

Table 1 - Experimental conditions with limitation and inhibition types for the four CFBRs

Reactor	Days	Condition			Imposed conditions in the bulk liquid
		DO (mg/L)	pH	Influent TAN (mg/L)	
1	0-200	6.5	7	60	Minimal limitation and inhibition
2	0-60	6.5	7	60	DO limitation
	61-160	3.8			
	161-200	2.5			
3	0-60	6.5	7	60	FA* and FNA** Inhibition potential
	61-200	7.6	8	150	
4	0-60	6.5	7	60	DO limitation and FA* and FNA** inhibition potential
	61-160	3.8	8	150	
	161-200	2.5			

* 0.6 mgFA/L is included in 60 mgTAN/L at pH 7 and 30 °C, while 15 mgFA/L is in 150 mgTAN/L at pH 8 and 30 °C.

** FNA inhibition is expected inside the biofilm. In case all TAN is converted to nitrite, 0.04 mgFNA/L is included in 60 mg/L of total nitrite nitrogen (TNiN) at pH 7 and 30 °C, while 0.4 mgFNA/L is included at pH 6.

Table 2 - Parameter values for simulations with the MSNBM

Kinetic parameter and Reactor operation parameter		Value	Reference
D_f	Diffusion coefficient of biofilm (cm ² /day)	1.6 ^I , 1.5 ^{II} , 1.5 ^{III} , 1.7 ^{IV} and 1.0 ^V	Picioreanu et al. (1997)
D	Diffusion coefficient of liquid-film (cm ² /day)	1.25 times D_f	Rittmann and McCarty (2001)
Y	Yield coefficient (mgVS/mgS)	0.33 ¹ 0.083 ²	
\hat{q}	Maximum specific substrate utilization rate (mgS/mgVS . day)	4.15 ¹ 17.30 ²	
K_S	Half-maximum-rate concentration of substrate (mgS/L)	2.53 ¹ 5.55 ²	
K_{DO}	Half rate concentration of oxygen (mgS/L)	0.5 ¹ 0.68 ²	
$K_{L,FA}$	Inhibition concentration (mgFA/L)	10 ¹ 0.5 ²	Park and Bae (2009)
$K_{L,FNA}$	Inhibition concentration (mgFNA/L)	0.75 ¹ 0.1 ²	
K_{eq}	Acid/base equilibrium constant	$NH_4^+ = 5.75 * 10^{-10}$ $HNO_2 = 5.13 * 10^{-4}$ $HNO_3 = 21.9$ $H_2CO_3 = 10^{-6.3}$ $HCO_3^- = 10^{-10.3}$ $H_2O = 10^{-14}$	Flora et al. (1999) Snoeyink and Jenkins (1980)
B	Endogenous-decay coefficient (day ⁻¹)	0.15	Rittmann and McCarty (2001)
f_d	Biodegradable fraction from decay	0.8	
b_{det}	Biofilm detachment rate (day ⁻¹)	0.06	
pH_{opt}	Optimal pH	8.4 ¹ 7.7 ²	Park et al. (2007)
W	pH range of nitrifying bacteria	3.2 ¹ 2.4 ²	
X_f	Total biofilm density (mgVS/cm ³)	18	This study
L_f^0	Initial length of biofilm (cm)	0.0001	
L	Length of liquid-film interface (cm)	0.007	
Q	Flow rate (cm ³ /day)	2000	
V	Reactor volume (cm ³)	1000	
A	biofilm surface area (cm ²)	750	

I: TAN, II: TNiN, III: TNaN, IV: Oxygen, V: Total inorganic carbon (TIC), 1: AOB, 2: NOB

Table 3 - Experimental biofilm mass and density in each CFBR

	Biofilm depth (μm)	Total VS (mg)	Total biofilm volume (cm^3) ^I	Biofilm density (mg/cm^3) ^{II}
Reactor 1	220	302	16.5	18
Reactor 2	176	264	13.2	20
Reactor 3	513	894	38.5	23
Reactor 4	587	1660	44.0	38
Average	Reactor 1 – 3			20
	Reactor 1 – 4			25

I. Total biofilm volume = biofilm depth/10000 (cm) \times 750 (cm^2 , biofilm surface area)

II. Biofilm density = Total VS / I