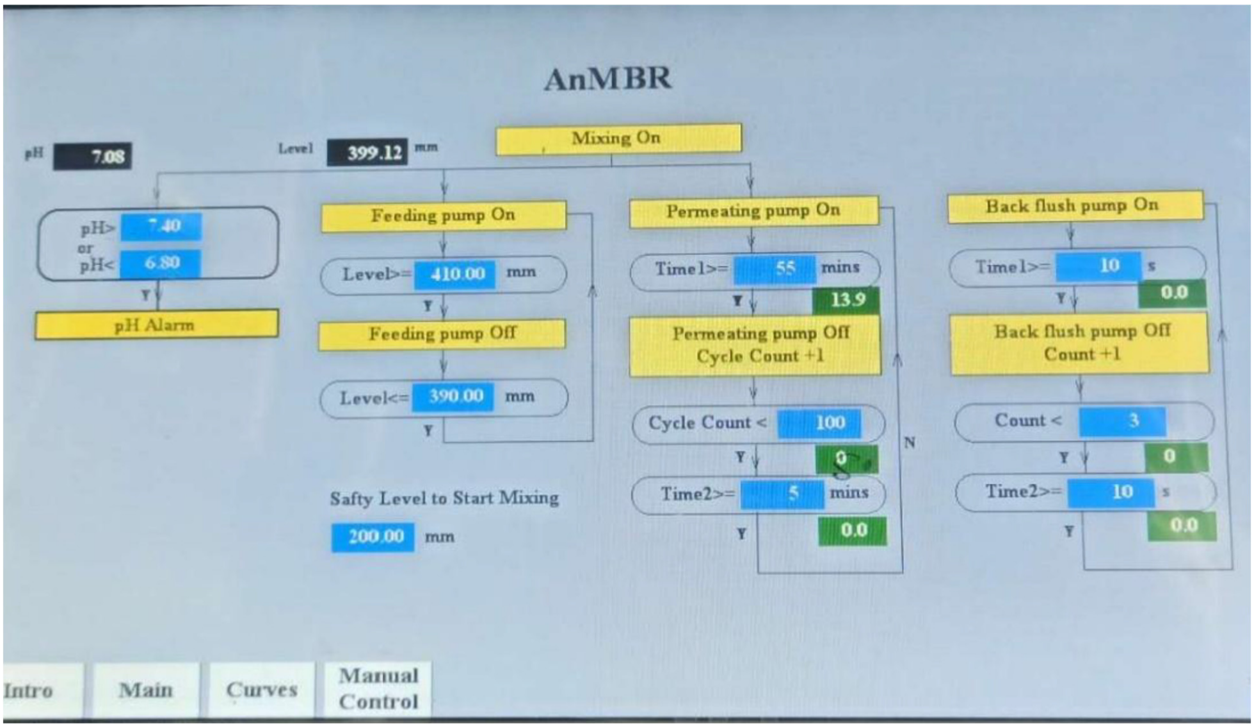

Figure S1. The novel control strategy.

S2: 3D EEM Analysis of Anaerobic Supernatant, Permeate, Backwashing Solutions and Cleaning Solutions

All samples taken for 3D EEM analysis were size-fractionated by membrane filter (≤ 0.45 μm) and UV absorbance was measured. The UV–Visible spectrometer equipped with a quartz cell (1 cm path length) was used to estimate absorbance at 254 nm (Shimadzu UV254, Japan). The absorbance at 254nm was measured beforehand in order to determine if the absorbance is <0.5 to avoid the inner filter effect, then the samples was diluted 50 times according to the UV_{254} data. Then three-dimensional EEM spectra were measured using a fluorescence spectrometry (F-7000, spectrophotometer, Hitachi, Japan). In this study, the EEM spectra were collected with corresponding scanning emission spectra from Emission wavelengths (Em) 220 nm to 550 nm at 5 nm increments by varying the excitation (Ex) wavelength from 200 nm to 400 nm at 5 nm sampling intervals. The scanning speed was set at 12000 nm/min for this study. The spectrum of deionized water was recorded as the blank. The software Origin Pro-2018 was employed to process the EEM data. The EEM spectra are plotted as the elliptical shape of contours. The X-axis represents the emission spectra (Em) from 200 nm to 550 nm while the Y-axis indicates the excitation (Ex) wavelength from 200 nm to 450 nm, and the third dimension, i.e., the contour line, is shown to express the fluorescence intensity at an interval of 5.

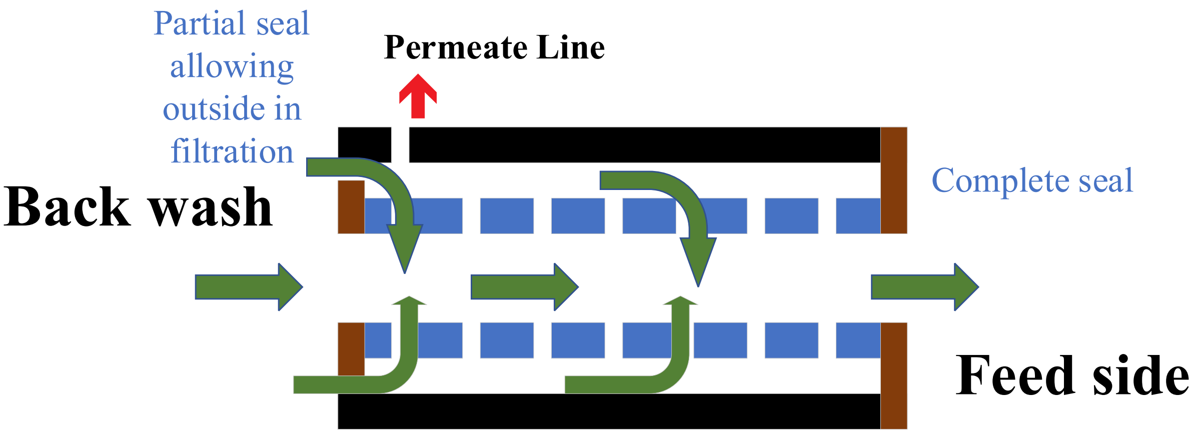

Figure S2. The outside in filtration mode during backwashing.

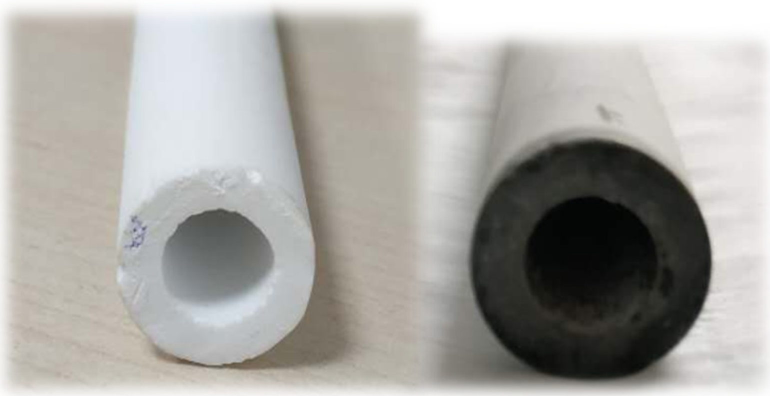

Figure S3. The images of virgin and fouled membranes. (**a**) The virgin membrane prior to filtration; (**b**) The fouled membrane after 60 days of filtration.

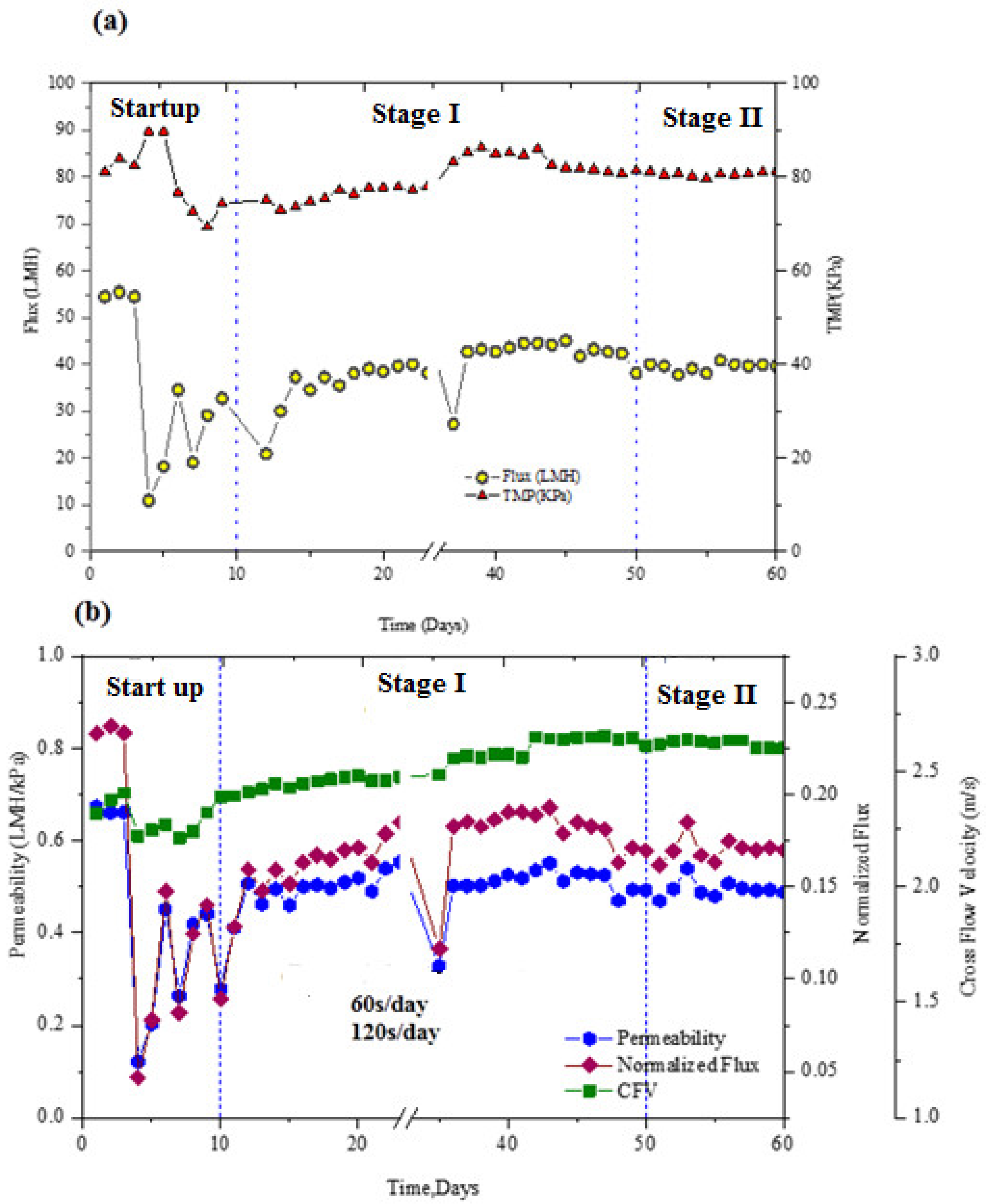

Figure S4. (**a**) Transmembrane pressure and flux evolution; (**b**) Permeability and cross flow velocity evolution

Table S1. : The permeability values at different scenarios.

	Permeability	P_x/P_i*100%
Original pure water	2.64	
Without backwashing	0.43	16.28
Stage 1	0.48	18.18
Stage 2	0.49	18.56
Purewater cleaning	2.12	80.30
NaOCl cleaning	2.61	98.86
Citric acid cleaning	2.18	82.57

x: initial purewater permeability i: permeability at different scenarios.

Table S2. Fluorescence Spectral parameters of samples of initial backwashing, final backwashing and the cleaning solutions.

Stage	Sample	Region 1 Ex: 200-250 Em230-330	Region 11 Ex: 200-250 Em330-380	Region 111 Ex: 200-250 Em380-500	Region IV Ex: 250-280 Em200-380	Region V Ex: 280-500 Em380- 500	FI*
1. Without backwashing	AnMBR				Em 340 Ex225 Z2365 Em 345 Ex 285 Z 2060		2.09
	Permeate		Em 345 Ex220 Z3614		Em 355 Ex 275 Z3267		2.14
2. First backwashing	AnMBR	--	Em 345nm Ex225nm Z3633	--	Em 340 Ex275 Z32724	Em 400 Ex315 Z1032	2.12
	Permeate	--	Em 360 Ex220 Z32628	--	Em 335 Ex275 Z32227	--	2.18
	Backwashing	--	Em 365 Ex225 Z32525	--	Em 365 Ex275 Z32090	--	2.19
3. Final	AnMBR	--	Em 325 Ex225 Z33416	--	Em 310 Ex280 Z33471	--	1.92
	Permeate	--	- Em 315 Ex220 Z3767.5	--	Em 310 Ex280 Z32029	--	1.88

	Backwashing	--	Em 360 Ex225 Z32591	--	Em 360 Ex275 Z32120	--	1.87
4. Chemical Cleaning	Pure water	--	-	--	--	--	2.67
	NaOCl	--	-	--	--	--	1.81
	Citric acid	--	Em 365 Ex230 Z3220	Em 410 Ex230 Z3387.3	--	--	2.09

*Fluorescence Index FI= Where the FI is given as the ratio of the emission intensities measured at 450 nm and at 500 nm respectively with an excitation of 370 nm.FI>1.9 indicates that the dissolved organic matter are mainly dominated by microorganisms and algae (endogenous), FI <1.4 main source is exogenous.

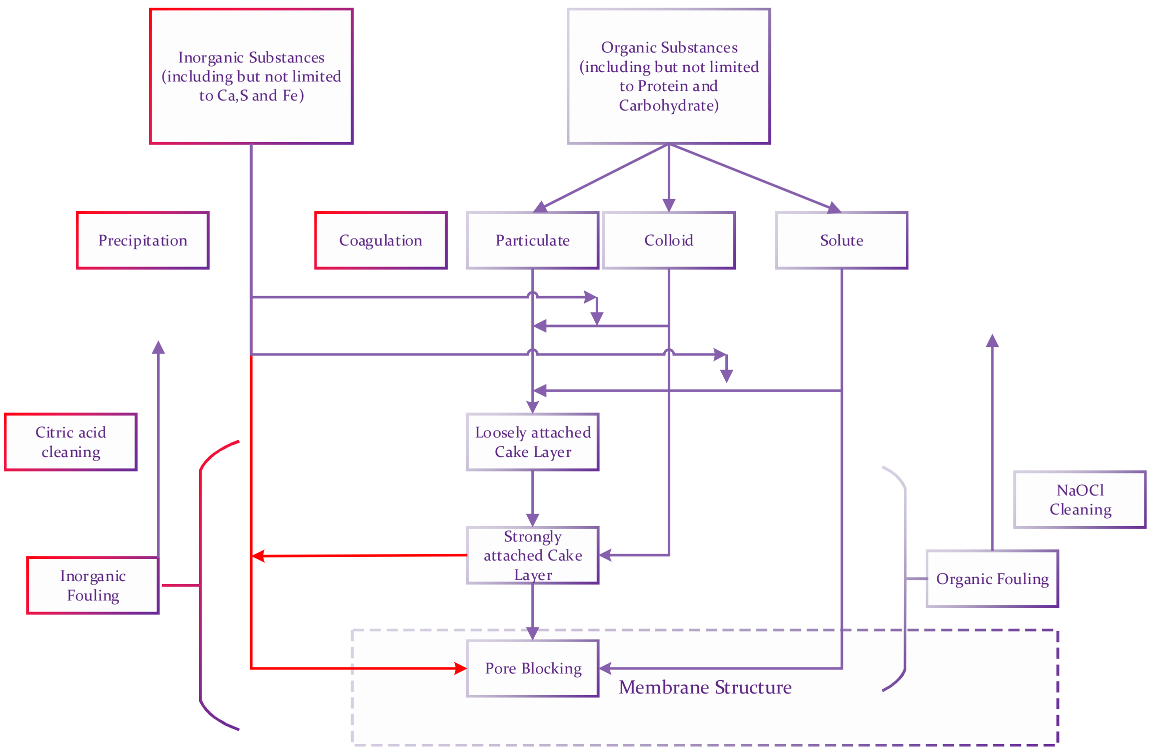

Figure S5. Conceptual diagram for ceramic membrane microbial fouling by Dong et al, 2015.

Table S3. The effectiveness of the cleaning solutions on microbial fouling control.

Sample estimators	Sobs	Shannon	Simpson	Ace	Chao	Coverage
Pure water	229	1.51	0.43	327.21	312	0.99
NaOCl	1047	5.05	0.02	1053.25	1053.27	0.99
Citric acid	1019	4.53	0.33	1070.44	1054.90	0.99