Equations, symbols and selected parameter base values

1 Equations

#	Parameter	Equation
1	Pressure, bar or Pascals, kg/(m s^2)	$P = F/A$
2	Volume or mass flow rate, m^3/h or kg/h	$Q = V/t$; $M = m/t$
3	Energy, Joules, kg m^2/s^2	$E = F\ d$
4	Power, Watts, kg m^2/s^3	$W = E/t$
5	Specific energy consumption	$SEC = E' = Energy/V = W/Q$
6	Flux, L/(m^2 h) (LMH) or m/h	$J = Q/A$
7	Permeability, LMH/bar	$K = J/P$
8	Recovery	$R = Q_p/Q_f$
9	Rejection	$r = C_p/C_f$
10	Concentration factor	$CF = 1/(1\text{-}R)$, when r = 100%
11	Specific aeration demand for membrane air scouring, Nm^3/m^2 membrane area	$SAD_m = Q_a/A$
12	Specific aeration demand for membrane air scouring, Nm^3/m^3 permeate	$Q'_{a,m} = SAD_m/J'$, J' in units of $m^3/m^2/h$
13	Specific aeration energy consumption for membrane scouring, kWh/Nm^3 air	$E'_{a,m} = 0.011/\varepsilon$
14	Specific aeration energy consumption for membrane scouring, kWh/m^3 permeate	$E_{a,m} = E'_{a,m}\ Q'_{am}\varepsilon$
15	Oxygen demand for biological processing, g/m^3	$O_2 = 0.67$ COD, COD in mg/L
16	Specific aeration demand for biological processing, Nm^3air/m^3permeate	$Q'_{a,b} = 0.0233 \times O_2$
17	Specific aeration energy consumption for biological processing, kWh/Nm^3air	$E'_{a,b} = 0.013/\varepsilon$
18	Specific aeration energy consumption for biological processing, kWh/m^3permeate	$E_{a,b} = E'_{a,b}\ Q'_{ab}$
19	Specific energy consumption for sludge pumping & stirring, kWh/m^3 permeate	$E_s = 0.032/\varepsilon$
20	Specific energy consumption for permeate pumping, kWh/m^3 permeate	$E_p = (P + P_{loss,filt})/(36\ \varepsilon)$
21	Total specific energy consumption of MBR, kWh/m^3 permeate	$E_{MBR} = (E_{a,m} + E_{a,b} + E_s + E_p + E_{ci})/R$
22	Osmotic pressure, bar	$\pi = 7.5\ c$, c in units of wt% salt
23	Specific energy consumption of RO, kWh/m^3 permeate	$E_{RO} = \frac{k}{\rho}\left(\frac{P_{RO} + P_{loss} + \pi CF}{\left(1 - \frac{1}{CF}\right)\varepsilon_{pump}} - \frac{(P_{RO} + \pi CF)\varepsilon_{turb}}{(CF - 1)}\right) + E_i$

2 List of symbols and base values

Symbol	*Parameter definition*	*Units **(SI)***	*Note*
A	Membrane area	m^2	
CF	Concentration factor = $1/(1\text{-}R)$	-	
$E_{a,b}$	Specific aeration energy consumption, biological processing	kWh/m^3permeate	
$E'_{a,b}$	Specific aeration energy consumption, biological processing	kWh/Nm^3 air	
$E_{a,m}$	Specific aeration energy consumption, membrane scouring	kWh/m^3 permeate	a
$E'_{a,m}$	Specific aeration energy consumption, membrane scouring	kWh/Nm^3 air	
E_{MBR}	Total specific energy consumption of MBR	kWh/m^3 permeate	
E	Energy	**kg m^2/s^2 or Joules**	
E_p	Specific energy consumption for permeate pumping	kWh/m^3 permeate	
E_{RO}	Total specific energy consumption of MBR	kWh/m^3 permeate	b
E_s	Specific energy consumption, sludge pumping & stirring	kWh/m^3permeate	
F	Force	**kg m/s^2 or Newtons**	
J	Flux	L m^{-2} h^{-1} or LMH	
K	Permeability	LMH/bar	
O_2	Oxygen demand for biological processing	g/m^3	
P	Pressure	**kg/(m s^2) or Pascals**	
$Q'_{a,b}$	Specific aeration demand for biological processing	Nm^3air/m^3permeate	
$Q'_{a,m}$	Specific aeration demand for membrane air scouring	Nm^3/m^3 permeate	
R	Recovery = $1 - 1/CF$	-	
r	Rejection	-	
SAD_m	Specific aeration demand for membrane air scouring	Nm^3/m^2 membr area	
t	time	**s**	
V	Volume	**m^3**	
W	Power	**kg m^2/s^3 or Watts**	
π	Osmotic pressure	bar	

Other parameters with their suggested base values			Base value
COD	COD concentration in wastewater	mg/L	800
k	Constant in RO equation	kWh/bar	27.8
$P_{loss,filt}$	Pressure losses, MBR	bar	0.15
P_{RO}	RO “pure water” operational pressure	bar	7.5
$P_{loss,RO}$	Pressure losses across RO retentate side	bar	2.2
c	Salt concentration	wt%	3.5
ε_{pump}	Efficiency of pumping	-	60%
ε_{turb}	Efficiency of energy recovery	-	85%
E_i	Electrical power consumption, instrumentation	kWh/m^3 permeate	0.1
ρ	Density (of water ~ 1000)	**kg/m^3**	

Note: conversion factors

a	1 Joule = 2.78 x 10^{-7} kWh
b	1 Pascal = 10^{-5} bar