WEST Models Guide

Version No.	Date	Comments	WEST Release
0	21/04/2021	Draft version for WDC	---
1	07/05/2021	First version	2021 – U1
2	15/09/2023	Second version	2024
3	12/06/2024	Third version	2024-U1
4	26/03/2025	Fourth version	2025

New sections in the 4th version:

- Biofilm models

LIST OF CONTENT

ASM2dMod

Category

ASM2dMod

Conversion Model

Default

The Conversion Model (Gujer Matrix) is illustrated in detail below.

P1: HydrolAer	
S_U	f_{S_U}
S_F	$1 - f_{S_U}$
S_PO	$-i_{P,S_F} \cdot (1 - f_{S_U}) - i_{P,S_U} \cdot f_{S_U} + i_{P,XC_B}$
S_NHx	$-i_{N,S_F} \cdot (1 - f_{S_U}) - i_{N,S_U} \cdot f_{S_U} + i_{N,XC_B}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot Monod_{S_O} \cdot Monod_{XC_B} \cdot C_{X_{OHO}}$

P2: HydrolAnox	
S_U	f_{S_U}
S_F	$1 - f_{S_U}$
S_PO	$-i_{P,S_F} \cdot (1 - f_{S_U}) - i_{P,S_U} \cdot f_{S_U} + i_{P,XC_B}$
S_NHx	$-i_{N,S_F} \cdot (1 - f_{S_U}) - i_{N,S_U} \cdot f_{S_U} + i_{N,XC_B}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot n_{NO,Hyd} \cdot Inhib_{S_O} \cdot Monod_{S_{NO}} \cdot Monod_{XC_B} \cdot C_{X_{OHO}}$

P3: HydrolAnaer	
S_U	f_{S_U}
S_F	$1 - f_{S_U}$
S_PO	$-i_{P,S_F} \cdot (1 - f_{S_U}) - i_{P,S_U} \cdot f_{S_U} + i_{P,XC_B}$
S_NHx	$-i_{N,S_F} \cdot (1 - f_{S_U}) - i_{N,S_U} \cdot f_{S_U} + i_{N,XC_B}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot n_{fe} \cdot Inhib_{S_O} \cdot Monod_{S_{NO}} \cdot Monod_{XC_B} \cdot C_{X_{OHO}}$

P4: Fermentation	
S_F	-1
S_VFA	1
S_PO	i_{P,S_F}
S_NHx	i_{N,S_F}
S_Alk	$\frac{1}{14} \cdot Sto[P_4, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_4, S_{PO}] - \frac{1}{64} \cdot Sto[P_4, S_{VFA}]$
Rate	$Q_{fe,Temp} \cdot Inhib_{S_O} \cdot Inhib_{S_{NO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_F}}{C_{S_F} + K_{fe}} \cdot C_{X_{OHO}}$

P5: GrowthAerSf	
S_O	$1-\left(\frac{1}{Y_{OHO}}\right)$
S_F	$-\frac{1}{Y_{OHO}}$
S_PO	$-\left(-\frac{1}{Y_{OHO}} \cdot i_{P,S_F} + i_{P,BM}\right)$
S_NHx	$-\left(-\frac{1}{Y_{OHO}} \cdot i_{N,S_F} + i_{N,BM}\right)$
S_Alk	$\frac{1}{14} \cdot Sto[P_5, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_5, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot Monod_{S_O} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P6: GrowthAerSvfa	
S_O	$1-\left(\frac{1}{Y_{OHO}}\right)$
S_VFA	$-\frac{1}{Y_{OHO}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_6, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_6, S_{PO}] - \frac{1}{64} \cdot Sto[P_6, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot Monod_{S_O} \cdot Monod_{S_{VFA}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P7: GrowthAnoxSf_NO3toNO2	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO3	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_7, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_7, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n2_{g_{OHO}} \cdot Inhib_{OH2} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Monod_{OHO_{NO3}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P8: GrowthAnoxSf_NO2toNO	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_8, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_8, S_{PO}] - \frac{1}{14} \cdot Sto[P_8, S_{NO2}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n3_{g_{OHO}} \cdot Inhib_{OH3} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Inhib3_{OHO_{NO}} * Monod_{OHO_{NO2}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P9: GrowthAnoxSf_NOtoN2O	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_9, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_9, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n4_{g_{OHO}} \cdot Inhib_{OH4} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Monod_{OHO_{NO}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P10: GrowthAnoxSf_N2OtoN2	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{10}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{10}, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n5_{g_{OHO}} \cdot Inhib_{OH5} \cdot Monod_{S_{F5}} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Inhib5_{OHO_{NO}} * Monod_{OHO_{N2O}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P11: GrowthAnoxSvfa_NO3toNO2	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO3	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{11}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{11}, S_{PO}] - \frac{1}{64} * Sto[P_{11}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n2_{g_{OHO}} \cdot Inhib_{OH2} \cdot Monod_{S_{VFA2}} * Monod_{OHO_{NO3}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P12: GrowthAnoxSvfa_NO2toNO	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{12}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{12}, S_{PO}] - \frac{1}{64} * Sto[P_{12}, S_{VFA}] - \frac{1}{14} * Sto[P_{10}, S_{NO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n3_{g_{OHO}} \cdot Inhib_{OH3} \cdot Monod_{S_{VFA3}} * Monod_{OHO_{NO2}} \cdot Monod_{S_{NH}} \cdot Inhib3_{OH_{NO}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P13: GrowthAnoxSvfa_NOtoN2O	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} * Sto\left[P_{13}, S_{NH_x}\right] - \frac{1.5}{31} * Sto[P_{13}, S_{PO}] - \frac{1}{64} * Sto[P_{13}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n4_{g_{OHO}} \cdot Inhib_{OH4} \cdot Monod_{S_{VFA4}} \cdot Monod_{OHO_{NO}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P14: GrowthAnoxSvfa_N2OtoN2	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 + Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto\left[P_{14}, S_{NH_x}\right] - \frac{1.5}{31} \cdot Sto[P_{14}, S_{PO}] - \frac{1}{64} \cdot Sto[P_{14}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n5_{g_{OHO}} \cdot Inhib_{OH5} \cdot Monod_{S_{VFA5}} \cdot Monod_{OHO_{NO}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P15: DenAOB_NO2toNO	
S_O	$-\left(\frac{\frac{2.2857}{Y_{AOB}}}{n_{Y_{AOB}}} - 1\right)$
S_NO2	$-\frac{1}{Y_{AOB} * n_{Y_{AOB}}}$
S_NO	$\frac{2}{Y_{AOB} * n_{Y_{AOB}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-\frac{1}{Y_{AOB} * n_{Y_{AOB}}} - i_{NBM}$
S_Alk	$\frac{1}{14} \cdot Sto\left[P_{15}, S_{NH_x}\right] - \frac{1.5}{31} \cdot Sto[P_{15}, S_{PO}] - \frac{1}{14} \cdot Sto[P_{15}, S_{NO2}]$
X_AOB	1
Rate	$n1_{AOB} * \mu_{AOB,T} * C_{X_{AOB}} * \frac{S_{FNA}}{K_{FNA_{AOBden}} + S_{FNA}} * \frac{S_{FA}}{K_{FA_{AOBden}} + S_{FA}} * Inhib_{AOBden_{SO}} * Monod_{AUT_{PO}} * Monod_{AUT_{ALK}}$

P16: DenAOB_NOtoN2O	
S_O	$-\left(\frac{2.2857}{Y_{AOB}*n_{Y_{AOB}}}-1\right)$
S_NO2	$\frac{1}{Y_{AOB} * n_{Y_{AOB}}}$
S_NO	$-\frac{2}{Y_{AOB} * n_{Y_{AOB}}}$
N2O	$\frac{2}{Y_{AOB} * n_{Y_{AOB}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-\frac{1}{Y_{AOB} * n_{Y_{AOB}}} - i_{NBM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{16}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{16}, S_{PO}] - \frac{1}{14} * Sto[P_{16}, S_{NO2}]$
X_AOB	1
Rate	$n2_{AOB} * \mu_{AOB,T} * C_{X_{AOB}} * \frac{C_{S_{NO}}}{K_{SNO_{AOBden}} + C_{S_{NO}}} * \frac{S_{FA}}{K_{FA_{AOBden}} + S_{FA}} * Inhib_{AOBden_{SO}} * Monod_{AUT_{PO}} * Monod_{AUT_{ALK}}$

P17: GrowthAOBauto	
S_O	$-\frac{3.4286-Y_{AOB}}{Y_{AOB}}$
S_NO2	$\frac{1}{Y_{AOB}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{NBM} - \frac{1}{Y_{AOB}}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{17}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{17}, S_{PO}] - \frac{1}{14} \cdot Sto[P_{17}, S_{NO2}]$
X_AOB	1
Rate	$\mu_{AOB,T} * Inhib_{FA_9} * Inhib_{FNA_9} * Monod_{AUT_{PO}} * Monod_{AUT_{ALK}} * C_{X_{AOB}}$

P18: GrowthNOBauto	
S_O	$-\frac{1.1429-Y_{NOB}}{Y_{NOB}}$
S_NO3	$\frac{1}{Y_{NOB}}$
S_NO2	$-\frac{1}{Y_{NOB}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{NBM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{18}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{18}, S_{PO}]$
X_NOB	1
Rate	$\mu_{NOB,T} * Inhib_{FNA_{10}} * Inhib_{FA_{10}} * Monod_{NOB_O} * Monod_{AUT_{PO}} * Monod_{AUT_{ALK}} * C_{X_{AOB}}$

P19: GrowthAerXPHA	
S_O	$1-\frac{1}{Y_{PAO}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{19},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{19},S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}}$
Rate	$\mu_{PAO,T}\cdot Monod_{S_O}\cdot Monod_{S_{NH}}\cdot Monod_{S_{Alk}}\cdot Monod_{S_{PO}}\cdot Monod_{X_{PAO,Stor}}\cdot C_{X_{PAO}}$

P20: GrowthAnoxXPHA_NO3toNO2	
S_NO3	$-\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_NO2	$\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{20},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{20},S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}*n_{Y_{PAO}}}$
Rate	$Rate_{19}*n2_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO3}}$

P21: GrowthAnoxXPHA_NO2toNO	
S_NO2	$-\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_NO	$\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{21},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{21},S_{PO}]-\frac{1}{14}\cdot\frac{-1+Y_{PAO}\cdot n_{Y_{PAO}}}{0.5715\cdot Y_{PAO}\cdot n_{Y_{PAO}}}$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}*n_{Y_{PAO}}}$
Rate	$Rate_{19}*n3_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO2}}*Inhib3_{PAO_{NO}}$

P22: GrowthAnoxXPHA_NOtoN2O	
S_NO	$-\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_N2O	$\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{22},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{22},S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}*n_{Y_{PAO}}}$
Rate	$Rate_{19}*n4_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO}}$

P23: GrowthAnoxXPHA_N2OtoN2	
S_N2O	$-\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_N2	$\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{23},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{23},S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}*n_{Y_{PAO}}}$
Rate	$Rate_{19}*n45_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO}}*Inhib5_{PAO_{NO}}$

P24: GrowthAnaerXANA	
S_NO3	1.52
S_NO2	$-1.52-\frac{1}{Y_{ANA}}$
S_N2	$\frac{2}{Y_{ANA}}$
S_NHx	$-\frac{1}{Y_{ANA}}-i_{N,BM}$
X_ANA	1
Rate	$\mu_{ANA,T}*\frac{C_{S_{NO2}}}{K_{NO2_{ANA}}+C_{S_{NO2}}+\frac{S_{NO2}^2}{KI_{NO2_{ANA}}}}*\frac{C_{S_{NHx}}}{K_{NH_{ANA}}+C_{S_{NHx}}}*\frac{K_{O_{ANA}}}{K_{O_{ANA}}+C_{S_O}}*C_{X_{ANA}}$

P25: StorageXPHA	
S_VFA	-1
S_PO	Y_{PO}
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{25},S_{PO}]-\frac{1}{64}\cdot Sto[P_{25},S_{VFA}]-\frac{1}{31}\cdot Sto[P_{25},X_{PAO,PP}]$
X_PAO_PP	$-Y_{PO}$
X_PAO_Stor	1
Rate	$Q_{PAO,Stor,Temp}\cdot Monod_{S_{VFA}}\cdot Monod_{S_{Alk}}\cdot\frac{C_{X_{PAO,PP}}}{\left(C_{X_{PAO,PP}}/C_{X_{PAO}}\right)+K_{PP}}$

P26: StorageAerXPP	
S_O	$-Y_{PAO,Stor}$
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{26},S_{PO}]-\frac{1}{31}\cdot Sto[P_{26},X_{PAO,PP}]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor}$
Rate	$Q_{PP,Temp}\cdot Monod_{S_O}\cdot Monod_{S_{Alk}}\cdot Monod_{X_{PAO,Stor}}\cdot\frac{C_{S_{PO}}}{C_{S_{PO}}+K_{PS}}\cdot$ $\frac{K_{max}-\left(C_{X_{PAO,PP}}/C_{X_{PAO}}\right)}{K_{IPP}+K_{max}-\left(C_{X_{PAO,PP}}/C_{X_{PAO}}\right)}\cdot C_{X_{PAO}}$

P27: StorageAnoxXPP_NO3toNO2	
S_NO3	$-\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_NO2	$\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{27},S_{PO}]-\frac{1}{31}\cdot Sto[P_{27},X_{PAO,PP}]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}$
Rate	$Rate_{26}*n2_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO3}}$

P28: StorageAnoxXPP_NO2toNO	
S_NO2	$-\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_NO	$\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{28},S_{PO}]-\frac{1}{31}\cdot Sto[P_{28},X_{PAO,PP}]-\frac{1}{14}\cdot\frac{-Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{0.5715}$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}$
Rate	$Rate_{26}*n3_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO2}}*Inhib3_{PAO_{NO}}$

P29: StorageAnoxXPP_NOtoN2O	
S_NO	$-\frac{Y_{PAO,Stor} * n_{Y_{PAO_{stor}}}}{1.1429}$
S_N2O	$\frac{Y_{PAO,Stor} * n_{Y_{PAO_{stor}}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{29}, S_{PO}] - \frac{1}{31} \cdot Sto[P_{29}, X_{PAO,PP}]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor} * n_{Y_{PAO_{stor}}}$
Rate	$Rate_{26} * n4_{PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO}}$

P30: StorageAnoxXPP_N2OtoN2	
S_N2O	$-\frac{Y_{PAO,Stor} * n_{Y_{PAO_{stor}}}}{1.1429}$
S_N2	$\frac{Y_{PAO,Stor} * n_{Y_{PAO_{stor}}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{30}, S_{PO}] - \frac{1}{31} \cdot Sto[P_{30}, X_{PAO,PP}]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor} * n_{Y_{PAO_{stor}}}$
Rate	$Rate_{26} * n4_{PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO}}$

P31: LysisOHO	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{31}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{31}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_OHO	-1
Rate	$b_{OHO,T} \cdot (Monod_{S_O} + n_{d,OHO} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{x_{OHO}}$

P32: LysisAOB	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{32}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{32}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_AOB	-1
Rate	$b_{AOB,T} \cdot (Monod_{S_O} + n_{d,AOB} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{x_{AOB}}$

P33: LysisNOB	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * \left(1 - f_{X_U}\right)$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * \left(1 - f_{X_U}\right)$
S_Alk	$\frac{1}{14} \cdot Sto\left[P_{33}, S_{NH_x}\right] - \frac{1.5}{31} \cdot Sto[P_{33}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_NOB	-1
Rate	$b_{NOB,T} \cdot \left(Monod_{S_O} + n_{d,NOB} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}\right) \cdot C_{x_{NOB}}$

P34: LysisPAO	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * \left(1 - f_{X_U}\right)$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * \left(1 - f_{X_U}\right)$
S_Alk	$\frac{1}{14} \cdot Sto\left[P_{34}, S_{NH_x}\right] - \frac{1.5}{31} \cdot Sto[P_{34}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_PAO	-1
Rate	$b_{PAO,T} \cdot \left(Monod_{S_O} + n_{P,d} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}\right) \cdot C_{X_{PAO}} \cdot Monod_{S_{Alk}}$

P35: LysisANA	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * \left(1 - f_{X_U}\right)$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * \left(1 - f_{X_U}\right)$
S_Alk	$\frac{1}{14} \cdot Sto\left[P_{35}, S_{NH_x}\right] - \frac{1.5}{31} \cdot Sto[P_{35}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_ANA	-1
Rate	$b_{ANA,T} \cdot C_{X_{ANA}}$

P36: LysisXPP	
S_PO	1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{36}, S_{PO}] - \frac{1}{31} \cdot Sto\left[P_{36}, X_{PAO,PP}\right]$
X_PAO_PP	-1
Rate	$b_{PP,T} \cdot \left(Monod_{S_O} + n_{P,d} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}\right) \cdot C_{X_{PAO,PP}} \cdot Monod_{S_{Alk}}$

P37: LysisXPHA	
S_VFA	1
S_Alk	$-\frac{1}{64}$
X_PAO_Stor	-1
Rate	$b_{PAO,Stor,T} \cdot \left(Monod_{S_O} + n_{P,d} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}\right) \cdot C_{X_{PAO,Stor}} \cdot Monod_{S_{Alk}}$

P38: Precipitation	
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{38}, S_{PO}]$
X_MEOH	$-Y_{MEOH}$
X_MEP	Y_{MEP}
Rate	$k_{pre}\cdot C_{S_{PO}}\cdot C_{X_{MEOH}}$

P39: Redissolution	
S_PO	1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{39}, S_{PO}]$
X_MEOH	Y_{MEOH}
X_MEP	$-Y_{MEP}$
Rate	$k_{red}\cdot C_{X_{MEP}}\cdot \frac{C_{S_{Alk}}}{K_{Alk,ANO}+C_{S_{Alk}}}$

P40: Aeration	
S_O	1
Rate	$k_{La}\cdot\left(C_{S_O}-S_{O_{sat}}\right)$

P41: StrippingN2	
S_N2	1
Rate	$rate_{strip_{N2}}$

P42: StrippingNO	
S_NO	1
Rate	$rate_{strip_{NO}}$

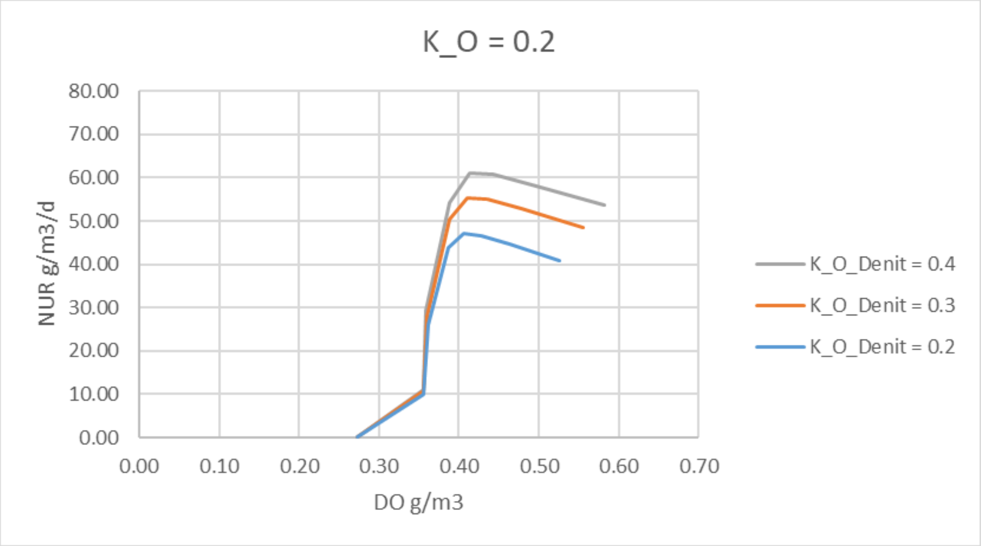
P43: StrippingN2O	
S_N2O	1
Rate	$rate_{strip_{N2O}}$

Nitrification-Denitrification in ASM2dMod

Nitrification (conversion of Ammonia to nitrate) is an aerobic process, whereas de-nitrification (nitrate to nitrogen gas) requires anoxic conditions. In ASM2dMod (and other ASM models) this is implemented through a dissolved oxygen inhibition term applied to the denitrification reactions, with a parameter K_O that has 0.2 mg O2/L as its default. Dentirification occurs over the entire DO concentration range, but at decreasing rates as the DO increases.

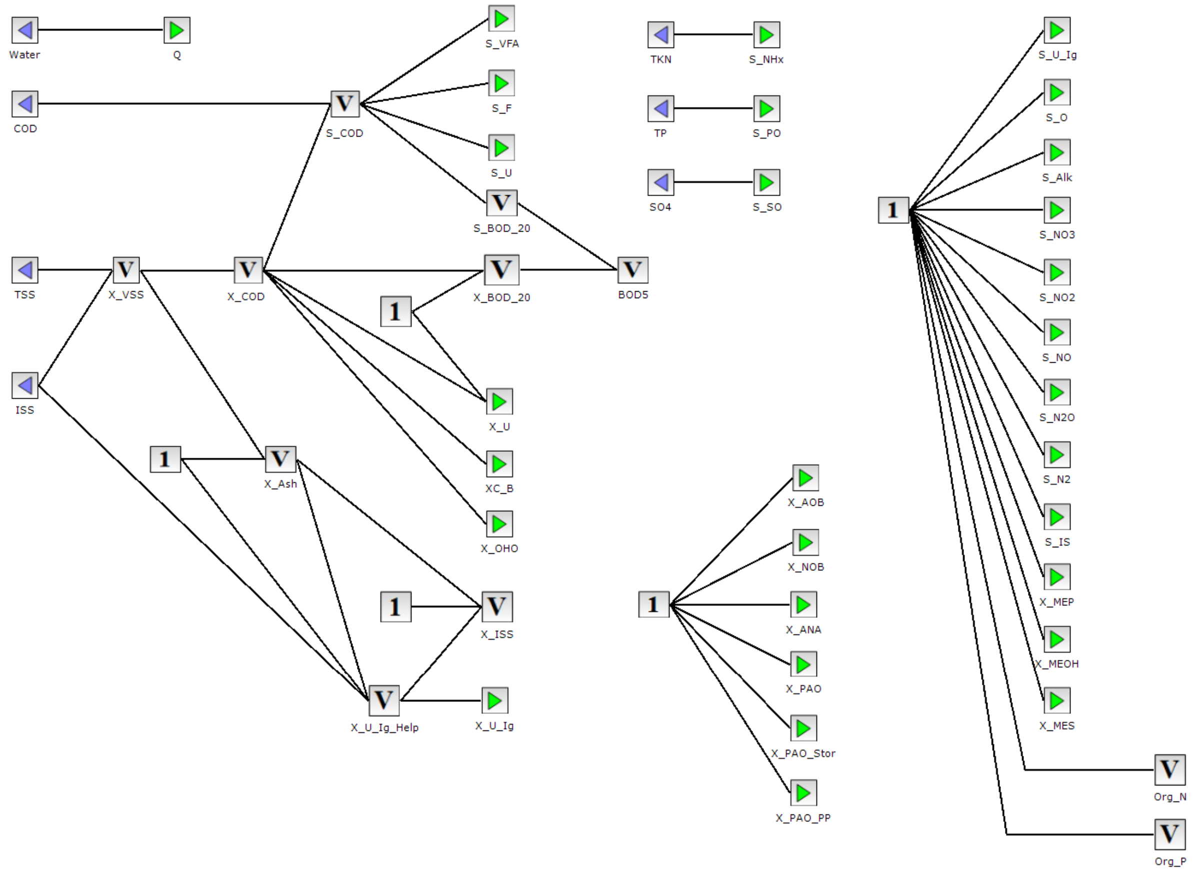
In reality activated sludge reactors often do not have completely uniform DO distributions due to imperfect mixing, and addition denitrification can occur in relatively anoxic zones within the reactor. A simple and rough way to calibrate this behaviour is to increase the K_O value to increase the denitrification rates. However, in ASM2dMod, same K_O parameters is used for a number of other processes, which are consequently also affected by altering the K_O value.

To avoid this, a separate inhibition parameter K_O_Denit has been added, which only affects the denitrification reactions. Its default value is also set to 0.2, so it has no special effect by default. If enhanced denitrification is desired, it can be achieved by increasing K_O_Denit as the following graph illustrates.



Increase in NUR (nitrate utilisation rate) with increasing K_O_Denit at different DO levels. Remark: 0.2 is the default value for both K_O and K_O_Denit.

The Fractionation Model



$$X_{VSS} = TSS - ISS$$

$$X_{COD} = i_{COD,VSS} \cdot X_{VSS}$$

$$S_{COD} = COD - X_{COD}$$

$$S_{BOD20} = S_{VFA} + S_F = S_{COD} \cdot \left(f_{S_{VFA}} + f_{S_F}\right)$$

$$\begin{aligned} X_{BOD20} &= F_{BOD,COD,X} \cdot \left(X_{OHO} + XC_B + X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in}\right) \\ &= F_{BOD,COD,X} \cdot \Big(X_{COD} \cdot \left(f_{XC_B} + f_{X_{OHO}}\right) + \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in}\right)\Big) \end{aligned}$$

$$BOD_5 = F_{BOD5,BOD20} \cdot \left(X_{BOD20} + S_{BOD20}\right)$$

$$S_{VFA} = f_{S_{VFA}} \cdot S_{COD}$$

$$S_F = f_{S_F} \cdot S_{COD}$$

$$S_U = S_{COD} \cdot \left(1 - f_{S_{VFA}} - f_{S_F}\right)$$

$$S_{UIg} = S_{UIg,in}$$

$$XC_B = f_{XC_B} \cdot X_{COD}$$

$$X_{OHO} = f_{X_{OHO}} \cdot X_{COD}$$

$$
\begin{aligned}
X_U &= X_{COD} - X_{OHO} - XC_B - X_{AOB,in} - X_{NOB,in} - X_{ANA,in} - X_{PAO,in} - X_{PAO,Stor,in} \\
&= X_{COD} \cdot \left(1 - \left(f_{XC_B} + f_{X_{OHO}}\right)\right) - \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in}\right)
\end{aligned}
$$

$$
\begin{aligned}
X_{Ash} &= i_{ISS,BM} \cdot \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{OHO}\right) \\
&= i_{ISS,BM} \cdot \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + (i_{COD,VSS} \cdot f_{X_{OHO}}) \cdot X\_VSS\right)
\end{aligned}
$$

$$X_{UIg} = ISS - \left(X_{MEOH,in} + X_{MEP,in} + i_{ISS,PP} \cdot X_{PAO,PP,in}\right) - X_{Ash}$$

$$S_{NHx} = TKN \cdot f_{S_{NH}}$$

$$S_{N2} = S_{N2,in}$$

$$S_O = S_{O,in}$$

$$S_{PO} = TP \cdot f_{S_{PO}}$$

$$S_{SO} = SO_4$$

$$S_{Alk} = S_{Alk,in}$$

$$S_{NO3} = S_{NO3,in}$$

$$S_{NO2} = S_{NO2,in}$$

$$S_{IS} = S_{IS,in}$$

$$S_{N2O} = S_{N2O,in}$$

$$S_{NO} = S_{NO,in}$$

$$X_{AOB} = X_{AOB,in}$$

$$X_{NOB} = X_{NOB,in}$$

$$X_{ANA} = X_{ANA,in}$$

$$X_{PAO} = X_{PAO,in}$$

$$X_{PAO,Stor} = X_{PAO,Stor,in}$$

$$X_{PAO,PP} = X_{PAO,PP,in}$$

$$X_{MEOH} = X_{MEOH,in}$$

$$X_{MEP} = X_{MEP,in}$$

$$X_{MES} = X_{MES,in}$$

$$OrgN = i_{N,XC_B} \cdot XC_B + i_{N,X_U} \cdot X_U + i_{N,X_{BM}} \cdot \left(X_{OHO} + X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in}\right) + i_{N,S_F} \cdot S_F + i_{N,S_U} \cdot S_U$$

$$OrgP = i_{P,XC_B} \cdot XC_B + i_{P,X_U} \cdot X_U + i_{P,X_{BM}} \cdot \left(X_{OHO} + X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in}\right) + i_{P,S_F} \cdot S_F + i_{P,S_U} \cdot S_U$$

ASM2dISS

This is an extension of ASM2dMod that allows for:

- a rigorous calculation of total-, volatile- and inorganic suspended solids
- a multi-step description of the nitrification / denitrification process

Category

ASM2dISS

Conversion Model

Default

The biological components

The components of the ASM2dISS model Category that form the **component vector** are listed in the following table.

Name	Description	Units
Q	Water	m^3/d
S_U	Soluble undegradable organics	g COD/m^3
S_U_Ig	Soluble undegradable inorganics	g DS/m3
S_O	Dissolved oxygen	g COD/m^3
S_N2	Dissolved nitrogen gas	g N/m^3
S_F	Fermentable organic matter	g COD/m^3
S_VFA	Fermentation products (as acetate)	g COD/m^3
S_NO3	Nitrate nitrogen	g N/m^3
S_NO2	Nitrite nitrogen	g N/m^3
S_NO	Nitric oxide	g N/m^3
S_N2O	Nitrous oxide	g N/m^3
S_PO	Soluble inorganic phosphorous	g P/m^3
S_NHx	Ammonium + ammonia nitrogen	g N/m^3
S_Alk	Alkalinity	mol/m^3
S_SO	Sulfate	g S/m^3
S_IS	Hydrogen sulfide	g S/m^3
X_U	Particulate undegradable organics	g COD/m^3
X_U_Ig	Particulate undegradable inorganics	g TSS/m^3
XC_B	Slowly biodegradable substrates	g COD/m^3
X_OHO	Ordinary heterotrophic organisms	g COD/m^3
X_PAO	Phosphorous accumulating organisms	g COD/m^3
X_PAO_PP	Stored polyphosphate in PAOs	g P/m^3
X_PAO_Stor	Cell internal storage product of PAOs	g COD/m^3
X_MEOH	Metal-hydroxides	g TSS/m^3
X_MEP	Metal-phosphates	g TSS/m^3
X_AOB	Ammonium Oxiding Bacteria	g COD/m^3
X_NOB	Nitrate Oxidising Bacteria	g COD/m^3
X_ANA	Anammox bacteria	g COD/m^3

The ASM2dISS model is an extension of the ASM2d model and takes into account carbon removal, nitrification, denitrification and phosphorus removal, with explicit balancing of volatile suspended solids (VSS) and inorganic suspended solids (ISS).

With respect to ASM1, several changes were introduced in ASM2 to accommodate for phosphorus removal; primarily, the biomass is assumed to have an internal structure.
The denitrifying capacity of phosphorus accumulating organisms (PAOs) was implemented because experimental evidence is available that some of the phosphorus accumulating organisms can denitrify.

ASM2d also includes poly-phosphates.

The components in the model are divided into two large groups, the solubles and the particulates. All particulate components must be electrically neutral but the solubles may carry ionic charges.

<table>
<tr><th colspan="5">Organic matter</th></tr>
<tr><th colspan="3">Soluble organic matter</th><th colspan="2">Particulate organic matter</th></tr>
<tr><td rowspan="2">Inert COD
S_U</td><th colspan="2">Readily biodegradable matter</th><td rowspan="2">Inert COD
X_U</td><td rowspan="2">Slowly biodegr. COD
XC_B</td></tr>
<tr><td>Readily biodegr. COD
S_F</td><td>Fermentation products
S_VFA</td></tr>
</table>

The heterogeneity of the biomass is expressed by the following groups of microorganisms:

- the ordinary heterotrophic organisms (X_OHO)
- the ammonium oxidizing- and the nitrate oxidizing bacteria (X_AOB and X_NOB)
- the phosphate-accumulating organisms (X_PAO)
- the Anammox bacteria (X_ANA)

The heterotrophic organisms grow both under aerobic and anoxic conditions and are active under anaerobic conditions too. Dinitrogen (S_N2) is assumed to be the only product of denitrification (anoxic growth).
The nitrifying organisms are obligate aerobic bacteria that oxidise ammonium to nitrite (S_NO2) and nitrate (S_NO3).
The concentration of the phosphate accumulating organisms does not include the internal storage products, poly-phosphates (X_PAO_PP) and cell internal organic storage products (X_PAO_Stor). However, poly-phosphate is a fraction of the activated sludge and is not expressed in COD. The cell internal organic storage products include poly-hydroxy-alkanoates, glycogen, etc., hence are only a functional component required for modelling but are not directly chemical identifiable. For stoichiometric considerations, cell internal organic storage products are assumed to have the chemical composition of poly-hydroxy-butyrate $(C_4H_6O_2)_n$.
Inorganic soluble (ortho)phosphate (S_PO) represents the bioavailable phosphorus fraction and is removed via uptake and conversion into internal poly-phosphate storage. For the balance of the electrical charges, it is assumed that S_PO exists as 50% $H_2PO_4^-$ and 50% HPO_4^{2-} independent of the pH.
For the precipitation of phosphates the components metal-hydroxides X_MeOH and metal-phosphates X_MEP are added. For stoichiometric computations it is assumed that the metal is iron, thus $Fe(OH)_3$ and $FePO_4$.

Compared to ASM2ModTemp, ASM2dISS introduces the following new elements:

1. The notation of the model components is in agreement with Corominas et al. (2010)
2. It allows balancing volatile suspended solids (VSS) and inorganic suspended solids (ISS), hence providing for more precise description of sludge balances in treatment systems. More specifically:
    a. Organic particulate components (X_OHO, X_AOB, X_NOB, X_ANA, X_PAO, XC_B, X_PAO_Stor, X_U) are used to calculate to VSS
    b. ISS account for inorganic solids present in the influent and accumulating in sludge (X_U_Ig), inorganic intracellular solids (here defined as ‘ash’), poly-phosphate storage and inorganic salts and precipitates originating from chemical phosphorus removal
3. Dissolved inorganic solids are described by the component S_U_Ig.

The Conversion Model

The processes modelled within the ASM2dISS are listed in the following table.

Name	Description
HydrolAer	Hydrolysis in aerobic conditions
HydrolAnox	Hydrolysis in anoxic conditions
HydrolAnaer	Hydrolysis in anaerobic conditions
Fermentation	Fermentation
GrowthAerSf	Heterotrophic growth on readily biodegradable matter
GrowthAerSvfa	Heterotrophic growth on fermentation products
GrowthAnoxSf_NO3toNO2	Anoxic growth on S_F with conversion NO3 to NO2
GrowthAnoxSf_NO2toNO	Anoxic growth on S_F with conversion NO2 to NO
GrowthAnoxSf_NOtoN2O	Anoxic growth on S_F with conversion NO to N2O
GrowthAnoxSf_N2OtoN2	Anoxic growth on S_F with conversion N2O to N2
GrowthAnoxSvfa_NO3toNO2	Anoxic growth on S_VFA with conversion NO3 to NO2
GrowthAnoxSvfa_NO2toNO	Anoxic growth on S_VFA with conversion NO2 to NO
GrowthAnoxSvfa_NOtoN2O	Anoxic growth on S_VFA with conversion NO to N2O
GrowthAnoxSvfa_N2OtoN2	Anoxic growth on S_VFA with conversion N2O to N2
DenAOB_NO2toNO	NO2 to NO denitrification by the ammonium oxidizing bacteria
DenAOB_NOtoN2O	NO to N2O denitrification by the ammonium oxidizing bacteria
GrowthAOBauto	Autotrophic growth of ammonium oxidizing bacteria
GrowthNOBauto	Autotrophic growth of nitrate oxidizing bacteria
GrowthAerXPHA	Aerobic growth of PAOs on PHA
GrowthAnoxXPHA_NO3toNO2	Anoxic growth of PAOs on PHA with conversion NO3 to NO2
GrowthAnoxXPHA_NO2toNO	Anoxic growth of PAOs on PHA with conversion NO2 to NO
GrowthAnoxXPHA_NOtoN2O	Anoxic growth of PAOs on PHA with conversion NO to N2O
GrowthAnoxXPHA_N2OtoN2	Anoxic growth of PAOs on PHA with conversion N2O to N2
GrowthAnaerXANA	Anaerobic growth of Anammox
StorageXPHA	Storage of cell internal organic storage material
StorageAerXPP	Storage of poly-phosphate in aerobic conditions
StorageAnoxXPP_NO3toNO2	Storage of poly-phosphate in anoxic conditions, NO3 to NO2
StorageAnoxXPP_NO2toNO	Storage of poly-phosphate in anoxic conditions, NO2 to NO
StorageAnoxXPP_NOtoN2O	Storage of poly-phosphate in anoxic conditions, NO to N2O
StorageAnoxXPP_NO2toN2	Storage of poly-phosphate in anoxic conditions, N2O to N2
LysisOHO	Lysis of ordinary heterotrophic
LysisAOB	Lysis of ammonium oxidizing bacteria
LysisNOB	Lysis of nitrate oxidizing bacteria
LysisPAO	Lysis of phosphorus accumulating organisms
LysisANA	Lysis of Anammox bacteria
LysisXPP	Lysis of poly-phosphate
LysisXPHA	Lysis of cell internal organic storage material
Precipitation	Precipitation of phosphorus
Redissolution	Re-dissolution of phosphorus
Aeration	Aeration
StrippingN2	Stripping of N2
StrippingNO	Stripping of NO
StrippingN2O	Stripping of N2O

The Conversion Model (Gujer Matrix) is illustrated in detail below.

P1: HydrolAer	
S_U	f_{S_U}
S_F	$1 - f_{S_U}$
S_PO	$-i_{P,S_F} \cdot (1 - f_{S_U}) - i_{P,S_U} \cdot f_{S_U} + i_{P,XC_B}$
S_NHx	$-i_{N,S_F} \cdot (1 - f_{S_U}) - i_{N,S_U} \cdot f_{S_U} + i_{N,XC_B}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot Monod_{S_O} \cdot Monod_{XC_B} \cdot C_{X_{OHO}}$

P2: HydrolAnox	
S_U	f_{S_U}
S_F	$1 - f_{S_U}$
S_PO	$-i_{P,S_F} \cdot (1 - f_{S_U}) - i_{P,S_U} \cdot f_{S_U} + i_{P,XC_B}$
S_NHx	$-i_{N,S_F} \cdot (1 - f_{S_U}) - i_{N,S_U} \cdot f_{S_U} + i_{N,XC_B}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot n_{NO,Hyd} \cdot Inhib_{S_O} \cdot Monod_{S_{NO}} \cdot Monod_{XC_B} \cdot C_{X_{OHO}}$

P3: HydrolAnaer	
S_U	f_{S_U}
S_F	$1 - f_{S_U}$
S_PO	$-i_{P,S_F} \cdot (1 - f_{S_U}) - i_{P,S_U} \cdot f_{S_U} + i_{P,XC_B}$
S_NHx	$-i_{N,S_F} \cdot (1 - f_{S_U}) - i_{N,S_U} \cdot f_{S_U} + i_{N,XC_B}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot n_{fe} \cdot Inhib_{S_O} \cdot Monod_{S_{NO}} \cdot Monod_{XC_B} \cdot C_{X_{OHO}}$

P4: Fermentation	
S_F	-1
S_VFA	1
S_PO	i_{P,S_F}
S_NHx	i_{N,S_F}
S_Alk	$\frac{1}{14} \cdot Sto[P_4, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_4, S_{PO}] - \frac{1}{64} \cdot Sto[P_4, S_{VFA}]$
Rate	$Q_{fe,Temp} \cdot Inhib_{S_O} \cdot Inhib_{S_{NO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_F}}{C_{S_F} + K_{fe}} \cdot C_{X_{OHO}}$

P5: GrowthAerSf	
S_O	$1-\left(\frac{1}{Y_{OHO}}\right)$
S_F	$-\frac{1}{Y_{OHO}}$
S_PO	$-\left(-\frac{1}{Y_{OHO}}\cdot i_{P,S_F}+i_{P,BM}\right)$
S_NHx	$-\left(-\frac{1}{Y_{OHO}}\cdot i_{N,S_F}+i_{N,BM}\right)$
S_Alk	$\frac{1}{14}\cdot Sto\left[P_5,S_{NH_x}\right]-\frac{1.5}{31}\cdot Sto[P_5,S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T}\cdot Monod_{S_O}\cdot Monod_{S_F}\cdot\frac{C_{S_F}}{C_{S_F}+C_{S_{VFA}}}\cdot Monod_{S_{NH}}\cdot Monod_{S_{PO}}\cdot Monod_{S_{Alk}}\cdot C_{X_{OHO}}$

P6: GrowthAerSvfa	
S_O	$1-\left(\frac{1}{Y_{OHO}}\right)$
S_VFA	$-\frac{1}{Y_{OHO}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto\left[P_6,S_{NH_x}\right]-\frac{1.5}{31}\cdot Sto[P_6,S_{PO}]-\frac{1}{64}\cdot Sto[P_6,S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T}\cdot Monod_{S_O}\cdot Monod_{S_{VFA}}\cdot\frac{C_{S_{VFA}}}{C_{S_F}+C_{S_{VFA}}}\cdot Monod_{S_{NH}}\cdot Monod_{S_{PO}}\cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P7: GrowthAnoxSf_NO3toNO2	
S_F	$-\frac{1}{Y_{OHO}*n_{Y_{OHO}}}$
S_NO3	$-\frac{1-Y_{OHO}*n_{Y_{OHO}}}{1.1429*Y_{OHO}*n_{Y_{OHO}}}$
S_NO2	$\frac{1-Y_{OHO}*n_{Y_{OHO}}}{1.1429*Y_{OHO}*n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO}*n_{Y_{OHO}}}\cdot i_{P,S_F}-i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO}*n_{Y_{OHO}}}\cdot i_{N,S_F}-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto\left[P_7,S_{NH_x}\right]-\frac{1.5}{31}\cdot Sto[P_7,S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T}\cdot n2_{g_{OHO}}\cdot Inhib_{OH2}\cdot Monod_{S_F}\cdot\frac{C_{S_F}}{C_{S_F}+C_{S_{VFA}}}\cdot Monod_{S_{NH}}\cdot Monod_{OHO_{NO3}} \cdot Monod_{S_{PO}}\cdot Monod_{S_{Alk}}\cdot C_{X_{OHO}}$

P8: GrowthAnoxSf_NO2toNO	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_8, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_8, S_{PO}] - \frac{1}{14} \cdot Sto[P_8, S_{NO2}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n3_{g_{OHO}} \cdot Inhib_{OH3} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Inhib3_{OHO_{NO}} * Monod_{OHO_{NO2}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P9: GrowthAnoxSf_NOtoN2O	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_9, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_9, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n4_{g_{OHO}} \cdot Inhib_{OH4} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Monod_{OHO_{NO}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P10: GrowthAnoxSf_N2OtoN2	
S_F	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{0{,}5715 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{P,S_F} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} * n_{Y_{OHO}}} \cdot i_{N,S_F} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{10}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{10}, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n5_{g_{OHO}} \cdot Inhib_{OH5} \cdot Monod_{S_{F5}} \cdot \frac{C_{S_F}}{C_{S_F} + C_{S_{VFA}}} \cdot Monod_{S_{NH}} \cdot Inhib5_{OHO_{NO}} * Monod_{OHO_{N2O}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot C_{X_{OHO}}$

P11: GrowthAnoxSvfa_NO3toNO2	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO3	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{11}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{11}, S_{PO}] - \frac{1}{64} * Sto[P_{11}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n2_{g_{OHO}} \cdot Inhib_{OH2} \cdot Monod_{S_{VFA2}} * Monod_{OHO_{NO3}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P12: GrowthAnoxSvfa_NO2toNO	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO2	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{12}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{12}, S_{PO}] - \frac{1}{64} * Sto[P_{12}, S_{VFA}] - \frac{1}{14} * Sto[P_{10}, S_{NO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n3_{g_{OHO}} \cdot Inhib_{OH3} \cdot Monod_{S_{VFA3}} * Monod_{OHO_{NO2}} \cdot Monod_{S_{NH}} \cdot Inhib3_{OHNO} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P13: GrowthAnoxSvfa_NOtoN2O	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_NO	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} * Sto[P_{13}, S_{NH_x}] - \frac{1.5}{31} * Sto[P_{13}, S_{PO}] - \frac{1}{64} * Sto[P_{13}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n4_{g_{OHO}} \cdot Inhib_{OH4} \cdot Monod_{S_{VFA4}} \cdot Monod_{OHO_{NO}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P14: GrowthAnoxSvfa_N2OtoN2	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
S_N2O	$-\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 * Y_{OHO} * n_{Y_{OHO}}}$
S_N2	$\frac{1 - Y_{OHO} * n_{Y_{OHO}}}{1.1429 + Y_{OHO} * n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{14}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{14}, S_{PO}] - \frac{1}{64} \cdot Sto[P_{14}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n5_{g_{OHO}} \cdot Inhib_{OH5} \cdot Monod_{S_{VFA5}} \cdot Monod_{OHO_{NO}} \cdot Monod_{S_{NH}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{S_{VFA}}}{C_{S_F} + C_{S_{VFA}}} \cdot C_{X_{OHO}}$

P15: DenAOB_NO2toNO	
S_O	$-\left(\frac{\frac{2.2857}{Y_{AOB}}}{n_{Y_{AOB}}} - 1\right)$
S_NO2	$-\frac{1}{Y_{AOB} * n_{Y_{AOB}}}$
S_NO	$\frac{2}{Y_{AOB} * n_{Y_{AOB}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-\frac{1}{Y_{AOB} * n_{Y_{AOB}}} - i_{NBM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{15}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{15}, S_{PO}] - \frac{1}{14} \cdot Sto[P_{15}, S_{NO2}]$
X_AOB	1
Rate	$n1_{AOB} * \mu_{AOB,T} * C_{X_{AOB}} * \frac{S_{FNA}}{K_{FNA_{AOBden}} + S_{FNA}} * \frac{S_{FA}}{K_{FA_{AOBden}} + S_{FA}} * Inhib_{AOBden_{SO}} * Monod_{AUT_{PO}} * Monod_{AUT_{ALK}}$

P16: DenAOB_NOtoN2O	
S_O	$-\left(\frac{2.2857}{Y_{AOB}*n_{Y_{AOB}}}-1\right)$
S_NO2	$\frac{1}{Y_{AOB}*n_{Y_{AOB}}}$
S_NO	$-\frac{2}{Y_{AOB}*n_{Y_{AOB}}}$
N2O	$\frac{2}{Y_{AOB}*n_{Y_{AOB}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-\frac{1}{Y_{AOB}*n_{Y_{AOB}}}-i_{N_{BM}}$
S_Alk	$\frac{1}{14}\cdot Sto\left[P_{16},S_{NH_x}\right]-\frac{1.5}{31}\cdot Sto[P_{16},S_{PO}]-\frac{1}{14}*Sto[P_{16},S_{NO2}]$
X_AOB	1
Rate	$n2_{AOB}*\mu_{AOB,T}*C_{X_{AOB}}*\frac{C_{S_{NO}}}{K_{SNO_{AOBden}}+C_{S_{NO}}}*\frac{S_{FA}}{K_{FA_{AOBden}}+S_{FA}}*Inhib_{AOBden_{SO}}*Monod_{AUT_{PO}}*Monod_{AUT_{ALK}}$

P17: GrowthAOBauto	
S_O	$-\frac{3.4286-Y_{AOB}}{Y_{AOB}}$
S_NO2	$\frac{1}{Y_{AOB}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N_{BM}}-\frac{1}{Y_{AOB}}$
S_Alk	$\frac{1}{14}\cdot Sto\left[P_{17},S_{NH_x}\right]-\frac{1.5}{31}\cdot Sto[P_{17},S_{PO}]-\frac{1}{14}\cdot Sto[P_{17},S_{NO2}]$
X_AOB	1
Rate	$\mu_{AOB,T}*Inhib_{FA_9}*Inhib_{FNA_9}*Monod_{AUT_{PO}}*Monod_{AUT_{ALK}}*C_{X_{AOB}}$

P18: GrowthNOBauto	
S_O	$-\frac{1.1429-Y_{NOB}}{Y_{NOB}}$
S_NO3	$\frac{1}{Y_{NOB}}$
S_NO2	$-\frac{1}{Y_{NOB}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N_{BM}}$
S_Alk	$\frac{1}{14}\cdot Sto\left[P_{18},S_{NH_x}\right]-\frac{1.5}{31}\cdot Sto[P_{18},S_{PO}]$
X_NOB	1
Rate	$\mu_{NOB,T}*Inhib_{FNA_{10}}*Inhib_{FA_{10}}*Monod_{NOB_O}*Monod_{AUT_{PO}}*Monod_{AUT_{ALK}}*C_{X_{AOB}}$

P19: GrowthAerXPHA	
S_O	$1 - \frac{1}{Y_{PAO}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{19}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{19}, S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}}$
Rate	$\mu_{PAO,T} \cdot Monod_{S_O} \cdot Monod_{S_{NH}} \cdot Monod_{S_{Alk}} \cdot Monod_{S_{PO}} \cdot Monod_{X_{PAO,Stor}} \cdot C_{X_{PAO}}$

P20: GrowthAnoxXPHA_NO3toNO2	
S_NO3	$-\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{1.1429 * Y_{PAO} * n_{Y_{PAO}}}$
S_NO2	$\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{1.1429 * Y_{PAO} * n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{20}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{20}, S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO} * n_{Y_{PAO}}}$
Rate	$Rate_{19} * n2_{PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO3}}$

P21: GrowthAnoxXPHA_NO2toNO	
S_NO2	$-\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{1.1429 * Y_{PAO} * n_{Y_{PAO}}}$
S_NO	$\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{1.1429 * Y_{PAO} * n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{21}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{21}, S_{PO}] - \frac{1}{14} \cdot \frac{-1 + Y_{PAO} \cdot n_{Y_{PAO}}}{0.5715 \cdot Y_{PAO} \cdot n_{Y_{PAO}}}$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO} * n_{Y_{PAO}}}$
Rate	$Rate_{19} * n3_{PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO2}} * Inhib3_{PAO_{NO}}$

P22: GrowthAnoxXPHA_NOtoN2O	
S_NO	$-\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_N2O	$\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{22},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{22},S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}*n_{Y_{PAO}}}$
Rate	$Rate_{19}*n4_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO}}$

P23: GrowthAnoxXPHA_N2OtoN2	
S_N2O	$-\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_N2	$\frac{1-Y_{PAO}*n_{Y_{PAO}}}{1.1429*Y_{PAO}*n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14}\cdot Sto[P_{23},S_{NH_x}]-\frac{1.5}{31}\cdot Sto[P_{23},S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO}*n_{Y_{PAO}}}$
Rate	$Rate_{19}*n45_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO}}*Inhib5_{PAO_{NO}}$

P24: GrowthAnaerXANA	
S_NO3	1.52
S_NO2	$-1.52-\frac{1}{Y_{ANA}}$
S_N2	$\frac{2}{Y_{ANA}}$
S_NHx	$-\frac{1}{Y_{ANA}}-i_{N,BM}$
X_ANA	1
Rate	$\mu_{ANA,T}*\frac{C_{S_{NO2}}}{K_{NO2_{ANA}}+C_{S_{NO2}}+\frac{S_{NO2}^2}{KI_{NO2_{ANA}}}}*\frac{C_{S_{NHx}}}{K_{NH_{ANA}}+C_{S_{NHx}}}*\frac{K_{O_{ANA}}}{K_{O_{ANA}}+C_{S_O}}*C_{X_{ANA}}$

P25: StorageXPHA	
S_VFA	-1
S_PO	Y_{PO}
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{25},S_{PO}]-\frac{1}{64}\cdot Sto[P_{25},S_{VFA}]-\frac{1}{31}\cdot Sto\left[P_{25},X_{PAO,PP}\right]$
X_PAO_PP	$-Y_{PO}$
X_PAO_Stor	1
Rate	$Q_{PAO,Stor,Temp}\cdot Monod_{S_{VFA}}\cdot Monod_{S_{Alk}}\cdot\frac{C_{X_{PAO,PP}}}{\left(C_{X_{PAO,PP}}/C_{X_{PAO}}\right)+K_{PP}}$

P26: StorageAerXPP	
S_O	$-Y_{PAO,Stor}$
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{26},S_{PO}]-\frac{1}{31}\cdot Sto\left[P_{26},X_{PAO,PP}\right]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor}$
Rate	$Q_{PP,Temp}\cdot Monod_{S_O}\cdot Monod_{S_{Alk}}\cdot Monod_{X_{PAO,Stor}}\cdot\frac{C_{S_{PO}}}{C_{S_{PO}}+K_{PS}}\cdot$ $\frac{K_{max}-\left(C_{X_{PAO,PP}}/C_{X_{PAO}}\right)}{K_{IPP}+K_{max}-\left(C_{X_{PAO,PP}}/C_{X_{PAO}}\right)}\cdot C_{X_{PAO}}$

P27: StorageAnoxXPP_NO3toNO2	
S_NO3	$-\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_NO2	$\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{27},S_{PO}]-\frac{1}{31}\cdot Sto\left[P_{27},X_{PAO,PP}\right]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}$
Rate	$Rate_{26}*n2_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO3}}$

P28: StorageAnoxXPP_NO2toNO	
S_NO2	$-\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_NO	$\frac{Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{28},S_{PO}]-\frac{1}{31}\cdot Sto\left[P_{28},X_{PAO,PP}\right]-\frac{1}{14}\cdot\frac{-Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}}{0.5715}$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor}*n_{Y_{PAO_{stor}}}$
Rate	$Rate_{26}*n3_{PAO}*\frac{K_{O_{PAO}}}{C_{S_O}}*Monod_{PAO_{NO2}}*Inhib3_{PAO_{NO}}$

P29: StorageAnoxXPP_NOtoN2O	
S_NO	$-\frac{Y_{PAO,Stor} * n_{Y_{PAOstor}}}{1.1429}$
S_N2O	$\frac{Y_{PAO,Stor} * n_{Y_{PAOstor}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{29}, S_{PO}] - \frac{1}{31} \cdot Sto[P_{29}, X_{PAO,PP}]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor} * n_{Y_{PAOstor}}$
Rate	$Rate_{26} * n4_{PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO}}$

P30: StorageAnoxXPP_N2OtoN2	
S_N2O	$-\frac{Y_{PAO,Stor} * n_{Y_{PAOstor}}}{1.1429}$
S_N2	$\frac{Y_{PAO,Stor} * n_{Y_{PAOstor}}}{1.1429}$
S_PO	-1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{30}, S_{PO}] - \frac{1}{31} \cdot Sto[P_{30}, X_{PAO,PP}]$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor} * n_{Y_{PAOstor}}$
Rate	$Rate_{26} * n4_{PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO}}$

P31: LysisOHO	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{31}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{31}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_OHO	-1
Rate	$b_{OHO,T} \cdot (Monod_{S_O} + n_{d,OHO} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{x_{OHO}}$

P32: LysisAOB	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{32}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{32}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_AOB	-1
Rate	$b_{AOB,T} \cdot (Monod_{S_O} + n_{d,AOB} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{x_{AOB}}$

P33: LysisNOB	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{33}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{33}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_NOB	-1
Rate	$b_{NOB,T} \cdot (Monod_{S_O} + n_{d,NOB} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{x_{NOB}}$

P34: LysisPAO	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{34}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{34}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_PAO	-1
Rate	$b_{PAO,T} \cdot (Monod_{S_O} + n_{P,d} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{X_{PAO}} \cdot Monod_{S_{Alk}}$

P35: LysisANA	
S_PO	$i_{P,BM} - i_{P,X_U} * f_{X_U} - i_{P,XC_B} * (1 - f_{X_U})$
S_NHx	$i_{N,BM} - i_{N,X_U} * f_{X_U} - i_{N,XC_B} * (1 - f_{X_U})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{35}, S_{NH_x}] - \frac{1.5}{31} \cdot Sto[P_{35}, S_{PO}]$
X_U	f_{X_U}
XC_B	$1 - f_{X_U}$
X_ANA	-1
Rate	$b_{ANA,T} \cdot C_{X_{ANA}}$

P36: LysisXPP	
S_PO	1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{36}, S_{PO}] - \frac{1}{31} \cdot Sto[P_{36}, X_{PAO,PP}]$
X_PAO_PP	-1
Rate	$b_{PP,T} \cdot (Monod_{S_O} + n_{P,d} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{X_{PAO,PP}} \cdot Monod_{S_{Alk}}$

P37: LysisXPHA	
S_VFA	1
S_Alk	$-\frac{1}{64}$
X_PAO_Stor	-1
Rate	$b_{PAO,Stor,T} \cdot (Monod_{S_O} + n_{P,d} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{X_{PAO,Stor}} \cdot Monod_{S_{Alk}}$

P38: Precipitation	
S_PO	-1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{38}, S_{PO}]$
X_MEOH	$-Y_{MEOH}$
X_MEP	Y_{MEP}
Rate	$k_{pre}\cdot C_{S_{PO}}\cdot C_{X_{MEOH}}$

P39: Redissolution	
S_PO	1
S_Alk	$-\frac{1.5}{31}\cdot Sto[P_{39}, S_{PO}]$
X_MEOH	Y_{MEOH}
X_MEP	$-Y_{MEP}$
Rate	$k_{red}\cdot C_{X_{MEP}}\cdot\frac{C_{S_{Alk}}}{K_{Alk,ANO}+C_{S_{Alk}}}$

P40: Aeration	
S_O	1
Rate	$k_{La}\cdot\left(C_{S_O}-S_{O_{sat}}\right)$

P41: StrippingN2	
S_N2	1
Rate	$rate_{strip_{N2}}$

P42: StrippingNO	
S_NO	1
Rate	$rate_{strip_{NO}}$

P43: StrippingN2O	
S_N2O	1
Rate	$rate_{strip_{N2O}}$

Parameters

Name	Description	Value	Units
F_BOD5_BOD20	Conversion BOD5/BOD20	0.66	---
F_BOD_COD_X	Conversion factor X_BOD/X_COD	0.65	---
i_COD_VSS	VSS content of other X_COD components	1.64	g COD/g VSS
i_COD_VSS_ANA	VSS content of ANAs	1.42	g COD/g VSS
i_COD_VSS_AOB	VSS content of AOBs	1.42	g COD/g VSS
i_COD_VSS_NOB	VSS content of NOBs	1.42	g COD/g VSS
i_COD_VSS_OHO	VSS content of OHOs	1.42	g COD/g VSS
i_COD_VSS_PAO	VSS content of PAOs	1.42	g COD/g VSS
i_ISS_BM	Ash content of biomass	0.08	g SS/g COD
i_ISS_PP	Polyphosphate conversion to ISS	3.065	g SS/g P
i_N_S_F	Nitrogen content of soluble substrate S_F	0.03	g N/g COD
i_N_S_U	Nitrogen content of inert soluble COD S_U	0.01	g N/g COD
i_N_XC_B	Nitrogen content of particulate substrate XC_B	0.04	g N/g COD
i_N_X_BM	Nitrogen content of biomass	0.07	g N/g COD
i_N_X_U	Nitrogen content of inert particulate COD X_U	0.03	g N/g COD
i_P_S_F	Phosphorus content of soluble substrate S_F	0.01	g P/g COD
i_P_S_U	Phosphorus content of inert soluble COD S_U	0.0	g P/g COD
i_P_XC_B	Phosphorus content of particulate substrate XC_B	0.01	g P/g COD
i_P_X_BM	Phosphorus content of biomass	0.02	g P/g COD
i_P_X_U	Phosphorus content of inert particulate COD X_U	0.01	g P/g COD
K2_O_OHO	Saturation/Inhibtion coeff for OHO's growth, NO3 to NO2	0.2	g/m^3
K3_O_OHO	Saturation/Inhibtion coeff for OHO's growth, NO2 to NO	0.2	g/m^3
K4_O_OHO	Saturation/Inhibtion coeff for OHO's growth, NO to N2O	0.2	g/m^3
K5_O_OHO	Saturation/Inhibtion coeff for OHO's growth, N2O to N2	0.2	g/m^3
KI10_FA	FA inhibition coeff, NO2 oxidation by NOB	0.5	g/m^3
KI10_FNA	FNA inhibition coeff, NO2 oxidation by NOB	0.1	g/m^3
KI3_NO_OHO	NO inhibition coeff for OHOs, NO2 to NO	0.5	g/m^3
KI3_NO_PAO	NO inhibition coeff for PAOs, NO2 to NO	0.5	g/m^3
KI4_NO_OHO	NO inhibition coeff for OHOs, NO to N2O	0.3	g/m^3
KI4_NO_PAO	NO inhibition coeff for PAOs, NO to N2O	0.3	g/m^3
KI5_NO_OHO	NO inhibition coeff for OHOs, N2O to N2	0.2	g/m^3
KI5_NO_PAO	NO inhibition coeff for PAOs, N2O to N2	0.2	g/m^3
KI9_FA	FA inhibition coeff, NH oxidation by AOB	1	g/m^3
KI9_FNA	FNA inhibition coeff, NH oxidation by AOB	0.1	g/m^3
KI_NO2_ANA	Nitrite inhibition coeff for Anammox	20	g/m^3
KI_O_AOBden	Inhibition coefficient for oxygen in AOB denitrification	0.035	g/m^3
K_ALK_AUT	Saturation coeff of autotrophs for alkalinity	0.5	g/m^3
K_Alk	Saturation coeff for alkalinity (HCO3-)	0.1	g/m^3
K_Alk_ANO	Saturation coeff of autotrophs for alkalinity	0.5	g/m^3
K_F1	S_F saturation coeff for aerobic growth	4	g/m^3
K_F2	S_F saturation coeff for OHO growth, NO3 to NO2	4	g/m^3
K_F3	S_F saturation coeff for OHO growth, NO2 to NO	4	g/m^3
K_F4	S_F saturation coeff for OHO growth, NO to N2O	4	g/m^3

Name	Description	Value	Units
K_F5	S_F saturation coeff for OHO growth, N2O to N2	4	g/m^3
K_FA	Half-saturation coeff for Free Ammonia (FA)	0.004	g/m^3
K_FA_AOBden	Ammonium half saturation coefficient for AOB denitrification	1	g/m^3
K_FNA	Half-saturation coeff for Free Nitrous Acid (FNA)	5e-006	g/m^3
K_FNA_AOBden	FNA saturation coefficient for AOB denitrifcation	0.0006	g/m^3
K_IPP	Inhibition coeff for X_PP storage	0.02	g/m^3
K_MAX	Maximum ratio of X_PP/X_PAO	0.34	g/m^3
K_N2O_OHO	N2O half saturation coeff for OHOs	0.02	g/m^3
K_N2O_PAO	N2O half saturation coeff for PAOs	0.02	g/m^3
K_NH	Saturation coeff for ammonium (nutrient)	0.05	g/m^3
K_NH_ANA	Ammonia half-saturation coeff for Anammox	0.07	g/m^3
K_NO2_ANA	Nitrite half-saturation coeff for Anammox	0.05	g/m^3
K_NO2_OHO	NO2 half saturation coeff for OHOs	0.3	g/m^3
K_NO2_PAO	NO2 half saturation coeff for PAOs	0.3	g/m^3
K_NO3_OHO	NO3 half saturation coeff for OHOs	1.5	g/m^3
K_NO3_PAO	NO3 half saturation coeff for PAOs	1.5	g/m^3
K_NO_OHO	NO half saturation coeff for OHOs	0.04	g/m^3
K_NO_PAO	NO half saturation coeff for PAOs	0.04	g/m^3
K_NOx	Saturation/inhibition coeff for nitrate+nitrite	0.5	g/m^3
K_O	Saturation/inhibition coeff for oxygen	0.2	g/m^3
K_O_ANA	Saturation/inhibition coeff for oxygen, ANA	0.01	g/m^3
K_O_AOB	Oxygen half-saturation coeff for AOB	0.6	g/m^3
K_O_AOBden	Saturation coefficient for oxygen in AOB denitrification	11.4	g/m^3
K_O_NOB	Oxygen half-saturation coeff for NOB	1.2	g/m^3
K_O_PAO	Saturation/Inhibition coefficient for oxygen, PAO	0.2	g/m^3
K_P	Saturation coeff for phosphorus (nutrient)	0.01	g/m^3
K_PAO_Stor	Saturation coeff for PHA	0.01	g/m^3
K_PP	Saturation coeff for poly-phosphate	0.01	g/m^3
K_PS	Saturation coeff for phosphorus in PP storage	0.2	g/m^3
K_P_AUT	Saturation coeff for phosphate (nutrient), autotrophs	0.01	g/m^3
K_SNO_AOBden	NO saturation coeff for AOB denitrification	1	g/m^3
K_VFA1	Saturation coeff for S_VFA (acetate)	4	g/m^3
K_VFA2	Half-saturation coeff for OHOs on VFA, NO3 to NO2	4	g/m^3
K_VFA3	Half-saturation coeff for OHOs on VFA, NO2 to NO	4	g/m^3
K_VFA4	Half-saturation coeff for OHOs on VFA, NO to N2O	4	g/m^3
K_VFA5	Half-saturation coeff for OHOs on VFA, N2O to N2	4	g/m^3
K_X	Saturation coeff for particulate COD	0.1	g/m^3
K_fe	Saturation coeff for fermentation on S_F	4	g/m^3
Q_PAO_Stor	Rate constant for storage of PHA (base: X_PP)	3	1/d
Q_PP	Rate constant for storage of PP	1.5	1/d
Q_fe	Maximum rate for fermentation	3	1/d
b_ANA	Decay rate of Anammox bacteria	0.0025	1/d
b_AOB	Decay rate of AOB	0.096	1/d
b_NOB	Decay rate of NOB	0.096	1/d
b_OHO	Rate constant for lysis and decay of OHO	0.4	1/d
b_PAO	Rate constant for lysis of X_PAO	0.2	1/d
b_PAO_Stor	Rate constant for lysis of X_PHA	0.2	1/d
b_PP	Rate constant for lysis of X_PP	0.2	1/d
k_PRE	Rate constant for P precipitation	1	1/d
k_RED	Rate constant for P redissolution	0.6	1/d
k_h	Hydrolysis rate constant	3	g COD/

Name	Description	Value	Units
			(g COD*d)
mu_ANA	Maximum growth rate for Anammox	0.019	1/d
mu_AOB	Maximum growth rate for AOBs	1	1/d
mu_NOB	Maximum growth rate for NOBs	1	1/d
mu_OHO	Maximum growth rate for OHOs	6	1/d
mu_PAO	Maximum growth rate for PAOs	1	1/d
n1_AOB	Growth factor for AOB denitrification step 1	0.5	---
n2_AOB	Growth factor for AOB denitrification step2	0.5	---
n2_PAO	Correction factor for anoxic growth of PAOs, NO3 to NO2	0.1	---
n2_g_OHO	Correction factor for anoxic growth of OHOs, NO3 to NO2	0.3	---
n3_PAO	Correction factor for anoxic growth of PAOs, NO2 to NO	0.1	---
n3_g_OHO	Correction factor for anoxic growth of OHOs, NO2 to NO	0.3	---
n4_PAO	Correction factor for anoxic growth of PAOs, NO to N2O	0.2	---
n4_g_OHO	Correction factor for anoxic growth of OHOs, NO to N2O	0.6	---
n5_PAO	Correction factor for anoxic growth of PAOs, N2O to N2	0.2	---
n5_g_OHO	Correction factor for anoxic growth of OHOs, N2O to N2	0.8	---
n_NO_Hyd	Anoxic hydrolysis reduction factor	0.6	---
n_d_AOB	Anoxic reduction factor for decay of AOB	0.33	---
n_d_NOB	Anoxic reduction factor for decay of NOB	0.33	---
n_d_OHO	Anoxic reduction factor for decay of heterotrophs	0.5	---
n_d_P	Anoxic reduction factor for decay of PAO, PP and PHA	0.33	---
n_fe	Anaerobic hydrolysis reduction factor	0.4	---
Y_ANA	Yield for Anammox biomass	0.159	---
Y_AOB	Yield for ammonia-oxidising biomass (AOB)	0.18	gCOD/gN
Y_MEOH	Yield of MEOH in redissolution process	3.45	---
Y_MEP	Yield of MEP in precipitation process	4.87	---
Y_NOB	Yield for nitrite-oxidising biomass (NOB)	0.06	gCOD/gN
Y_OHO	Yield for Heterotrophic Biomass	0.625	gCOD/gCOD
Y_PAO	Yield coeff (biomass/PHA)	0.625	---
Y_PAO_Stor	PHA requirement for PP storage	0.2	---
Y_PO	PP requirement (S_PO4 release) per PHA stored	0.4	---
f_S_U	Fraction of inert COD in particulate substrate	0	---
f_X_U	Fraction of inert COD generated in biomass lysis	0.1	---
n_Y_AOB	Anoxic yield factor for AOB denitrification	0.83	---
n_Y_OHO	Anoxic yield factor for OHO	0.9	---
n_Y_PAO	Anoxic yield factor for PAO	0.9	---
n_Y_PAO_Stor	Anoxic yield factor for PHA requirement for PP storage	0.9	---
H_Ref	Depth of the reference tank (lab-scale)	0.8	---
KlaN2O_anox	N2O transfer constant under anoxic condition	20	---
mode_strip	Stripping mechanism (0=Henry, 1=kLa)	0	---
A_Air	Aeration field size	200	m^2
H_Tank	Depth of the tank	5.0	m

State Variables

Name / Description	Expression
IT3_OHO_NO Inhibition of NO on OHOs growth	$= \frac{KI3_{NO_{OHO}}}{KI3_{NO_{OHO}} + C_{S_{NO}}}$
IT3_PAO_NO Inhibition of NO on PAOs growth	$= \frac{KI3_{NO_{PAO}}}{KI3_{NO_{PAO}} + C_{S_{NO}}}$
IT5_OHO_NO Inhibition of NO on OHOs growth	$= \frac{KI5_{NO_{OHO}}}{KI5_{NO_{OHO}} + C_{S_{NO}}}$
IT5_PAO_NO Inhibition of NO on PAOs growth	$= \frac{KI5_{NO_{PAO}}}{KI5_{NO_{PAO}} + C_{S_{NO}}}$
IT_AOBden_SO Haldane inhibition term of oxygen for AOB denitrification	$= \frac{C_{S_O}}{K_{O_{AOBden}} + \left(1 - 2 * \left(\frac{K_{O_{AOBden}}}{KI_{O_{AOBden}}}\right)^{0.5}\right) * C_{S_O} + \frac{C_{S_O}^2}{KI_{O_{AOBden}}}}$
IT_FA_10 Inhibition of Free Ammonia on Autotrophic Growth of NOB	$= \frac{KI10_{FA}}{KI10_{FA} + S_{FA}}$
IT_FA_9 Inhibition of Free Ammonia on Autotrophic Growth of AOB	$= \frac{S\_FA}{(K_{FA} + S_{FA} + S_{FA}^2)/KI9_{FA}}$
IT_FNA_10 Inhibition of Free Nitric Acid on Autotrophic Growth of NOB	$= \frac{S\_FNA}{(K_{FNA} + S_{FNA} + S_{FNA}^2)/KI10_{FNA}}$
IT_FNA_9 Inhibition of Free Nitric Acid on Autotrophic Growth of AOB	$= \frac{KI9_{FNA}}{KI9_{FNA} + S_{FNA}}$
IT_OH2 Oxygen inhibition on OHO's growth, NO3 to NO2	$= \frac{K2_{O_{OHO}}}{K2_{O_{OHO}} + C_{S_O}}$
IT_OH3 Oxygen inhibition on OHO's growth, NO2 to NO	$= \frac{K3_{O_{OHO}}}{K3_{O_{OHO}} + C_{S_O}}$
IT_OH4 Oxygen inhibition on OHO's growth, NO to N2O	$= \frac{K4_{O_{OHO}}}{K4_{O_{OHO}} + C_{S_O}}$
IT_OH5 Oxygen inhibition on OHO's growth, N2O to N2	$= \frac{K5_{O_{OHO}}}{K5_{O_{OHO}} + C_{S_O}}$
IT_S_NOx Inhibition term for S_NOx	$= \frac{K_{NOx}}{K_{NOx} + S_{NOx}}$
IT_S_O The inhibition term for oxygen	$= \frac{K_O}{K_O + C_{S_O}}$
MT_AOB_O S_O Monod term for autotrophic growth of AOBs	$= \frac{C_{S_O}}{K_{O_{AOB}} + C_{S_O}}$
MT_AUT_ALK S_Alk Monod term for AOBs, NOBs	$= \frac{C_{S_{Alk}}}{C_{S_{Alk}} + K_{ALK_{AUT}}}$
MT_AUT_PO S_PO Monod term for AOBs, NOBs	$= \frac{C_{PO}}{K_{P_{AUT}} + C_{S_{PO}}}$
MT_NOB_O S_O Monod term for autotrophic growth of NOBs	$= \frac{C_{S_O}}{K_{O_{NOB}} + C_{S_O}}$

Name / Description	Expression
MT_OHO_N2O N2O Monod term for anoxic growth of OHOs	$= \frac{C_{S_{N2O}}}{K_{N2O_{OHO}} + C_{S_{N2O}}}$
MT_OHO_NO NO Monod term for anoxic growth of OHOs	$= \frac{C_{S_{NO}}}{(K_{NO_{OHO}} + C_{S_{NO}}) + \frac{C_{S_{NO}}^2}{KI4_{NO_{OHO}}}}$
MT_OHO_NO2 NO2 Monod term for anoxic growth of OHOs	$= \frac{C_{S_{NO2}}}{K_{NO2_{OHO}} + C_{S_{NO2}}}$
MT_OHO_NO3 NO3 Monod term for anoxic growth of OHOs	$= \frac{C_{S_{NO3}}}{K_{NO3_{OHO}} + C_{S_{NO3}}}$
MT_PAO_N2O N2O Monod term for anoxic growth of PAOs	$= \frac{C_{S_{N2O}}}{K_{N2O_{PAO}} + C_{S_{N2O}}}$
MT_PAO_NO NO Monod term for anoxic growth of PAOs	$= \frac{C_{S_{NO}}}{K_{NO_{PAO}} + C_{S_{NO}} + \frac{C_{S_{NO}}^2}{KI4_{NO_{PAO}}}}$
MT_PAO_NO2 NO2 Monod term for anoxic growth of PAOs	$= \frac{C_{S_{NO2}}}{K_{NO2_{PAO}} + C_{S_{NO2}}}$
MT_PAO_NO3 NO3 Monod term for anoxic growth of PAOs	$= \frac{C_{S_{NO3}}}{K_{NO3_{PAO}} + C_{S_{NO3}}}$
MT_S_ALK Monod term for alkalinity	$= \frac{C_{S_{Alk}}}{K_{Alk} + C_{S_{Alk}}}$
MT_S_F1 Monod term for S_F	$= \frac{C_{S_F}}{K_{F1} + C_{S_F}}$
MT_S_F2 Monod term for S_F, NO3 to NO2	$= \frac{C_{S_F}}{K_{F2} + C_{S_F}}$
MT_S_F3 Monod term for S_F, NO2 to NO	$= \frac{C_{S_F}}{K_{F3} + C_{S_F}}$
MT_S_F4 Monod term for S_F, NO to N2O	$= \frac{C_{S_F}}{K_{F4} + C_{S_F}}$
MT_S_F5 Monod term for S_F, N2O to N2	$= \frac{C_{S_F}}{K_{F5} + C_{S_F}}$
MT_S_NH Monod term for ammonium	$= \frac{C_{S_{NHx}}}{K_{NH} + C_{S_{NHx}}}$
MT_S_NOx Monod term for S_NO	$= \frac{S_{NOx}}{K_{NOx} + S_{NOx}}$
MT_S_O Monod term for oxygen	$= \frac{C_{S_O}}{K_O + C_{S_O}}$
MT_S_PO Monod term for S_PO	$= \frac{C_{S_{PO}}}{K_P + C_{S_{PO}}}$
MT_S_VFA1 Monod term for S_VFA	$= \frac{C_{S_{VFA}}}{K_{VFA1} + C_{S_{VFA}}}$
MT_S_VFA2 Substrate Monod term for anoxic growth of OHOs, NO3 to NO2	$= \frac{C_{S_{VFA}}}{K_{VFA2} + C_{S_{VFA}}}$

Name / Description	Expression
MT_S_VFA3 Substrate Monod term for anoxic growth of OHOs, NO2 to NO	$= \frac{C_{S_{VFA}}}{K_{VFA3} + C_{S_{VFA}}}$
MT_S_VFA4 Substrate Monod term for anoxic growth of OHOs, NO to N2O	$= \frac{C_{S_{VFA}}}{K_{VFA4} + C_{S_{VFA}}}$
MT_S_VFA5 Substrate Monod term for anoxic growth of OHOs, N2O to N2	$= \frac{C_{S_{VFA}}}{K_{VFA5} + C_{S_{VFA}}}$
MT_XC_B Monod term for XC_B	$= \frac{\left(C_{XC_B}/C_{X_{OHO}}\right)}{K_{X,Temp} + \left(C_{XC_B}/C_{X_{OHO}}\right)}$
MT_X_PAO_Stor Monod term for X_PAO_Stor	$= \frac{\left(C_{X_{PAO,Stor}}/C_{X_{PAO}}\right)}{K_{PAO,Stor} + \left(C_{X_{PAO,Stor}}/C_{X_{PAO}}\right)}$

Name	Description	Units
Org_N	Organic nitrogen	g/m^3
Org_P	Organic phosphorus	g/m^3
S_BOD20	Soluble BOD20	g/m^3
S_COD	Soluble COD	g/m^3
S_FA	Concentration of Free Ammonia	g/m^3
S_FNA	Concentration of Free Nitric Acid	g/m^3
S_NOx	Concentration of nitrate + nitrite	g/m^3
X_Ash	Ash content of biomass	g/m^3
X_BOD20	Particulate BOD20	g/m^3
X_COD	Particulate COD	g/m^3
X_ISS	Inorganic Suspended Solids	g/m^3
X_TSS	Total Suspended Solids	g/m^3
X_VSS	Volatile Suspended Solids	g/m^3
K_X_Temp	K_X at the system temperature	---
Q_PAO_Stor_Temp	Q_PAO_Stor at the system temperature	1/d
Q_PP_Temp	Q_PP at the system temperature	1/d
Q_fe_Temp	Q_fe at the system temperature	1/d
S_O_Saturation	Oxygen saturation concentration	g/m^3
b_ANA_Temp	b_ANA at the system temperature	1/d
b_AOB_Temp	b_AOB at the system temperature	1/d
b_NOB_Temp	b_NOB at the system temperature	1/d
b_OHO_Temp	b_OHO at the system temperature	1/d
b_PAO_Stor_Temp	b_PAO_Stor at the system temperature	1/d
b_PAO_Temp	b_PAO at the system temperature	1/d
b_PP_Temp	b_PP at the system temperature	1/d
k_h_Temp	k_h at the system temperature	1/d
mu_ANA_Temp	mu_ANA at the system temperature	1/d
mu_AOB_Temp	mu_AOB at the system temperature	1/d
mu_NOB_Temp	mu_NOB at the system temperature	1/d
mu_OHO_Temp	mu_OHO at the system temperature	1/d
mu_PAO_Temp	mu_PAO at the system temperature	1/d
M	Mass vector	g
Kla_Actual	The actual Kla in the system	
Kla_N2	Nitrogen transfer coefficient	---
Kla_N2O	Nitrous Oxide transfer coefficient	---
Kla_NO	Nitric Oxide transfer coefficient	---
M_O2	Mass of oxygen per unit volume of air	g/m^3
Q_Air_Actual	Actual air flow rate	m^3/d
Temp_Actual	Actual temperature	C
pH_Actual	pH	---

Name	Description	Units
H_N2O_Temp	Dimensionless Henry's coefficient for N2O at process temperature	---
Kla_Actual_Temp	Kla at the given temperature	1/d
kLa_N2O_Ref	N2O mass transfer coefficient at 20 degC	1/d
kLa_N2O_Temp	Actual N2O mass transfer coefficient	1/d
k_H	Henry's coefficient (mol/L/bar) for N2O at process temperature	---
r_N2O_Aer	N2O stripping rate with active aeration	1/d
rate_Strip_N2	N2 stripping rate	1/d
rate_Strip_N2O	N2O stripping rate	1/d
rate_Strip_NO	NO stripping rate	1/d
v_g	Superficial velocity	m/s

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Q_Air_In	in_2	Air flow rate	100,000	---
T_air	in_2	Air temperature	15	---
Temp	in_2	Temperature of the liquor	15	---
pH_Tank	in_2	pH	7	---
AUR	out_2	Ammonium Uptake Rate	---	$g/m^3/d$
BOD20	out_2	Biological Oxygen Demand measurement	---	g/m^3
BOD5	out_2	BOD5	---	g/m^3
COD	out_2	Chemical Oxygen Demand measurement	---	g/m^3
DO	out_2	Dissolved oxygen concentration	---	g/m^3
ISS	out_2	Inert Suspended Solids	---	g/m^3
Kla_ASU	out_2	Kla measurement data	---	1/d
N2O	out_2	Nitrous oxide concentration measurement		
NH4	out_2	Ammonium concentration	---	g/m^3
NO2	out_2	Nitrite concentration measurement		
NO3	out_2	Nitrate concentration measurement	---	g/m^3
NPR	out_2	Nitrate Production Rate measurement data	---	$g/m^3/d$
NUR	out_2	Nitrate Uptake Rate measurement data	---	$g/m^3/d$
OUR_ASU	out_2	Oxygen Uptake Rate measurement data	---	$g/m^3/d$
PO4	out_2	Phosphorous concentration measurement	---	g/m^3
PUR	out_2	Phosphate Uptake Rate measurement dat	---	$g/m^3/d$
Q_air	out_2	Required air flow rate (estimation)		
TKN	out_2	Total Kjeldahl Nitrogen concentration measurement	---	g/m^3
TN	out_2	Total nitrogen concentration measurement	---	g/m^3
TP	out_2	Total phosphorous concentration measurement	---	g/m^3
TSS	out_2	Total suspended solids concentration	---	g/m^3
VSS	out_2	Volatile Suspended Solids	---	g/m^3

Temperature dependency

For all rate constants, a temperature dependency is incorporated according to an Arrhenius type equation:

$$k_T = k_{T_{ref}} \cdot e^{\theta(T-T_{ref})}$$

where:

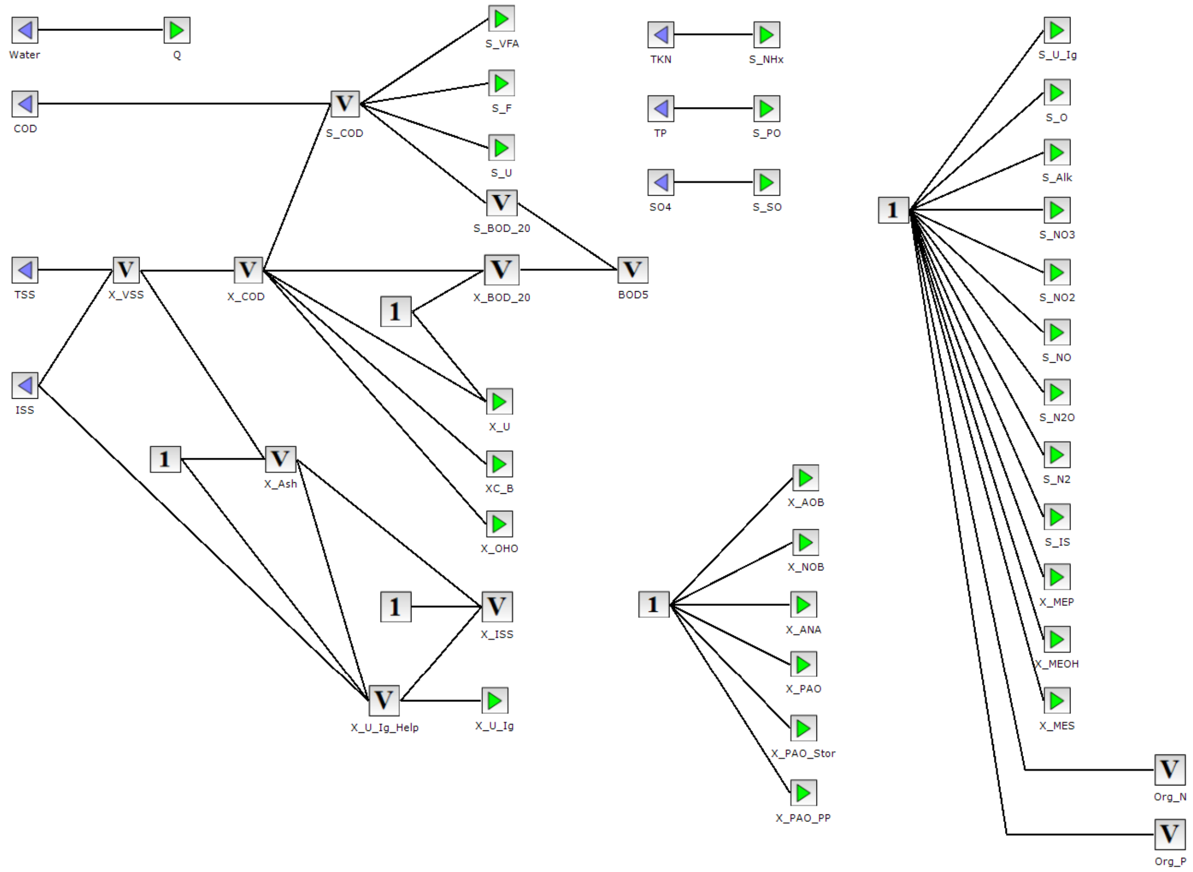
- k_T denotes the kinetic parameter: i.e. the maximum specific growth rate (**μ**), the decay coefficient (**b**) or the hydrolysis constant (**k**) at the actual temperature T;
- T_{ref} is the reference temperature (20°C); and
- θ is the Arrhenius constant.

This equation does not take into account the decrease in biomass activity at temperatures above 40°C.

The dependency of the oxygen saturation concentration is calculated as follows:

$$S_{O,Sat} = 290326 \cdot EXP\left(-66.7354 + \frac{87.4755}{\frac{T + 273.15}{100}} + 24.4526 \cdot ln\left(\frac{T + 273.15}{100}\right)\right)$$

The Fractionation Model



$$X_{VSS} = TSS - ISS$$

$$X_{COD} = i_{COD,VSS} \cdot X_{VSS}$$

$$S_{COD} = COD - X_{COD}$$

$$S_{BOD20} = S_{VFA} + S_F = S_{COD} \cdot \left(f_{S_{VFA}} + f_{S_F}\right)$$

$$\begin{aligned} X_{BOD20} &= F_{BOD,COD,X} \cdot \left(X_{OHO} + XC_B + X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in}\right) \\ &= F_{BOD,COD,X} \cdot \Big(X_{COD} \cdot \left(f_{XC_B} + f_{X_{OHO}}\right) + \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in}\right)\Big) \end{aligned}$$

$$BOD_5 = F_{BOD5,BOD20} \cdot \left(X_{BOD20} + S_{BOD20}\right)$$

$$S_{VFA} = f_{S_{VFA}} \cdot S_{COD}$$

$$S_F = f_{S_F} \cdot S_{COD}$$

$$S_U = S_{COD} \cdot \left(1 - f_{S_{VFA}} - f_{S_F}\right)$$

$$S_{UIg} = S_{UIg,in}$$

$$XC_B = f_{XC_B} \cdot X_{COD}$$

$$X_{OHO} = f_{X_{OHO}} \cdot X_{COD}$$

$$\begin{aligned} X_{U} &= X_{COD} - X_{OHO} - XC_{B} - X_{AOB,in} - X_{NOB,in} - X_{ANA,in} - X_{PAO,in} - X_{PAO,Stor,in} \\ &= X_{COD} \cdot \left(1 - \left(f_{XC_{B}} + f_{X_{OHO}}\right)\right) - \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in}\right) \end{aligned}$$

$$\begin{aligned} X_{Ash} &= i_{ISS,BM} \cdot \left(X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{OHO}\right) \\ &= i_{ISS,BM} \cdot (X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + (i_{COD,VSS} \cdot f_{X_{OHO}}) \cdot X\_VSS) \end{aligned}$$

$$X_{UIg} = ISS - \left(X_{MEOH,in} + X_{MEP,in} + i_{ISS,PP} \cdot X_{PAO,PP,in}\right) - X_{Ash}$$

$$S_{NHx} = TKN \cdot f_{S_{NH}}$$

$$S_{N2} = S_{N2,in}$$

$$S_{O} = S_{O,in}$$

$$S_{PO} = TP \cdot f_{S_{PO}}$$

$$S_{SO} = SO_{4}$$

$$S_{Alk} = S_{Alk,in}$$

$$S_{NO3} = S_{NO3,in}$$

$$S_{NO2} = S_{NO2,in}$$

$$S_{IS} = S_{IS,in}$$

$$S_{N2O} = S_{N20,in}$$

$$S_{NO} = S_{NO,in}$$

$$X_{AOB} = X_{AOB,in}$$

$$X_{NOB} = X_{NOB,in}$$

$$X_{ANA} = X_{ANA,in}$$

$$X_{PAO} = X_{PAO,in}$$

$$X_{PAO,Stor} = X_{PAO,Stor,in}$$

$$X_{PAO,PP} = X_{PAO,PP,in}$$

$$X_{MEOH} = X_{MEOH,in}$$

$$X_{MEP} = X_{MEP,in}$$

$$X_{MES} = X_{MES,in}$$

$$OrgN = i_{N,XC_B} \cdot XC_B + i_{N,X_U} \cdot X_U + i_{N,X_{BM}} \cdot \left(X_{OHO} + X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in}\right) + i_{N,S_F} \cdot S_F + i_{N,S_U} \cdot S_U$$

$$OrgP = i_{P,XC_B} \cdot XC_B + i_{P,X_U} \cdot X_U + i_{P,X_{BM}} \cdot \left(X_{OHO} + X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in}\right) + i_{P,S_F} \cdot S_F + i_{P,S_U} \cdot S_U$$

Parameters

Name	Description	Value	Units
F_BOD_COD_X	Conversion X_BOD/COD	0.65	---
F_BOD5_BOD20	Conversion BOD5/BOD20	0.66	---
f_S_F	S_F fraction of S_COD	0.375	---
f_S_NHx	Total nitrogen to ammonia ratio	0.60	---
f_S_PO	Total phosphorous to PO ratio	0.50	---
f_S_VFA	S_VFA fraction of S_COD	0.25	---
f_X_OHO	Particulate COD to X_OHO ratio	0.17	---
f_XC_B	Particulate COD to XC_B ratio	0.69	---
i_COD_VSS	COD to VSS ratio	1.6	g COD/g VSS
i_ISS_BM	Ash content of biomass	0.08	g ISS/g COD
i_ISS_PP	Poly-phosphate conversion to ISS	3.065	g ISS/g P
i_N_BM	Nitrogen content of biomass	0.07	g N/g COD
i_N_S_F	Nitrogen content of soluble substrate S_F	0.03	g N/g COD
i_N_S_U	Nitrogen content of inert soluble COD S_U	0.01	g N/g COD
i_N_X_U	Nitrogen content of inert particulate COD X_U	0.03	g N/g COD
i_N_XC_B	Nitrogen content of particulate substrate XC_B	0.04	g N/g COD
i_P_BM	Phosphorus content of biomass	0.02	g P/g COD
i_P_S_F	Phosphorus content of soluble substrate S_F	0.01	g P/g COD
i_P_S_U	Phosphorus content of inert soluble COD S_U	0.0	g P/g COD
i_P_X_U	Phosphorus content of inert particulate COD X_U	0.01	g P/g COD
i_P_XC_B	Phosphorus content of particulate substrate XC_B	0.01	g P/g COD
S_Alk_In	Alkalinity	30.0	mol/m^3
S_IS_In	Inorganic S	0.01	g/m^3
S_N2_In	Nitrogen	0.01	g/m^3
S_N2O_In	N2O	0.01	g/m^3
S_NO_In	NO	0.01	g/m^3
S_NO2_In	Nitrite	0.01	g/m^3
S_NO3_In	Nitrate	0.01	g/m^3
S_O_In	Oxygen	0.01	g/m^3
S_U_Ig_In	Dissolved inorganic solids	1.0	g/m^3
X_ANA_In	Anammox biomass	0.01	g/m^3
X_AOB_In	Ammonia oxidizing biomass (AOB)	0.01	g/m^3
X_MeOH_In	Metal hydroxide	0.01	g/m^3
X_MeP_In	Metal phosphate	0.01	g/m^3
X_MeS_In	Metal sulphate	0.01	g/m^3
X_NOB_In	Nitrate oxidizing biomass (NOB)	0.01	g/m^3
X_PAO_In	P-accumulating organisms	0.01	g/m^3
X_PAO_PP_In	Poly-phosphate	0.01	g/m^3
X_PAO_Stor_In	X_PAO_Stor	0.01	g/m^3

State Variables

Name	Description	Units
S_COD	Soluble COD	g/m^3
X_COD	Particulate COD	g/m^3
S_BOD20	Soluble BOD20	g/m^3
X_BOD20	Particulate BOD20	g/m^3

Name	Description	Units
BOD5	BOD5	g/m^3
Org_N	Organic nitrogen	g/m^3
Org_P	Organic phosphorous	g/m^3
X_Ash	Ash from the biomass	g/m^3
X_VSS	Volatile Suspended Solids	g/m^3
X_ISS	Inorganic Suspended Solids	g/m^3

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Water	---	Flow rate	---	m^3/d
TSS	---	Total Suspended Solids	---	g/m^3
ISS	---	Inert Suspended Solids	---	g/m^3
COD	---	Total COD	---	g/m^3
TKN	---	Total Kjeldahl Nitrogen	---	g/m^3
TP	---	Total phosphorous	---	g/m^3
SO4	---	Total sulphate	---	g/m^3
Influent_Load	---	ASM2dIIS component vector	---	g/d

PWM_SA

The UCT three phase (aqueous-gas-solid) plant-wide dynamic model (PWM_SA) is developed for simulation of nutrient removal activated sludge systems coupled with the anaerobic, aerobic and anoxic-aerobic digestion of sewage sludge including waste activated sludge (WAS) produced by Biological Excess Phosphorus Removal (BEPR) plants.

The three phase plant-wide dynamic model is based on strict material mass balance and is prepared by linking:

- a variation of ASM2 (Henze et al., 1995) for activated sludge nitrogen and phosphorus removal and aerobic or anoxic – aerobic digestion;
- a variation of the anaerobic digestion model by Sötemann et al. (2005a).

The main extensions to the original models are through their integration within a three phase mixed weak acid/base chemical and physical processes models of the inorganic carbon, ammonia, acetate, propionate and phosphate systems.

The model components and transformation processes are described further below.

More information on the calibration of the two models can be obtained from Ikumi et al. (2013a).

PWM_SA based models can be particularly difficult to get started, especially where the configuration contains anaerobic digesters. The last section of these notes describes features that have been included to assist the startup of new models.

Category

PWM_SA

Conversion Models

Default, VolumeFixedAS

The biological components

The set of plant-wide model components of the PWM_SA model category are listed in the following table.

The subscripts in the elemental formulae for the generic organics are adjustable parameters in the model.

Name	Empirical formula	Description	Units
H2O	**H2O**	Water	m^3/d
S_H	**H^+**	Hydrogen ion	gH/m^3
S_Na	**Na^+**	Sodium	gNa/m^3
S_K	**K^+**	Potassium	gK/m^3
S_Ca	**Ca^{2+}**	Calcium	gCa/m^3
S_Mg	**Mg^{2+}**	Magnesium	gMg/m^3
S_NH	**NH_4^+**	Ammonium	gNH_4/m^3
S_Cl	**Cl^-**	Chloride	gCl/m^3
S_VFA	**CH_3COO^-**	Acetate	gAc/m^3
S_Pr	**$CH_3CH_2COO^-$**	Propionate	gPr/m^3
S_CO3	**CO_3^{2-}**	Carbonate	gCO_3/m^3
S_SO4	**SO_4^{2-}**	Sulphate	gSO_4/m^3
S_PO4	**PO_4^{3-}**	Phosphate	gPO_4/m^3
S_HS	**HS^-**	Sulphide	gHS/m^3
S_NO2	**NO_2^-**	Nitrite	gNO_2/m^3
S_NO3	**NO_3^-**	Nitrate	gNO_3/m^3
S_Fer	**Fe^{2+}**	Ferrous ion (reduced iron)	gFe/m^3
S_Feo	**Fe^{3+}**	Ferric ion (oxidized iron)	gFe/m^3
S_Al	**Al^{3+}**	Aluminium	gAl/m^3
S_H2	**H_2**	Dissolved hydrogen	gH_2/m^3
S_U	**$CH_{Yu}O_{Zu}N_{Au}P_{Bu}$**	Unbiodegradable Soluble Organics	g/m^3
S_F	**$CH_{Yf}O_{Zf}N_{Af}P_{Bf}$**	Fermentable Biodegradable Soluble Organics	g/m^3
S_Glu	**$C_6H_{12}O_6$**	Glucose	g/m^3

Name	Empirical formula	Description	Units
S_CH$_4$	**CH_4**	Dissolved methane	gNO$_3$/m^3
S_O	**O_2**	Dissolved oxygen	gO$_2$/m^3
X_U_Inf	**$CH_{Yup}O_{Zup}N_{Aup}P_{Bup}$**	Unbiodegradable particulate organics	g/m^3
X_B_Org	**$CH_{Ybp}O_{zbp}N_{Abp}P_{Bbp}$**	Biodegradable particulate organics	g/m^3
X_PAO_PP	**$K_{kp}Mg_{mp}Ca_{cp}PO_3$**	Polyphosphate	g/m^3
X_PAO_Stor	**$C_4H_6O_2$**	Poly-hydroxy-alkanoate	g/m^3
X_Str_NH4	**$MgNH_4PO_4.6H_2O$**	Struvite	g/m^3
X_ACP	**$Ca_3(PO_4)_2$**	Calcium Phosphate	g/m^3
X_Str_K	**$MgKPO_4.6H_2O$**	K-struvite	g/m^3
X_Cal	**CaCO3**	Calcite	g/m^3
X_Mag	**MgCO3**	Magnesite	g/m^3
X_Newb	**MgHPO4**	Newberyite	g/m^3
X_OHO	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Ordinary heterotrophic organisms	g/m^3
X_PAO	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Phosphate accumulating organisms	g/m^3
X_AD	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Acidogens	g/m^3
X_AC	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Acetogens	g/m^3
X_AM	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Acetoclastic Methanogens	g/m^3
X_HM	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Hydrogenotrophic methanogens	g/m^3
X_U_Org	**$CH_{ye}O_{ze}N_{ae}P_{be}$**	Endogenous residue	g/m^3
X_B_Inf	**$CH_{Ybps}O_{Zbps}N_{Abps}P_{Bbps}$**	Primary sludge biodegradable particulate organics	g/m^3
X_ANO	**$CH_{Yo}O_{Zo}N_{Ao}P_{Bo}$**	Autotrophic nitrifying organisms	g/m^3
X_ISS		Influent inorganic settleable solids	gISS/m^3
G_CH$_4$	**CH_4**	Gaseous Methane	gCH$_4$/m^3
G_CO$_2$	**CO_2**	Gaseous Carbon dioxide	gCO$_2$/m^3
G_N2	**N_2**	Gaseous Nitrogen	gN$_2$/m^3

The model currently uses twenty particulate components, these are mainly precipitates formed during anaerobic digestion, sewage particulate organics and biomass (with their storage products such as polyphosphate and poly-hydroxy-alkanoates included as separate components) from activated sludge and anaerobic digestion units. Carbon dioxide and methane are included as the two main gases that are evolved during transformation reactions for treatment of municipal waste. The remaining components are all soluble, including three dissolved sewage organics, thirteen dissolved ionic components, three dissolved gases (oxygen, hydrogen and methane) and water.

The model requires that strict material mass balances are set up over the transformation processes to be modelled. To ensure this, each component's elemental formulation is included – most components (e.g. dissolved ionic components, gases and precipitates) have distinct chemical formulations, which enables the direct calculation of their molar and material (COD, C, H, O, N and P) masses. However, the organic components (i.e. the seven organism groups and the sewage: FBSO (Fermentable Biodegradable Soluble Organics), USO (Unbiodegradable Soluble Organics), BPO (Biodegradable Particulate Organics), UPO (Unbiodegradable Particulate Organics)) were given parameterized (variable) compositions in the general form ($C_XH_YO_ZN_AP_B$), so their compositions can be entered as model inputs. The elemental molar ratios (i.e. the X, Y, Z, A and B values) of their elemental formulation were coded as model parameters to cater for the variability in sewage characteristics. Based on experimental evidence, the unbiodegradable organics in the wastewater and generated in the activated sludge reactor (endogenous residue) remain unbiodegradable in the anaerobic digester (Ekama et al. 2006a; Ikumi et al., 2013b). The composition assigned to the endogenous residue is the same as that of the live Ordinary Heterotrophic Organisms (OHO) and Phosphate Accumulating Organisms (PAO) biomass which produces it. The composition of these unbiodegradable organics remains unchanged throughout the WWTP. All organism groups (aerobic and anaerobic) were given the same elemental formulation of $C_{X\_o}H_{Y\_o}O_{Z\_o}N_{A\_o}P_{B\_o}$, where each organism component (or species) is taken to represent a "surrogate" of its kind performing a particular function of interest, as has generally been accepted in WWTP modelling (Henze et al., 1995). The polyphosphate (PP, $Mg_dK_eCa_fPO_3$) and poyhydroxy alkanoates (PHA, $C_4H_6O_2$) which are normally stored within (hence are part of) phosphorus accumulating organisms (PAOs) are included in the model as separate components, to avoid complications that would result in extending the PAO biomass formula (such as merging their stoichiometric coefficients in transformations).

All components are represented as masses, or mass concentrations (with the units of g/m^3 or milligrams per litre) but further provisions are made to parameterize the component descriptions in as COD concentrations. These parameterized values were useful in formulating some of the models' stoichiometric coefficients and variables.

Most components and parameters have been named according to the system suggested by Corominas et al. (2010).

Ionic speciation routine and interphase transfers

The ionic speciation routine (Brouckaert et al., 2010), contained in the PWM_SA model provides a general algebraic approach to modelling the very rapid ionic dissociation and ion pairing equilibrium reactions separately from the slower biological and physical processes and can be applied to any combination of mixed weak acid/base systems. Because the weak acid/base chemistry processes for precipitation and gas exchange are slow, they are included with the slow bioprocesses, which are modelled with kinetic equations.

Not all of the ionic components (S_H to S_Al in the table above) are currently used by the model, although the speciation routine does take them into account. The following have been included in anticipation of future developments: S_HS, S_NO2, S_Fer, S_Feo and S_Al.

Ionic speciation

The concentrations of ionic species belonging to various weak acid/base sub-systems that are simultaneously present in solution, and govern pH, are governed by sets of aqueous phase equilibrium dissociation and mass balance equations (see below).

Since total concentrations are the appropriate quantities to use in material balance calculations, Brouckaert et al. (2010) included the total species components to represent the total concentrations of the various weak acid/base systems concerned, e.g. CO_3 represents CO_3^{2-} plus HCO_3^- plus H_2CO_3 plus various other aqueous ion pair (not precipitates) carbonate complexes present in the solution, such as $MgCO_3$ and $CaHCO_3^+$. The model considers 96 ionic species, which are combinations of the component ions (ion pairs). These are mostly of no interest to the model, apart from their involvement in determining the solution pH.

The principles of ionic speciation calculations are set out in Stumm and Morgan (1996). The concentrations of the ionic species are related to the total concentrations of the 18 components by a set of 18 stoichiometric balances, together with a set of 30 equilibrium relationships. The equilibrium relationships are formulated in terms of species activities, which are related to their concentrations by activity coefficients.

The following table gives an example of a set of equilibrium and mass balance equations used in the ionic speciation subroutine.

Weak acid sub-system	Aqueous Phase Equilibrium Equations	Mass Balance Equation
Ammonia	$[NH_3] = \frac{K_{NH_4} \cdot [NH_4^+]}{(H^+)}$ $[NH_4SO_4^-] = \frac{[SO_4^{2-}][NH_4^+]}{K_{NH_4SO_4}}$	$N_T = [NH_4^+] + [NH_3] + [NH_4SO_4^-]$

where:

- (H^+) is the hydrogen ion activity

- [X] the molar concentrations of species X
- $K_{X'}$ is the thermodynamic equilibrium constant for species X, adjusted for Debye Hückel effects to account for the activity of ions in low salinity water

The ionic speciation model forms an important part of the PWM_SA model. The inclusion of this ionic speciation model, required coding the ionic speciation routine (containing the aqueous phase equilibrium and mass balance reactions) in a separate C++ file, which is then linked to the WEST block library. This separate coding was done to alleviate the numerical handling of these 'instantaneous' equilibrium reactions.

The equilibrium vapour pressures required for liquid-gas transfer and saturation ratios for mineral precipitation are also outputs of the speciation subroutine.

Ionic composition inputs

The model accounts for any changes in ionic composition that occur due to the treatment processes, but requires the ion concentrations in the influent streams as input. It is very unusual that the ionic composition of a wastewater stream is fully known, and in many cases the measured information is very sparse, so that ion concentrations must be estimated.

Two special input blocks are currently (April 2021) provided for influent streams (beside the standard municipal wastewater block, which can be used where the stream composition is fully specified in terms of model components). The *FractionatorInput* accepts a limited set of component data, as would be prepared by the separate Excel-based fractionator tool. The *Fractionator* block accepts plant measurement data and transforms it into component data, following a similar algorithm to the one used by the Excel fractionator. Both include a facility to generate a reasonable estimate of the ionic composition from parameters that can be adjusted. These will be further developed to accept measured values such as pH and alkalinity in future releases.

Interphase transfer

The PWM_SA model considers three phases (liquid, gas and solid) and so can simulate active gas exchange through liquid to gaseous phase evolution and multiple mineral precipitation from liquid to solid or dissolution from solid into liquid phase.

Liquid-Gas transfer

Six gases are considered in the model (i.e. CO_2, CH_4, H_2, NH_3, N_2 and O_2). Ammonia (NH_3) is known to have a (virtually) zero atmospheric concentration, so is modelled as an infinite sink (Sötemann et al., 2005a, b) and its dissolution is effectively zero. Therefore (for simplicity), unlike the other five gases, $NH_{3(g)}$ is not included as a model component but its equilibrium vapour pressure is calculated in the equilibrium speciation routine mentioned above.

Methane (CH_4) is relatively insoluble in water (at atmospheric pressure) and is not utilized in the biological or chemical processes. It is a model component, and is modelled to be directly produced in its gaseous phase by the AD methanogenic processes (acetoclastic and hydrogenotrophic methanogenesis). Carbon dioxide (CO_2) is significantly soluble and is evolved relatively slowly, so is modelled with the CO_2 evolution process, i.e.:

$$H^{+} + CO_3^{=} \leftrightarrow CO_{2(g)} + H_2O$$

Hydrogen (H_2) is sparingly soluble but is utilized very rapidly at an inter-organism species level by the hydrogenotrophic methanogenesis process, leaving only trace quantities of residual concentration. Therefore, , H_2 was modelled as remaining a dissolved compound. Its equilibrium vapour pressure influences the acidogenesis process (Sötemann et al., 2005a). Only dissolved oxygen is included as a model component, since it is modelled to be utilized by the active organisms in its dissolved state within aerobic (aerated) biological reactors. It is set to zero in the AD, which does not affect the COD balance of the AD or WWTP as a whole.

Liquid-Solid transfer (precipitation/dissolution)

In the anaerobic and aerobic digestion unit operations, (especially those treating sludge from biological excess phosphorus removal systems), magnesium, potassium and calcium can be present at sufficiently high concentrations for precipitation to occur. The solids most likely to precipitate were identified by Musvoto et al. (2000b) as struvite ($MgNH_4PO_4$), newberyite ($MgHPO_4$), amorphous calcium phosphate ($Ca(PO_4)_2$), calcite ($CaCO_3$) and magnesite ($MgCO_3$).

Musvoto et al. (2000a) modelled mineral precipitation or dissolution, in terms of five reversible reactions (one for each mineral), which are driven backwards or forwards depending on whether the solubility products of the respective minerals are exceeded by the ionic product. Although they found that newberyite, calcite and magnesite hardly precipitated at all, these three minerals were included in this plant-wide model, as well as potassium struvite for situations where NH_4^+ is low like in aerobic digestion.

The processes

The ASM2 is a widely accepted model that is applicable to NDBEPR (nitrification-denitrification, biological excess phosphorus removal) system design, operation and process optimisation for activated sludge systems.

It includes the biological growth and death processes for OHO, PAO and Autotrophic nitrifying organisms (ANO) biomass and predicts oxygen demand and sludge production together with storage and lysis of polyphosphate and poly-3-hydoxyalkanoates for PAOs for strictly aerobic P uptake BEPR.

The ASM2 was selected because it was calibrated against consistent set experimental results (Wentzel et al., 1989a,b; Clayton et al., 1991).

The ASM2, which was developed for simulating activated sludge systems, can also be used to simulate the aerobic digestion (AerD) because, at least theoretically, AerD is a continuation of the biomass aerobic endogenous process and the endogenous respiration rate of PAOs (bPAO) was measured in long-term aerobic digestion batch tests. However, this may require calibrating the relative rates of the various processes and (if necessary) adjusting the appropriate kinetic and stoichiometric constants (Sötemann et al., 2006). For instance, the release of polyphosphate by PAOs without acetate uptake may be different to the endogenous respiration rate (Vogts and Ekama, 2010).

The ASM2 model was modified by including the inorganic settleable solids (ISS) model of Ekama and Wentzel (2004), together with a mixed weak acid/base chemistry model illustrated above. The integration of these models together with the set of plant-wide components, to ensure complete compatibility in development of the plant-wide model, required converting the model process stoichiometry from COD-based to mass concentration-based. The kinetic and stoichiometric coefficients for the ASM2 rates were also evaluated and transformed to be compatible with the revised components and stoichiometric process coefficients in different units. In some cases the kinetic equations, together with their included parameters, were changed to make them consistent with the components of the PWM_SA model.

Also added to the ASM2 model, is the process of CO_2 stripping from the aerated reactor together with mineral precipitation and dissolution processes that could take place during the aerobic or anoxic-aerobic digestion of NDBEPR WAS. For the aerobic CO_2 stripping process, the CO_2 is continuously generated, hence no equilibrium is achieved between the aqueous ($H_2CO_3^*$) and gas phase CO_2 (Sötemann et al., 2005b).

The AD model of Sötemann et al. (2005a) is similar to the IWA AD model (Batstone et al., 2002) in that it includes the reactions mediated by the same four organism groups (acidogens, acetogens, acetoclastic methanogens and hydrogenotrophic methanogens), but with a single hydrolysis process acting on a generic organic material representing sewage sludge i.e. $C_XH_YO_ZN_A$. This hydrolysis process directly generates an idealised carbohydrate ‘glucose’ while maintaining COD, C, N, H and O mass balances also producing NH_3 and taking up H_2CO_3. The processes that follow hydrolysis, such as the growth and death of biomass, have faster kinetics and are simulated to yield digester end products i.e. biomass, CH_4, CO_2 and water.

This PWM_SA model extends the ASM and ADM models by Sötemann et al. (2005a,b) by adding P and integrating it within a three phase mixed weak acid/base chemical and physical processes model of the inorganic carbon, ammonia, acetate, propionate and phosphate systems. The main extensions in the new model include:

- additional soluble and particulate biodegradable organic components to represent material which might be combined from different sources in the WWTP and fed to the anaerobic digester (PS and WAS);
- anaerobic and aerobic digestion of waste activated sludge (WAS) from BEPR systems;
- inclusion of the ionic speciation routine and interphase transfer processes mentioned in I above for modelling the "instantaneous" aqueous phase equilibrium reactions and ion paring together with active gas exchange and multiple mineral precipitation.

The list of all the processes and a schematic of the AD processes are given below.

Name	Description
AerHydrol	Aerobic hydrolysis of biodegradable particulate organics (BPO)
AnHydrol	Anoxic hydrolysis of BPO
AnaerHydrol	Anaerobic hydrolysis of BPO
AerGrowthOnSf	Aerobic OHO growth on fermentable soluble organics (FBSO)
AerGrowthOnSa	Aerobic OHO growth on Acetate
AnGrowthOnSfDenitrif	Anoxic OHO growth on FBSO
AnGrowthOnSaDenitrif	Anoxic OHO growth on Acetate
Fermentation	Fermentation of FBSO
LysisOfAuto	Storage of poly-hydroxy-alkanoate (PHA) by PAOs
StorageOfXPP	Aerobic storage of PP with PHA uptake
AerGrowthOnXPHA	Aerobic growth of PAOs
LysisOfXPP	Release and hydrolysis of polyphosphate (PP)
LysisOfXPHA	Release and hydrolysis of PHA
GrowthOfAuto	Aerobic growth of ANOs with nitrification
OHO_Lysis	Lysis of OHOs in aerobic systems
LysisOfXPAO	Lysis of PAOs in aerobic systems
LysisOfAuto	Lysis of ANOs in AS system
Aeration	Oxygen supply to aerobic reactor
FSO_Hydrolysis	Hydrolysis of FBSO in AD system
BPO_Hydrolysis	Hydrolysis of BPO produced by dead biomass
BPO_PS_Hydrolysis	Hydrolysis of BPO from primary sludge (PS)
OHO_Lysis_AD	Lysis of OHOs in AD system
PAO_Lysis_AD	Lysis of PAOs in AD system
PP_Release	Release of PP with uptake of PHA in AD system
PP_Hydrolysis	Release and hydrolysis of PP in AD system
PHA_Hydrolysis	Release and hydrolysis of PHA in AD system
Acidogenesis_L	Low hydrogen partial pressure (p_{H2}) Acidogenesis
Acidogenesis_H	High p_{H2} Acidogenesis
AD_decay	Lysis of acidogens
Acetogenesis	Growth of acetogens in AD system
AC_decay	Lysis of acetogens
Acet_methanogenesis	Growth of acetoclastic methanogens in AD system
AM_decay	Lysis of acetoclastic methanogens
Hyd_methanogenesis	Growth of hydrogenotrophic methanogens in AD system
HM_decay	Lysis of hydrogenotrophic methanogens

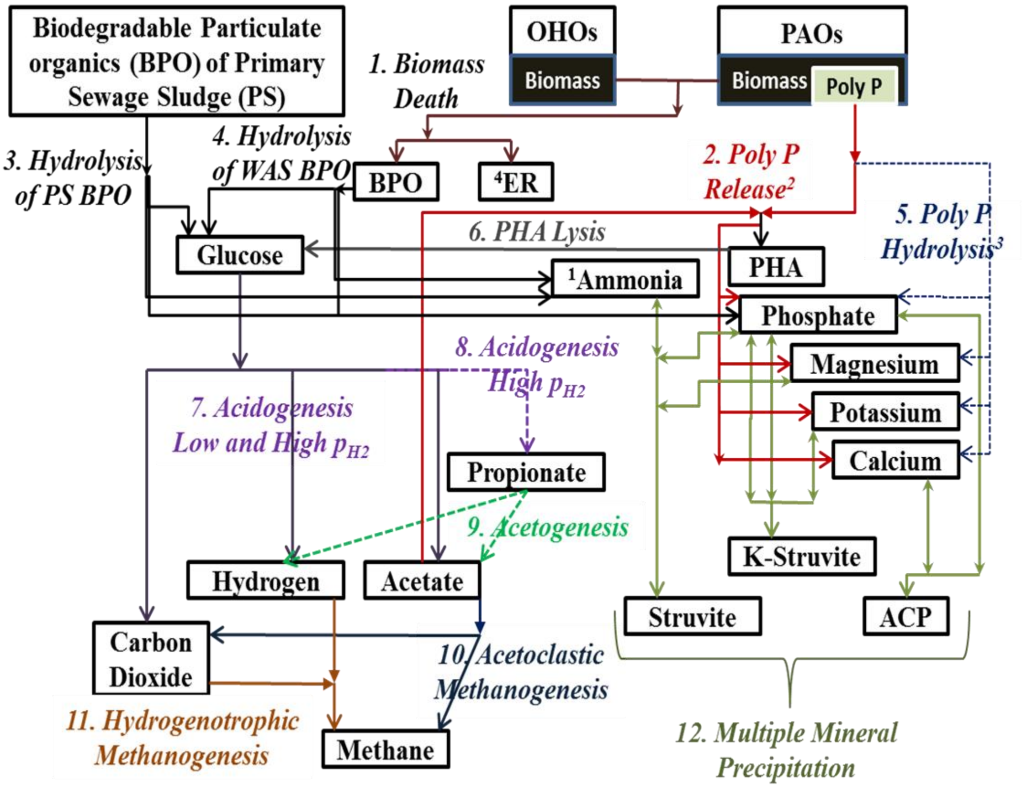


Figure 1 - Process scheme for the anaerobic sub-model of the PWM_SA model.
Note that (1) ammonia is released in the NH_3 form and picks up a proton from H_2CO_3 to form NH_4^+ (the N content of influent organics is alkalinity fed to the AD), (2) Process 2 is for PP release with the uptake of acetate and (3) process 5 is for the PP hydrolysis with the death of the PAOs, (4) ER stands for the endogenous residue of biomass. Process 12 only shows for P precipitates, but other precipitates (i.e. newberyite, calcite and magnesite, which are less likely to form) are also included in the model.

The ISS model

The principle of Gujer (1993) for calculating total settleable solids (TSS) from stoichiometric TSS/COD ratios of the individual mixed liquor organic compounds is employed in ASM2. However, with the addition of ISS and PP as components in the model, new provisions can be made for tracking the effect of this on the ionic mix and conductivity. The influent ISS (silt) and clay is deemed not to take part in any reactions; hence, it simply gets enmeshed in the sludge mass and increases with sludge age. Moreover, as modelled by Ekama and Wentzel (2004), influent inorganic dissolved ions are taken up by the organism biomass as intracellular ions. These ions precipitate as ISS in the drying step of the TSS/VSS test and so in effect add to the mixed liquor ISS concentration. An ISS content of OHO and PAO (without PP) of 0.15 mgISS/mg biomass VSS was measured by Ekama and Wentzel (2004) and confirmed by Ekama et al. (2006b). Because the uptake of these ions by the biomass has a small effect on the conductivity, this process is not included in the model. However, the effect of the uptake and release of the metals and OP that make up PP in the PAOs on the ionic mix is included in the model. Compared with the ion exchange between the biomass and aqueous phase, the effect of the PP is much greater, up to nine times higher, at high PAO PP content. So (1) the effect of the ion exchange between the biomass and the aqueous phase ionic matrix and conductivity was not included but (2) its effect on the reactor TSS was included by adding 0.15 (f_{iOHO} and f_{iPAO}) times the OHO and PAO biomass concentrations to the ISS arising from the influent wastewater. In contrast, the effect of the metal ion and OP exchange between the biomass and aqueous ionic matrix and conductivity and the reactor ISS concentration by the release and uptake of PP were both included in the model. So the total reactor ISS concentration comprises the ISS content of the OHO and PAO and ANO biomass (i.e. ISS_{BM} = 0.15 mgISS/mg biomassVSS), the stored PP in the PAOs, all precipitates (struvite, K-stuvite, ACP, magnesite and calcite) formed and the influent ISS that is enmeshed with the sludge. This was simple to include because all components are already mass-based (given in units of mg/l). Moreover, the TSS is also included in the model base as a variable, which is calculated as the sum of all the aforementioned particulate components. Other lumped parameter variables that provide useful interpretation of the simulated results were also included by coding in the necessary component additions and transformation calculations. These include pH, total alkalinity (in mg$CaCO_3$/l), TKN and FSA (in mg N/l), TP, OP (in mgP/l), total COD (in mgCOD/l), VSS (in mg/l), and total metal concentrations (i.e. Mg, Ca, K all in mg/l).

Parameters

The parameters defined for the PWM_SA model category are listed in the following table.

- Group: Stoichiometry

Name	Description	Value	Units
f_SU_SF	Inert Fraction in Fermentable Soluble Organics	0	gCOD/gCOD
f_XU_Bio_lysis	Unbiodegradable fraction of biomass that accumulates on lysis with death regeneration model	0.08	gCOD/gCOD
i_Ca_PP_mol_perP	Molar fraction of Ca/P in polyphosphate	0.03	molCa/molPP
i_H_Org_mol_perC	H/C : organisms	1.458333	molH/molC
i_H_SF_mol_perC	H/C : fermentable soluble	1.567209	molH/molC
i_H_SU_mol_perC	H/C: unbiodegradable soluble	1.546307	molH/molC
i_H_XBInf_mol_perC	H/C: PS biodegradable particulate	1.990487	molH/molC
i_H_XBOrg_mol_perC	H/C: biodegradable particulate	1.458333	molH/molC
i_H_XUInf_mol_perC	H/C: unbiodegradable particulate	1.458333	molH/molC
i_H_XUOrg_mol_perC	H/C: endogenous residue	1.458333	molH/molC
i_K_PP_mol_perP	Molar fraction of K/P in polyphosphate	0.312	molK/molP
i_Mg_PP_mol_perP	Molar fraction of Mg/P in polyphosphate	0.297	molMg/molP
i_N_Org_mol_perC	N/C : organisms	0.166667	molN/molC
i_N_SF_mol_perC	N/C: fermentable soluble	0.057026	molN/molC
i_N_SU_mol_perC	N/C: unbiodegradable soluble	0.061887	molN/molC
i_N_XBInf_mol_perC	N/C: PS biodegradable particulate	0.053	molN/molC
i_N_XBOrg_mol_perC	N/C: biodegradable particulate	0.166667	molN/molC
i_N_XUInf_mol_perC	N/C: unbiodegradable particulate	0.166667	molN/molC
i_N_XUOrg_mol_perC	N/C: endogenous residue	0.166667	molN/molC
i_O_Org_mol_perC	O/C : organisms	0.416667	molO/molC
i_O_SF_mol_perC	O/C : fermentable soluble	0.587228	molO/molC
i_O_SU_mol_perC	O/C: unbiodegradable soluble	0.543126	molO/molC
i_O_XBInf_mol_perC	O/C: PS biodegradable particulate	0.561719	molO/molC
i_O_XBOrg_mol_perC	O/C: biodegradable particulate	0.416667	molO/molC
i_O_XUInf_mol_perC	O/C: unbiodegradable particulate	0.416667	molO/molC
i_O_XUOrg_mol_perC	O/C: endogenous residue	0.416667	molO/molC
i_P_Org_mol_perC	P/C : organisms	0.026042	molP/molC
i_P_SF_mol_perC	P/C: fermentable soluble	0.007502	molP/molC
i_P_SU_mol_perC	P/C: unbiodegradable soluble	0.008221	molP/molC
i_P_XBInf_mol_perC	P/C: PS biodegradable particulate	0.002857	molP/molC
i_P_XBOrg_mol_perC	P/C: biodegradable particulate	0.026042	molP/molC
i_P_XUInf_mol_perC	P/C: unbiodegradable particulate	0.026042	molP/molC
i_P_XUOrg_mol_perC	P/C: endogenous residue	0.026042	molP/molC
K_MAX_fPP_PAO	Maximum ratio of X_PP/X_PAO	1.05	mgPP/mgPAO
kH_F_AD_hyd	Hydrolysis rate constant for FSO	10	/d
kH_PHA_AD_hyd	Hydrolysis rate constant for PHA	0.2	/d
kH_PP_AD_hyd	Hydrolysis rate constant for PP	0.5	/d
kM_BInf_AD_hyd	Hydrolysis rate constant for BPO_PS	2.004	/d
kM_BOrg_AD_hyd	Hydrolysis rate constant for BPO	1.95	/d
kM_fPP_PAO_PHAstor	maximum rate for PP release with anaerobic PHA storage	0.3	/d

Name	Description	Value	Units
k_M_BInf_OHO_hyd	Maximum Specific Hydrolysis Rate	3	/d
kdis_cal	Dissolution of calcite	0.5	/d
kdis_cap	Dissolution of calcium phosphate	150	/d
kdis_mag	Dissolution of magnesite	50	/d
kdis_mgkp	Dissolution of K-struvite	100	/d
kdis_newb	Dissolution of newberyite	0.05	/d
kdis_stru	Dissolution of struvite	300	/d

- Group: Kinetics

Name	Description	Value	Units
A_20	Activation/inhibition term at 20°C	1	---
A_35	Activation/inhibition term at 35°C	1	---
A_55	Activation/inhibition term at 55°C	1	---
ISS_BM	ISS to biomass for OHO and PAO	0.15	mgISS/mgOHO
KA_CO2	CO2 liquid to gas phase equilibrium constant	1.64346E-5	1/d
KA_H_N	Inhibition of bacteria growth due to high pH	1E-7	molH/l
KI_H_N	Inhibition of bacteria growth due to low pH	0.00085	molH/l
KLa_CO2	Rate of active CO2 gas exchange rate with aeration	1	1/d
KS_AC	Half Sat coeff for acetogens	0.089	g/m^3
KS_AD	Half Sat coeff for acidogens	0.78	g/m^3
KS_AM	Half Sat coeff for acetoclastic methanogens	0.013	g/m^3
KS_HM	Half Sat coeff for hydrogenotrophic methanogens	0.156	g/m^3
KS_BInf_AD_hyd	Half sat coeff for BPO_PS	10.124	gCOD/gCOD
KS_BOrg_AD_hyd	Half sat coeff for BPO	10.37	gCOD/gCOD
KS_fPP_PAO_PHAstor	Saturation coeff for poly-phosphate	0.01	g
K_CO2_eq	Equilibrium constant for CO2 liquid-gas phase exchange	1.21E-8	mol/l
K_CO2	Rate constant for CO2 exchange in AD	0.1	/d
K_F_OHO	Saturation/inhibtion coeff for growth on S_F	4	$gCOD/m^3$
K_I_H2	Inhibition coefficient for H2 in acidogenesis	1.25	$gCOD/m^3$
K_I_H_AD	H+ inhibition for acidogens	0.0155	molH/l
K_I_H_AM	H+ inhibition for acetoclastic methanogens	1.15E-6	moH/l
K_I_H_HM	H+ inhibition for hydrogenotrophic methanogens	0.00053	moH/l
K_I_NH3	NH3 Inhibition for AD organisms	25.2	gN/m^3
K_I_PP_PAO	Inhibition coeff for X_PP storage	0.02	gP/m^3
K_MAX_fPP_PAO	Maximum ratio of X_PP/X_PAO	1.05	gPP/gPAO
K_NOx_OHO	Nitrate Half-Saturation Coefficient For Denitrifying Heterotrophic Biomass	0.5	gNO_3-N/m^3
K_O2	Saturation/inhibition coeff for oxygen	0.2	gO_2/m^3
K_O2_ANO	Saturation/inhibition coeff of autotrophs for oxygen	0.5	gO_2/m^3
K_S_ALK	Saturation coeff for alkalinity (HCO_3^-)	0.1	mol/l
K_S_ALK_ANO	Saturation coeff of autotrophs for alkalinity	0.5	mol/l
K_S_BInf_OHO_hyd	Half Saturation Coefficient For Hydrolysis Of Slowly Biodegradable Substrate	0.1	$gCOD/m^3$
K_S_F_OHO_ferm	Saturation coeff for fermentation on S_F	20	$gCOD/m^3$
K_S_NHx	Ammonia Half-Saturation Coefficient For Organisms Growth	1	gNH_3-N/m3

Name	Description	Value	Units
K_S_NHx_ANO	Saturation coeff of autotrophs for ammonium	1	gNH$_3$-N/m3
K_S_PHA_PAO	Saturation coeff for PHA	0.01	gCOD/m^3
K_S_PO4	Saturation coeff for phosphorus (nutrient)	0.01	gP/m^3
K_S_PO4_PAO_PPstor	Saturation coeff for phosphorus in PP storage	0.2	gP/m^3
K_S_VFA	Saturation coeff for S_A (acetate)	4	gCOD/m^3
Q_OHO_F_VFA_ferm	Maximum rate for fermentation	20	/d
Q_PAO_PO4_PPstor	Rate constant for storage of PP	1.5	/d
Q_PAO_PP_PHAstor	Rate constant for storage of PHA (base: X_PP)	3	/d
Q_under	Underflow rate	0	m^3/d
S_O_Sat	Oxygen saturation concentration	8.9	gO/m^3
TempCoeff	Rate temperature coefficient	0.0667	-
Temperature	System Temperature	20	°C
Th_d_XG_20	Temp correction factor for decay of PAOs at 20°C	1.12	-
Th_d_XG_35	Temp correction factor for decay of PAOs at 35°C	1.12	-
Th_d_XH_20	Temp correction factor for decay of OHOs at 20°C	1.12	-
Th_d_XH_35	Temp correction factor for decay of OHOs at 35°C	1.12	-
Th_d_XN_20	Temp correction factor for decay of ANOs at 20°C	1.072	-
Th_d_XN_35	Temp correction factor for decay of ANOs at 35°C	1.072	-
Th_h_20	Temp correction factor for hydrolysis at 20°C	1.116	-
Th_h_35	Temp correction factor for hydrolysis at 35°C	0.05	-
Th_m_XH_20	Temp correct. factor for growth of OHOs at 20°C	1.072	/d
Th_m_XN_20	Temp correct. factor for growth of ANOs at 20°C	1.103	/d
Tref	Reference temperature for kinetics	20	°C
Y_AC	Acidogenesis yield	0.0278	mol/mol
Y_AD	Lo H2 Acetogenesis yield	0.1074	mol/mol
Y_AH	Hi H2 Acetogenesis yield	0.1074	mol/mol
Y_AM	Acetoclastic Methanogenesis yield	0.0157	mol/mol
Y_ANO	Yield For Autotrophic Biomass	0.24	gCOD/gN
Y_HM	Hydrogenotrophic Methanogenesis yield	0.004	gCOD/gCOD
Y_OHO	Yield For Heterotrophic Biomass	0.67	gCOD/gCOD
Y_PAO	Yield coeff (biomass/PHA)	0.67	gCOD/gCOD
Y_PP_Stor_PAO	PP requirement (S_PO4 release) per PHA stored	0.4	molP/molPHA
Y_Stor_PP_PAO	PHA requirement for PP storage	0.2	gCOD/gCOD
b_AC	Decay rate constant for Xac	0.015	/d
b_AD	Decay rate constant for Xad	0.041	/d
b_AM	Decay rate constant for Xam	0.037	/d
b_ANO	Decay rate	0.15	/d
b_HM	Decay rate constant for Xhm	0.01	/d
b_OHO	Decay Coefficient For Heterotrophic Biomass	0.24	/d
b_OHO_AD	Decay rate constant for X_OHO in AD	20	/d
b_PAO	Rate constant for lysis of X_PAO	0.04	/d

Name	Description	Value	Units
b_PAO_AD	Decay rate constant for X_PAO in AD	20	/d
b_PHA	Rate constant for lysis of X_PHA	0.04	/d
b_PP	Rate constant for lysis of X_PP	0.017	/d
mu_AC	Max specific growth rate for acetogens	1.15	/d
mu_AD	Max specific growth rate for acidogens	0.8	/d
mu_AM	Max spec. growth rate for acetoclastic methanogens	4.39	/d
mu_ANO	Maximum specific growth rate for ANOs	1	/d
mu_HM	Max spec. growth rate for hydrogenotrophic methanogens	1.2	/d
mu_OHO_max	Maximum Specific Growth Rate For Heterotrophic Biomass	6	/d
mu_PAO	Maximum growth rate for PAOs	1	/d
n_NO_Het	Reduction factor for denitrification	0.1	-
n_OHO_BInf_ferm	Anaerobic hydrolysis reduction factor	0.1	-
n_OHO_BInf_hyd	Anoxic hydrolysis reduction factor	0.6	-

The anerobic digester gas phase

Four gaseous components are considered: **G_CH4, G_CO2, G_N2** and **H2O**.

H2O is considered to be in equilibrium with the liquid phase at all times, i.e. its partial pressure is equilibrium vapour pressure at the operating temperature.

CH_4 is evolved from the liquid at a rate determined by the difference between the equilibrium vapour pressure (calculated from the concentration of the liquid phase **S_CH4**) and the partial pressure in the vapour phase.

CO_2 evolution is similar, except that its equilibrium vapour pressure is a complex function of ionic component concentration, although principally **S_CO3** and **S_H**.

N_2 is modelled as a gaseous component only, and is supposed to only enter the digester by leakage, represented by the parameter **N2_Inflow**.

The initial conditions only have **G_CH4**, **G_CO2** and **G_N2**, because the mass of **H2O** is not independently variable – it is set by the gas volume and the temperature.

The gas space is considered to be perfectly mixed, and the gas leaves at a rate proportional to the difference between total pressure and the external pressure. The proportionality constant is the parameter **K_gas.**

Exponential smoothing is applied to the equilibrium vapour pressures of CH_4 sand CO_2, in order to reduce the stiffness of the model. This is useful to speed up the convergence of a steady-state model, but might distort the kinetics of a dynamic model. and the smoothing introduces two extra derived variables **PCH4_smooth**, and **PCO2_smooth**, which require initial values, and the degree of smoothing can be set by the parameter **Kp_smooth**. Note that a smaller value of **Kp_smooth** (< 1) results in a higher degree of smoothing.

Model startup

The PWM_SA anaerobic digestion model requires suitable initial values to get started, similar to the behaviour of a real digester. This arises from two inter-related aspects of the model, the sensitivity of methanogens to pH, and the dynamics of the liquid-gas transfer processes. If the initial values are "unbalanced", the model will either run extremely slowly, or even completely fail to converge to steady-state operation. The problem with finding suitably "balanced" initial values is made more difficult because the relationships of the critical variables to the initial component masses are not intuitive.

To assist in getting the model to start quickly, the default initial values are taken from a converged steady-state model, but for a digester with liquid and gas space volumes of 1 m^3 each. These values should be scaled to the volumes of the reactor being simulated, separately for the liquid phase and gas phase components. For this purpose, a routine has been provided, which is invoked by the initialisation code. It has an associated parameter **Rescale_Initial_Masses**. If set to 1, the rescaling

will be performed, but not if set to 0. Since this is normally meant to be used for a new model only, the parameter is automatically set to zero after the rescaling runs. It can be manually set back to 1 if required, but one should be aware of the sequence of events that takes place. The initial masses that one can set manually are not accessible by the initialisation code. What happens is that their values are copied to the working variables before the initialisation code runs, and it is the working variables that get rescaled before the simulation starts. It should be noted that WEST standardly rescales the initial mass of water, but not the other components, and this can interfere with the PWM_SA rescaling. For the latter to work properly, the mass of **H2O** must be in the correct relation to the the masses of the other liquid components.
The aerobic reactor model has a similar rescale facility, except that it has no gas space, so only the liquid phase components get rescaled.

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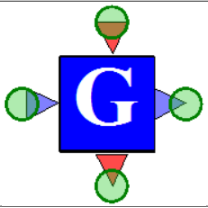
Wentzel M.C., Dold P.L., Ekama G.A. and Marais G.vR. (1989b) Enhanced polyphosphate organism cultures in activated sludge systems Part III - Kinetic model. Water SA, 15(2) 89-102.

GENERATORS

	Palette Group	**Input and Output**
	Category	IUWS_Generators
	Icon	generator

DWF2

Instances

IUWS1, IUWS2

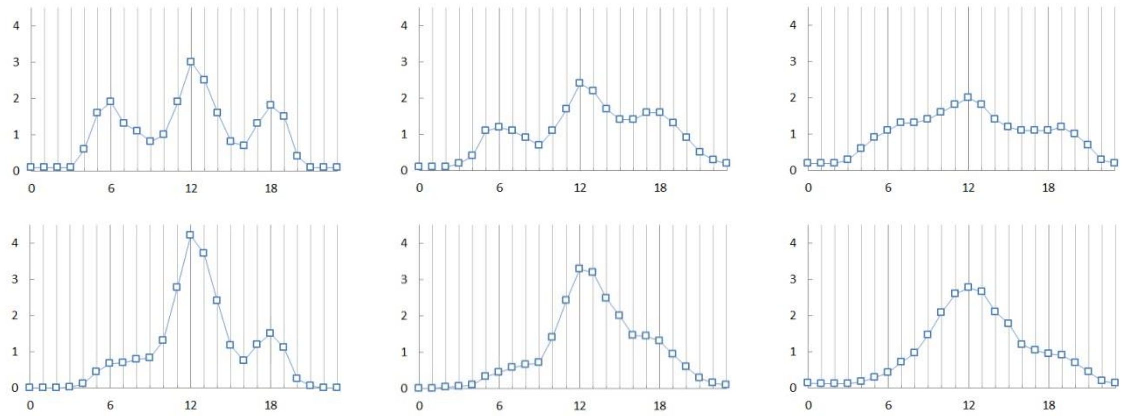
Description

The model generates a dry weather flow influent vector that uses the following components, as state variables: water (flow rate), particulate and soluble COD, total suspended solids, ammonia and phosphate.

Four flow and concentration daily patterns are available (see figure below):

- Lower than 5,000 PE
- Between 5,000 and 10,000 PE
- Between 10,000 and 50,000 PE
- Custom

Each pattern is discretised in 24 time-steps.



Dynamic patterns for flow rate (top) and concentration (bottom), for under 5 kPE (left), 5-10 kPE (centre) and 10-50 kPE (right)

Flow and concentrations are calculated, by combining the respective average values (provided as input) and daily patterns, as follows:

$$Q = Q^{*} \text{ and } C_i = C_{i,ave} \cdot C_i^{*}$$

$$Q^{*} = f_{tourist} \cdot f_{we} \cdot Q_{ave} \cdot \left[P_{Q,t} \cdot (1 - w) + P_{Q,t+1} \cdot w\right] + Q_{Inf} + Q_{Ind}$$

$$C_i^{*} = f_{tourist} \cdot f_{we} \cdot Q_{ave} \cdot \left[P_{C,t} \cdot (1 - w) + P_{C,t+1} \cdot w\right]$$

where:

- f_{we} is zero (0) during working days
- $f_{tourist}$ is zero (0) during non-tourist season
- $P_{Q,t}$ and $P_{C,t}$ denote the flow and the concentration patterns at time t
- w is the weight
- Q_{Inf} and Q_{Ind} denote the infiltration and industrial flow rates

The weight is a function of the time between two time-steps, i.e. two subsequent hours of the day.

Parameters

Name	Description	Value	Units
Tourist_begin	Start of tourist season (day nr)	162	---
Touirst_end	End of tourist season (day nr)	300	---
Weekday1	Week day at the start of the year, Monday= -1, Tuesday=5, Wednesday=4, Thursday=3, Friday=2, Saturday=1, Sunday=0	1	---
A_Tot	Total area of the subcatchment	2,000,000	m2
Inh	Number of inhabitants	3,000	---
Qavg_tot	Average volume produced	---	m3/d
QxInh	Wastewater produced per inhabitant per day	0.15	---
f_Conc_tourist	Correction factor for concentration in touristic season	1.1	---
f_Conc_we	Correction factor for concentration during weekends	0.5	---
f_Flow_tourist	Correction factor for flow rate in tourist season	1	---
f_Flow_we	Correction factor for flow rate during weekends	0.7	---
Inf_ampl	Maximum increase/decrease from average infiltration (amplitude of periodic function)	0.4	---
Inf_phase	Phase of periodic function (days before year start when infiltration equals average)	60	---
Infiltr	Water infiltration flow (l/s/ha)	0.11	---
idx_P_Infiltr	Seasonal infiltration pattern: 0 (Custom), 1 (constant), 2 (periodic function)	0	---
Extra_L	Containing extra loads (vector)	0	g/inh/d
Mean_L	Containing the mean loads (vector)	---	g/d
Mean_LxIE	Containing the mean loads (vector)	---	g/inh/d
idx_PP	Daily DWF pollution pattern (component vector): 1 (same as generic), 0 (Custom)	1	---
idx_PPwe	Daily DWF pollution pattern during weekend (component vector): 1 (same as generic), 0 (Custom)	1	---
idx_P_Flow	Daily DWF pattern (0-5 kPe), 2 (5-10 kPe), 3 (10-50 kPe), 4 (Spangen), 5 Constant), 6 (Commercial), 0 (Custom)	1	---
idx_P_Flow_we	Daily DWF pattern during weekend: 1 (same as weekday), 0 (Custom)	1	---
idx_P_Pollution	Daily DWF pollution pattern (0-5 kPe), 2 (5-10 kPe), 3 (10-50 kPe), 4 (Spangen), 5 Constant), 6 (Commercial), 0 (Custom)	1	---
idx_P_Pollution_we	Daily DWF pollution pattern during weekend: 1 (same as weekday), 0 (Custom)	1	---
PF_corr	Corrected flow pattern (per hour)	---	---
PFwe_corr	Corrected flow pattern during weekends (per hour)	---	---
P_Flow	Actual flow pattern (per hour)	---	---
P_Flow_we	Actual flow pattern during weekends (per hour)	---	---
PF_ATV0to5thIE	Flow pattern for 0-5 kPe (per hour)	---	---
PF_ATV10to50thIE	Flow pattern for 10-50 kPe (per hour)	---	---
PF_ATV5to10thIE	Flow pattern for 5-10 kPe (per hour)	---	---
PF_Commercial8_18	Commercial flow pattern (per hour)	---	---
PF_Constant	Constant flow pattern (per hour)	---	---
PF_Custom	User defined flow pattern(per hour)	---	---
PF_Spangen	Spangen flow pattern(per hour)	---	---
PF_we	User defined flow pattern for weekends (per hour)	---	---
P_Infiltr	Seasonal infiltration pattern (per month)	---	---
P_InfiltrConst	Constant infiltration pattern (per month)	---	----
P_InfiltrCustom	Custom infiltration pattern (per month)	---	---
PP_NP	Actual pollution pattern (NH4, PO4) (per hour)	---	---

Name	Description	Value	Units
PP_NP_corr	Corrected pollution pattern (NH4, PO4) (per hour)	---	---
PPwe_NP	Actual pollution pattern for weekends (NH4, PO4) (per hour)	---	---
PPwe_NP_corr	Corrected pollution pattern for weekends (NH4, PO4) (per hour)	---	---
PP_X	Actual pollution pattern (particulates) (per hour)	---	---
PP_X_corr	Corrected pollution pattern (particulates) (per hour)	---	---
PPwe_X	Actual pollution pattern for weekends (particulates) (per hour)	---	---
PPwe_X_corr	Corrected pollution pattern for weekends (particulates) (per hour)	---	---
PPwe_corr	Corrected pollution pattern during weekends (per hour)	---	---
P_Pollution	Actual pollution pattern (per hour)	---	---
P_Pollution_we	Actual pollution pattern during weekends (per hour)	---	---
PP_S0to5thIE	Pollution pattern for 0-5 kPe (per hour)	---	---
PP_S10to50thIE	Pollution pattern for 10-50 kPe (per hour)	---	---
PP_S5to10thIE	Pollution pattern for 5-10 kPe (per hour)	---	---
PP_Commercial8_18	Commercial pollution pattern (per hour)	---	---
PP_Constant	Constant pollution pattern (per hour)	---	---
PP_Custom	User defined pollution pattern (per hour)	---	---
PP_NP_Custom	User defined pollution pattern (NH4, PO4) (per hour)	---	---
PP_X_Custom	User defined pollution pattern (particulates) (per hour)	----	---
PP_S_Custom	User defined pollution pattern (solubles) (per hour)	---	---
PP_Spangen	Spangen pollution pattern (per hour)	---	---
PP_NP_we	User defined pollution pattern (NH4, PO4) for weekends (per hour)	---	---
PP_S_we	User defined pollution pattern (solubles) for weekends (per hour)	---	---
PP_X_we	User defined pollution pattern (particulates) for weekends (per hour)	---	---
PP_we	User defined pollution pattern for weekends (per hour)	---	---
PP_S	Actual pollution pattern (solubles) (per hour)	---	---
PP_S_corr	Corrected pollution pattern (solubles) (per hour)	---	---
PPwe_S	Actual pollution pattern for weekends (solubles) (per hour)	---	---
PPwe_S_corr	Corrected pollution pattern for weekends (solubles) (per hour)	---	---

State Variables

Name	Description	Units
DayOfWeek	Day of the week	---
DayOfYear	Day of the year	---
MonthNr	Nr of the month in the year	---
NextMonthNr	Nr of next month	---
NextTimestep	Next time step	---
TimeInHours	Hour of the day	---
Timestep	Current time step	---
wHours	Weight of the time-in-hours	---
wMonth	Weight of the months	---
Q_Infiltr	Total infiltration	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	Out_1	Outflow (component vector)	---	---
Q_DWF	Out_2	Dry weather flow	---	m3/d

Calc_Evaporation

Instances

IUWS1, IUWS2

Description

It generates evaporation flow (mm/d) based on the yearly evaporation, the solar radiation and the air temperature.

$$E = \frac{E_{year}}{2} \cdot \left(\frac{I0 \cdot GSA_{I0}}{I_{0,mean}} + \frac{T_{air} \cdot GSA_{T}}{T_{air,mean}} \right)$$

where:

- E_{year} is the average yearly potential evaporation
- $I0$ and $I_{0,mean}$ denote the solar radiation and the mean solar radiation, respectively
- GSA_{I0} and GSA_{T} indicate the solar radiation factor and temperature factor for GSA
- T_{Air} and $T_{air,mean}$ denote the air temperature and the mean air temperature, respectively

Parameters

Name	Description	Value	Units
Evap_Year	Average yearly potential evaporation	657	mm/year
Mean_I0	Mean solar radiation	400	W/m2
Mean_T_Air	Mean air temperature	15	degC
GSA_I0	Radiation (I0) factor for GSA	1	---
GSA_T	Temperature factor for GSA	1	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Evap	in_3	Evaporation	---	mm/d
I0	*in_2*	*Solar radiation*	*15*	*W/m2*
T_Air	*in_2*	*Air temperature*	*15*	*degC*

Runoff

Instances

IUWS1, IUWS2

Description

The model describes the rainfall-runoff relation in a catchment area, incorporating accumulation and wash-off.

The run-off after wetting and filling depressions (mm/d), i.e. if the filling degree is greater than unity, is calculated as:

$dr_{fill} = q_{rain} \cdot f_{rain} / SI_{max}$ in rainy conditions; or

$dr_{fill} = -E \cdot r_{fill} / SI_{max}$ in dry-weather conditions

$$R_{imp} = R_{imp,max} \cdot q_{rain} \cdot f_{rain}$$

where:

- q_{rain} and f_{rain} denote the rainfall (mm/d) and the rain factor, respectively
- SI_{max} is the maximum depression storage capacity (mm)
- E is the evaporation intensity (mm/d)
- r_{fill} and dr_{fill} indicate the filling degree and its rate of change
- R_{imp} is the run-off after wetting and filling depressions (mm/d)
- $R_{imp,max}$ is the maximum run-off coefficient for impervious areas

The accumulation and wash-off term is calculated as:

$$r_{MA,i} = r_{acc,i} \cdot A_{imp} - M_i$$

$$M_i = K_e \cdot R_{imp} \cdot MA_i$$

where:

- $r_{acc,i}$ is the accumulation rate for the *i*-th component (kg/ha/d)
- A_{imp} is the impervious area of the catchment (ha)
- M_i is the flux of the *i*-th component (g/d)
- MA_i is the accumulate mass of the *i*-th component (g/d)
- K_e indicates the wash-off rate (1/mm)

The resulting run-off flow and mass flux are calculated as follows:

$$Q_{Out} = R_{imp} \cdot A_{imp} \cdot 10$$

$Out_i = M_i$ if accumulation is present; or

$Out_i = Q_{Out} \cdot C_{imp,i}$ if accumulation does not occur

where:

- $C_{imp,i}$ is the concentration of the *i*-th component (g/m3) from impervious areas

Parameters

Name	Description	Value	Units
A_Tot	Total area of the sub-catchment	1	ha
f_Rain	Rain factor	1	---
t_evap	Time window for calculation of average evaporation	7	d
C_Imp	Pollutant concentrations from the impervious areas	0.001	g/m3
IsAccuWash	Surface accumulation and wash-off: on (1), fixed EMC (0)	1	---
Ke	Wash-off rate	0.15	1/mm
RunoffImp_Max	The maximum runoff coefficient Psi_e, impervious	1	---
StorageImp_Max	Maximum depression storage for impervious areas	0.6	mm
f_Imp	Impervious fraction of the total area of the catchment	1	---
r_Acc	Accumulation rate (component vector)	---	kg/ha/d
t_acc_max	Maximum days of accumulation	5	d

State Variables

Name	Description	Units
FillingImp	Filling degree of the depression storage impervious	---
M_A	Accumulation mass at the surface (component vector)	g/d
RunoffImp	Water runoff after wetting and depressions	mm/d
Q_Out	Effluent flow rate	m3/d

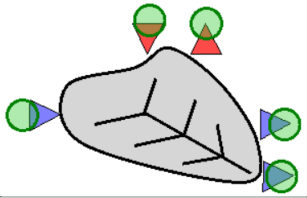
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow (component vector)	---	---
Evap	*in_2*	*Evaporation*	*0*	*mm/d*
Rain	*in_2*	*Input from the rain influent file*	*0*	*mm/d*

CATCHMENT

	Palette Group	**Sewer**
	Category	Kosim
	Icon	catchment

Combined_NoVol

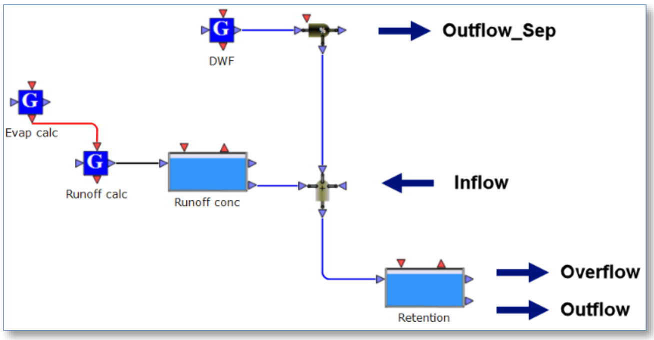
Instances

IUWS1, IUWS2

Description

This is a model of a catchment with no retention volume.
It combines the following elements (see figure):

- a dry weather generator
- an evaporation calculator
- a run-off calculator
- a fictitious, ideal (no volume) retention tank that splits the flow into two components (outflow and overflow)



For a detailed description of each sub-model, please refer to the corresponding section of this manual.

Submodels

Name	Model
dwf	IUWS_Generators.DWF2
evap_calc	IUWS_Generators.Calc_Evaporation
mix	IUWS[n].Mix03s
runoff_calc	IUWS[n].Runoff
runoff_conc	Tanks_Sewer.Runoff2
split	IUWS[n].SplitRel02s
outover	Tanks_Sewer.Retention_NoVol

Parameters

Name	Description	Value	Units
Evap_Year	Average yearly potential evaporation	600	mm/year
IsSeparate	Separate (1) vs. combined (0) sewer	0	---
Mean_I0	Mean solar radiation	400	W/m2
Mean_T_Air	Mean air temperature	15	°C
Inh	Number of inhabitants	3,000	---
Q_Ind	Industrial contribution (constant)	0	m3/d
QxInh	Wastewater produced per inhabitant per day	0.15	---
A_Tot	Total area of the subcatchment	1	ha
f0_Inf	Infiltration factor 0	0.001	---
f1_Inf	Infiltration factor 1	0.0001	---
f2_Inf	Infiltration factor 2	5	---
f_Rain	Rain factor	1	---
t_rain	Time window for calculation of average rain	30	d
Extra_L	Vector containing extra loads (component vector)	0	g/inh/d

Name	Description	Value	Units
Mean_LxIE[Q]	Vector containing the mean loads	1	g/inh/d
Mean_LxIE[NH4]	Vector containing the mean loads	10	g/inh/d
Mean_LxIE[PO4]	Vector containing the mean loads	2	g/inh/d
Mean_LxIE[SCOD]	Vector containing the mean loads	30	g/inh/d
Mean_LxIE[XCOD]	Vector containing the mean loads	70	g/inh/d
Mean_LxIE[XTSS]	Vector containing the mean loads	70	g/inh/d
idx_P_Flow	Index of flow pattern: steeper (1), flatter (2)	1	---
GSA_I0	Radiation (I0) factor GSA	1	---
GSA_T	Temperature factor for GSA	1	---
C_Imp[Q]	Pollutant concentrations coming from the impervious areas	1,000,000	g/m3
C_Imp[NH4]	Pollutant concentrations coming from the impervious areas	2	g/m3
C_Imp[PO4]	Pollutant concentrations coming from the impervious areas	0.2	g/m3
C_Imp[SCOD]	Pollutant concentrations coming from the impervious areas	10	g/m3
C_Imp[XCOD]	Pollutant concentrations coming from the impervious areas	20	g/m3
C_Imp[XTSS]	Pollutant concentrations coming from the impervious areas	30	g/m3
IsAccuWash	Surface accumulation and washoff: on (1), fixed EMC (0)	1	---
Ke	Washoff rate	0.15	1/mm
StorageImp_Max	Maximum depression storage for impervious areas	0.6	mm
f_Imp	Impervious fraction of the total area of the catchment	1	---
m	Exponent (1=linearity)	1	---
r_Acc[Q]	Accumulation rate	0	kg/ha/d
r_Acc[NH4]	Accumulation rate	1	kg/ha/d
r_Acc[PO4]	Accumulation rate	1	kg/ha/d
r_Acc[SCOD]	Accumulation rate	1	kg/ha/d
r_Acc[XCOD]	Accumulation rate	1	kg/ha/d
r_Acc[XTSS]	Accumulation rate	1.5	kg/ha/d
t_a	Time to peak	7	min
t_acc_max	Maximum days of accumulation	5	d

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	g/d
Outflow_Sep	out_1	Outflow from dry-weather, if separate sewer	---	g/d
Overflow	out_3	Overflow (component vector)	---	g/d
I0	*in_2*	*Solar radiation*	*15*	*W/m2*
Q_Max	*in_2*	*Maximum outflow*	*10*	*m3/d*
Rain	*in_2*	*Input from the rain influent file*	*0*	*mm/d*
T_Air	*in_2*	*Air temperature*	*15*	*°C*
Q_DWF	out_2	Dry weather flow	---	m3/d
Q_Out	out_2	Outflow from dry and wet weather	---	m3/d
Q_Over	out_2	Overflow from dry and wet weather	---	m3/d
Q_WWF	out_2	Wet-weather outflow	---	m3/d
V_Over	out_2	Cumulated overflown volume (in wet-weather)	---	m3

Combined_WithVol

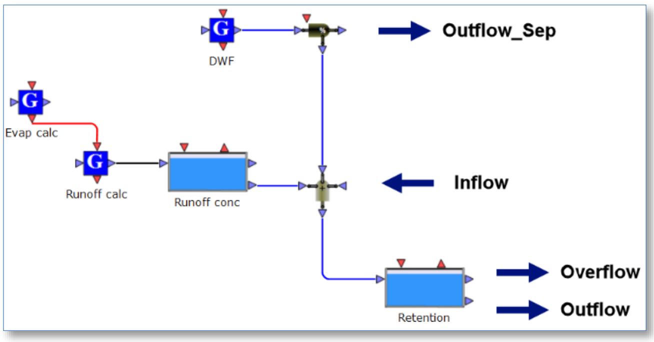
Instances

IUWS1, IUWS2

Description

This is a model of a catchment with no retention volume.
It combines the following elements (see figure):

- a dry weather generator
- an evaporation calculator
- a run-off calculator
- a retention tank that splits the flow into two components (outflow and overflow)



For a detailed description of each sub-model, please refer to the corresponding section of this manual.

Submodels

Name	Model
dwf	IUWS_Generators.DWF2
evap_calc	IUWS_Generators.Calc_Evaporation
mix	IUWS[n].Mix03s
runoff_calc	IUWS[n].Runoff
runoff_conc	Tanks_Sewer.Runoff2
split	IUWS[n].SplitRel02s

Parameters

Name	Description	Value	Units
Evap_Year	Average yearly potential evaporation	600	mm/year
IsSeparate	Separate (1) vs. combined (0) sewer	0	---
Mean_I0	Mean solar radiation	400	W/m2
Mean_T_Air	Mean air temperature	15	°C
Inh	Number of inhabitants	3,000	---
Q_Ind	Industrial contribution (constant)	0	m3/d
QxInh	Wastewater produced per inhabitant per day	0.15	---
A_Tot	Total area of the subcatchment	1	ha
f0_Inf	Infiltration factor 0	0.001	---
f1_Inf	Infiltration factor 1	0.0001	---
f2_Inf	Infiltration factor 2	5	---
f_Rain	Rain factor	1	---
t_rain	Time window for calculation of average rain	30	d
Extra_L	Vector containing extra loads (component vector)	0	g/inh/d
Mean_LxIE[Q]	Vector containing the mean loads	1	g/inh/d
Mean_LxIE[NH4]	Vector containing the mean loads	10	g/inh/d

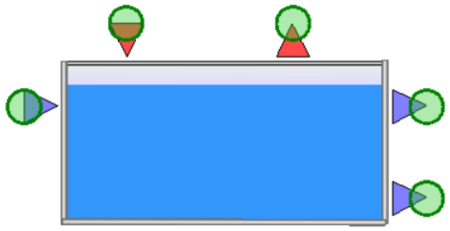
Name	Description	Value	Units
Mean_LxIE[PO4]	Vector containing the mean loads	2	g/inh/d
Mean_LxIE[SCOD]	Vector containing the mean loads	30	g/inh/d
Mean_LxIE[XCOD]	Vector containing the mean loads	70	g/inh/d
Mean_LxIE[XTSS]	Vector containing the mean loads	70	g/inh/d
idx_P_Flow	Index of flow pattern: steeper (1), flatter (2)	1	---
GSA_I0	Radiation (I0) factor GSA	1	---
GSA_T	Temperature factor for GSA	1	---
D	Diameter of the pipe	0.6	m
V_Ret	Retention volume	1,000	m3
N_Pumps	Number of pumps	0	---
f_Vol	Fraction of volume above which Qout=Qpump	0.05	---
t_pause	Time between off and on for pumps	1	d
FD_Res	Threshold between resuspention and deposition of TSS and COD particulate	0.4	---
FD_Sed	Filling degree threshold for sedimentation in WWF	0.5	---
f_Dep_Max	Maximum TSS and COD particulate deposition fraction in dry-weather	0.1	---
f_Dep_WW	TSS and COD particulate deposition fraction in wet-weather	0.5	---
f_V_Max	Maximum fraction of V_Max occupied by deposited TSS	0.1	---
r_Res_Max	Maximum TSS and COD resuspention rate	10	---
C_Imp[Q]	Pollutant concentrations coming from the impervious areas	1,000,000	g/m3
C_Imp[NH4]	Pollutant concentrations coming from the impervious areas	2	g/m3
C_Imp[PO4]	Pollutant concentrations coming from the impervious areas	0.2	g/m3
C_Imp[SCOD]	Pollutant concentrations coming from the impervious areas	10	g/m3
C_Imp[XCOD]	Pollutant concentrations coming from the impervious areas	20	g/m3
C_Imp[XTSS]	Pollutant concentrations coming from the impervious areas	30	g/m3
IsAccuWash	Surface accumulation and washoff: on (1), fixed EMC (0)	1	---
Ke	Washoff rate	0.15	1/mm
StorageImp_Max	Maximum depression storage for impervious areas	0.6	mm
f_Imp	Impervious fraction of the total area of the catchment	1	---
m	Exponent (1=linearity)	1	---
r_Acc[Q]	Accumulation rate	0	kg/ha/d
r_Acc[NH4]	Accumulation rate	1	kg/ha/d
r_Acc[PO4]	Accumulation rate	1	kg/ha/d
r_Acc[SCOD]	Accumulation rate	1	kg/ha/d
r_Acc[XCOD]	Accumulation rate	1	kg/ha/d
r_Acc[XTSS]	Accumulation rate	1.5	kg/ha/d
t_a	Time to peak	7	min
t_acc_max	Maximum days of accumulation	5	d

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	g/d
Outflow_Sep	out_1	Outflow from dry-weather, if separate sewer	---	g/d
Overflow	out_3	Overflow (component vector)	---	g/d

I0	*in_2*	*Solar radiation*	*15*	*W/m2*
Q_Max	*in_2*	*Maximum outflow*	*10*	*m3/d*
Rain	*in_2*	*Input from the rain influent file*	*0*	*mm/d*
T_Air	*in_2*	*Air temperature*	*15*	*°C*
E_Pump_sp	*in_2*	*Energy requirement for pumping per unit flow*	*0.04*	*kWh/m3*
Q_Pump	*in_2*	*Maximum pumped outflow*	*1*	*m3/d*
E_Pump	out_2	Pumping energy	---	kW/d
FD	out_2	Filling degree	---	---
Q_DWF	out_2	Dry weather flow	---	m3/d
Q_Out	out_2	Outflow from dry and wet weather	---	m3/d
Q_Over	out_2	Overflow from dry and wet weather	---	m3/d
Q_WWF	out_2	Wet-weather outflow	---	m3/d
V_Over	out_2	Cumulated overflown volume (in wet-weather)	---	m3

SEWER TANK

	Palette Group	**Sewer**
	Category	Tanks_Sewer
	Icon	sewer_tank

Freeflow

Instances

IUWS1, IUWS2

Description

The model describes a retention tank in which the outgoing flow can be regulated by a pump, or is free (i.e. *gravity flow*) and is limited by an upper bound:

$$(V < V_{min}): Q_{out}^{*} = 0$$
$$(V \geq V_{min}): Q_{out}^{*} = \sqrt{2g \cdot H \cdot FD} \cdot c_{o} \cdot FD \cdot H^{2}$$

$$(Pump\ On): Q_{out} = Q_{pump}^{*}$$
$$(Pump\ Off): Q_{out} = Q_{out}^{*} \div Q_{max}^{*}$$

$$Q_{over} = C_{d} \cdot \sqrt{g} \cdot B \cdot \sqrt{Du^{3}}$$

where:

- V and V_{min} indicate the volume and the minimum volume of the tank (m3)
- H, FD and c_{o} denote the height (m), the filling degree (-) and the actual fraction of the cross section (-) of the pipe
- Q_{out}^{*} and Q_{over} denote the *calculated* outflow- and the overflow flow rates (m3/s)
- Q_{pump}^{*} and Q_{max}^{*} denote the *actual* pump- and maximum flow rates (m3/d)
- C_{d} and B are empirical coefficients
- Du denotes the height above weir (m)

The actual pump flow rate is calculated as:

$$(V < V_{min}): Q_{pump}^{*} = 0$$
$$\left(Q_{in} \geq Q_{pump} \,||\, V \geq f \cdot V_{max}\right): Q_{pump}^{*} = Q_{pump}$$
$$\left(Q_{in} < Q_{pump} \,||\, V < f \cdot V_{max}\right): Q_{pump}^{*} = Q_{in}$$

The actual maximum flow rate, as:

$$\left(FD_{dw} < FD_{dw,lim} \,||\, FD^{*} > FD\right): Q_{max}^{*} = Q_{max}$$
$$\left(FD_{dw} \geq FD_{dw,lim} \,||\, FD^{*} \leq FD\right): Q_{max}^{*} = Q_{max,lim}$$

And the height above the weir, as:

$$Du = \frac{V - V_{max}}{V_{max}/H}$$

$$FD = \frac{V}{V_{max}}$$

where:

- Q_{pump} and Q_{max} denote the desired pump and maximum flow rates (m3/d)
- $Q_{max,lim}$ is maximum outflow if $FD_{dw} > FD_{dw,lim}$

- f and V_{max} indicate a fraction of the volume and the maximum volume of the tank (m3)
- FD_{dw} and $FD_{dw,lim}$ indicate the filling degree (-) and the threshold of the filling degree (-) for the downstream tank
- FD^* and FD indicate the actual filling degree (-) and the threshold of the filling degree (-) for the tank

Solids (and COD) deposition and resuspension are modelled.

Parameters

Name	Description	Value	Units
FD_h	Filling degree at which orifice is placed	0	---
FD_th	Filling degree threshold for downstream tank	2.0	---
FD_th_int	Filling degree threshold for this tank	0	---
N_Pumps	Number of pumps	0	---
Orifice	Pump and orifice active (1) vs. pump or orifice active (0)	0	---
Q_Max_Lim	Maximum outflow if FD_In > FD_th	1	m3/d
f_Vol	Fraction of volume above which Qout=Qpump	0.05	---
t_pause	Time between off and on for pumps	1	d
FD_Res	Threshold resuspension / deposition of TSS and X_COD	0.4	---
FD_Sed	Filling degree below which sediments settle in WWF	0.25	---
f_Dep_Max	Max TSS and X_COD deposition fraction in dry-weather	0.1	---
f_Dep_WW	TSS and X_COD deposition fraction in wet-weather	0.5	---
f_V_Max	Maximum fraction of V_Max occupied by deposited TSS	0.1	---
r_Res_Max	Maximum TSS and COD resuspension rate	5	---
D	Diameter of the pipe	0.6	m
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	10.0	m3
Cd	Coefficient to compute overflow	0.85	---
B	Coefficient to compute overflow	20.0	---
c_o	Throttle coefficient (1=total cross-section)	1.0	---

State Variables

Name	Description	Units
M	Mass (component vector)	g
C	Concentration (component vector)	---
V	Actual volume of the tank	m3
Du	Height above the crest of the weir	m
FD_Tank	Filling degree	
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Over	Overflow flow rate	m3/d
Q_Max_Actual	Actual Q max (with no pumping)	m3/d

Derived State Variables

Name	Description	Units
COD_Dep	Deposited mass of COD	g
TSS_Dep	Deposited mass of TSS	g

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	g/d

Name	Terminal	Description	Value	Units
Overflow	out_3	Overflow (component vector)	---	g/d
E_Pump_sp	*in_2*		*0.04*	*kWh/m3*
FD_In	*in_2*		*0*	
Q_Max	*in_2*		*10*	*m3/d*
Q_Pump	*in_2*		*1*	*m3/d*
V_Over	out_3	Accumulated overflown volume	---	m3
E_Pump	out_3	Pumping energy	---	kW/d
V_Tank	out_3	Volume of the tank	---	m3
Q_WWF	out_3	Wet-weather outflow	---	m3/d

Runoff2

Instances

IUWS1, IUWS2

Description

The model is a large simplification of the rainfall-runoff relation in a catchment area.
It represents a fictitious, variable volume reservoir, where the effluent flow is a function of the volume:

$$Q_{out} = \left(\frac{V - V_{Min}}{k}\right)^{\frac{1}{m}}$$

where:

- V and V_{min} denote the current and minimum volume (m3) of the tank/reservoir
- k (d) is the time constant
- m is an empirical factor

Parameters

Name	Description	Value	Units
V_Min	Minimum volume to avoid numerical problems	1	m3
k	Reservoir time constant	0.0056	d
m	Exponent (1=linearity)	1	---
t_a	Time to peak	7	min

State Variables

Name	Description	Units
M	Mass (component vector)	g
C	Concentration (component vector)	---
V	Actual volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	---
Outflow	out_1	Outflow (component vector)	---	---
Q_WWF	out_3	Wet-weather outflow	---	m3/d
V_Over	out_3	Outflow from wet weather	---	m3
V_Tank	out_3	Volume of the tank	---	m3

Retention_NoVol

Instances

IUWS1, IUWS2

Description

This is an ideal (no-volume) retention tank that splits the incoming flow into two outgoing streams, the main outflow being limited to an upper limit:

$$Q_{Out} = min(Q_{In}, Q_{Max})$$

$$Q_{Over} = Q_{in} - Q_{Max}$$

Parameters

None

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Over	Overflow rate	m3/d

Derived State Variables

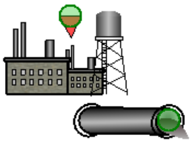
None

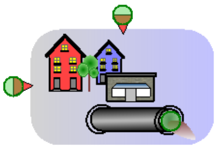
Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	g/d
Overflow	out_2	Overflow (component vector)	---	g/d
V_Over	out_3	Accumulated overflown volume (in wet weather)	---	m3
Q_Max	*in_2*	*Maximum outflow*	*10*	*m3/d*

INFLUENT

	Palette Group	**Input and Output**
	Category	n/d
	Icon	(influent) Muncipality

	Palette Group	**Input and Output**
	Category	n/d
	Icon	(influent) Industry

	Palette Group	**Input and Output**
	Category	
	Icon	inwwtp

ASM2dMod.Influent_ASM2a

Instances

ASM2dMod

Description

The Influent Fractionator converts a set of time series of measurements into a set of time series of model components using a dynamic regression technique. The measurements can be on different time schedules.

Only Flow plus (COD or TSS) are essential; however additional measurements improve the characterisation of the stream.

Measurements

The set of measurements that can be considered are ones that can be modelled as concentration-weighted sums of contributions by the model components:

$$Measurement[m] = \sum_i MeasurementFactor[m, i] \cdot c[i]$$

Name	Description
Flow	Stream flowrate
COD	Chemical Oxygen Demand (total)
COD_filtered	Soluble COD
COD_up	Unbiodegradable particulate COD
COD_us	Unbiodegradable soluble COD
FSA	Free and saline ammonia
PO4	Ortho-phosphate
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
VFA	Volatile fatty acid

Estimates

Where the available measurements do not provide sufficient information to determine all the model component concentrations, estimates are used to fill in the gaps. Estimates can be thought of as second-class measurements, which receive lower weightings in the regression than the actual measurements. The fractionator uses two types of estimates: *interpolation* and *cross-reference*.

Interpolation

Gaps in the measurement time series are filled in by interpolation between the measured values. Interpolated values are assigned lower weights according to the time to the nearest measurement. The nearest measurement may be in the future, which is something that cannot be detected within a WEST model, so the interpolation and corresponding calculation of weights is handled by the *FractionationPreprocessor*, which is a R routine. This produces an input file which can be connected to the fractionator via a standard WEST input module.

Cross-reference

Estimates are calculated from measurements if present, or other estimates where measurements are missing, using the following ratios:

Name	Description	Default Value
f_codf	COD_filtered / COD	0.1775
f_codup	COD_up/COD	0.0748
f_codus	COD_us/COD	0.0319
f_fsa	FSA/TN	0.4819
f_orthop	PO4/TP	0.142
f_tn	TN/COD	0.0711
f_tp	TP/COD	0.0429
f_tss	TSS/COD	0.6759
f_vfa	VFA/COD	0.001
f_codf	COD_filtered / COD	0.1775

The default values for these estimation parameters are appropriate for fractionating a raw sewage stream. For other streams, such as settled sewage, they should be re-considered. Adjusting them might also improve the fractionation for a particular plant.

Weights

Weighting factors are used to steer the regression at several levels. A higher weighted variable has more influence than one with a lower weight.

- *Interpolation weights* are calculated by the pre-processor as discussed above.
- *Relative weights* are used to emphasise or de-emphasis particular measurements or estimates relative to other measurements.
- *Estimate weights* de-emphasise values calculated by ratios relative to measured or interpolated values.

Limits

Each fitted component concentration must fall between its corresponding Upper_limit and Lower_limit. These are not hard limits – the regression algorithm adds a penalty to the objective function as the concentration approaches the limit, so a limit may occasionally be exceeded.

Ratios

The simulated measurements corresponding to the fitted component concentrations should have ratios in a range above and below the cross-reference ratios (such as f_tss) set by the parameters Upper_ratio and Lower_ratio. These parameters values are relative to the corresponding cross-reference parameter. These are handled by the optimiser in the same way as the limits.

Relaxation Time

The optimiser routine does not calculate the component concentrations directly at each time step. Instead, it calculates the objective function to be optimised, and its derivatives with respect to the component concentrations. These are converted to time derivatives by dividing bay the relaxation time Tr, so that the WEST solver drives the component concentrations towards the optimum point. A higher value of Tr will cause the simulated measurements to follow the input measurements more closely, whereas a lower value of Tr will result in a smoother output.

Key Parameters

As explained above, the key parameters for tuning the fractionation are Tr, the cross-reference ratios (e.g. f_tss), the upper and lower limits, and the upper and lower ratios. The MeasurementFactors are intrinsic properties of the components, and so should not be adjusted directly. However, those involving N and P are set according to the N and P contents of the relevant components, which can be adjusted (e.g. i_N_X_S, the N content of X_S). When this is done, the component composition parameters should be made top-level parameters applicable to all units in the plant model.

Fractionator Outputs

Outflow: a vector of component fluxes.

Fitted: Fitted values of component concentration, effectively the same as FittedValue.
Component margins: Differences between fitted component concentrations and their upper and lower limits.
Measurement margins: Margins for simulated measurements.
Estimates: estimated values of measurements calculated from cross-reference ratios.
Matched: simulated measurements calculated from fitted component concentrations.
weight: combined weighting for each measurement input to the optimiser.
wt: weights returned by the optimiser, which may reflect penalties associated with limits.
Objective: weighted sum of squared differences between matched and input measurements or estimates.
ErrorIndex: contribution of each measurement to the Objective.
Lower_bound, Upper_bound: limits for simulated measurements calculated from the lower and upper ratios.

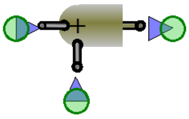
Evaluating Results

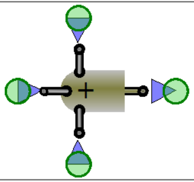
The outputs provide a number of aids to evaluating the fractionation. For example:

- If a fitted variable consistently has a small Lower_margin or Upper_margin, it indicates that a limit or an estimation ratio or component compositions parameter needs adjustment (the variable is consistently running close to a limit).
- A sharp spike in the objective function suggests an inconsistency in the measurements around that time. The ErrorIndex trace may help to identify which measurement is causing the problem.
- A consistently high ErrorIndex means that the corresponding variable is being prevented from reaching its optimum values. Depending on the variable and the available measurements, this can indicate a problem with a limit, a cross-reference estimation parameter or a composition parameter (such as i_N_X_S, the nitrogen content of X_S)

In general, an ideal fractionation will have low ErrorIndex values, Matched values between the Upper_bounds and Lower_bounds, FittedValues between the Upper_limits and Lower_limits

COMBINERS

	Palette Group	**Flow**
	Category	Mixers, KOSIM,
	Icon	mixer_02

	Palette Group	**Flow**
	Category	Mixers, KOSIM,
	Icon	mixer_03

Mix_02

Instances

All

Description

It combines 2 incoming flows.

Parameters

None

State Variables

Name	Description	Units
Q_In1	Flow rate, inflow no.1	m3/d
Q_In2	Flow rate, inflow no.2	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow1	in_1	Inflow vector no.1	---	g/d
Inflow2	in_2	Inflow vector no.2	---	g/d
Outflow	out_1	Outflow vector	---	g/d

Mix_03

Instances
All

Description
It combines 3 incoming flows.

Parameters
None

State Variables

Name	Description	Units
Q_In1	Flow rate, inflow no.1	m3/d
Q_In2	Flow rate, inflow no.2	m3/d
Q_In3	Flow rate, inflow no.3	m3/d

Derived State Variables
None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow1	in_1	Inflow vector no.1	---	g/d
Inflow2	in_2	Inflow vector no.2	---	g/d
Inflow3	in_3	Inflow vector no.3	---	g/d
Outflow	out_1	Outflow vector	---	g/d

Mix_03s

Instances

IUWS1, IUWS2

Description

It combines 3 incoming flows, for sewer models.

Parameters

None

State Variables

Name	Description	Units
Q_In1	Flow rate, inflow no.1	m3/d
Q_In2	Flow rate, inflow no.2	m3/d
Q_In3	Flow rate, inflow no.3	m3/d

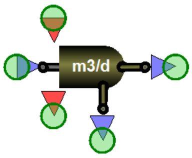
Derived State Variables

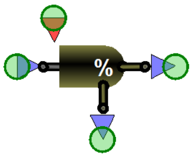
None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow1	in_1	Inflow vector no.1	---	g/d
Inflow2	in_2	Inflow vector no.2	---	g/d
Inflow3	in_3	Inflow vector no.3	---	g/d
Outflow	out_1	Outflow vector	---	g/d

SPLITTERS

	Palette Group	**Flow**
	Category	Splitters
	Icon	split_flow_02

	Palette Group	**Flow**
	Category	Splitters, KOSIM,
	Icon	split_valve_02

SplitAbs02

Instances

All

Description

It splits the incoming flow into two flows:

$$Q_{out,2} = Q_{in} - Q_{out,1}$$

$$\left(Q^*_{out,1} > Q_{in}\right): Q_{out,1} = Q_{in}$$
$$\left(Q^*_{out,1} \leq Q_{in}\right): Q_{out,1} = Q^*_{out,1}$$

where:

- Q_{in}, $Q_{out,1}$ and $Q_{out,2}$ denote the influent-, effluent #1 and effluent #2 flow rates (m3/d)
- $Q^*_{out,1}$ is the pump flow rate (m3/d), i.e. desired effluent #1 flow rate

The energy consumption for pumping is to be computed externally (i.e. via a pump model) by using the relevant $Q_{Op,i}$ flow rates (sensors).

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = F \cdot Q_{out,1}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)

Parameters

None

State Variables

Name	Description	Units
Actual_Q_Out1	Actual effluent flow no.1	m3/d
Actual_Q_Out2	Actual effluent flow no.2	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Q_Out_01	*in_2*	*Desired flow rate #01*	*10*	*m3/d*
E_Pump_sp	*in_2*	*Energy requirement for pumping*	*0.04*	*kWh/m3*
Out_01	out_1	Outflow #01	---	g/d
Out_02	out_2	Outflow #02	---	g/d
P_P_01	out_3	Pumping power #01	---	kWh/d
Q_Op_01	out_3	Actual flow rate #01	---	kWh/d

SplitRel02

Instances

All

Description

It splits the incoming flow into two flows:

$$Q_{out,2} = Q_{in} - Q_{out,1}$$

$$(f_{out,1} > 1): Q_{out,1} = Q_{in}$$
$$(f_{out,1} \leq 1): Q_{out,1} = f_{out,1} \cdot Q_{in}$$

where:

- Q_{in}, $Q_{out,1}$ and $Q_{out,2}$ denote the influent-, effluent #1 and effluent #2 flow rates (m3/d)
- $f_{out,1}$ is the desired fraction (-) of the influent that is diverted to effluent #1

Parameters

None

State Variables

Name	Description	Units
Actual_Q_Out1	Actual effluent flow no.1	m3/d
Actual_Q_Out2	Actual effluent flow no.2	m3/d
f_Out_02	Portion of flow to outflow #2	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
f_Out_01	*in_2*	*Desired portion of flow to outflow #1*	*0.5*	---
Out_01	out_1	Outflow #01	---	g/d
Out_02	out_2	Outflow #02	---	g/d

SplitRel02w

Instances

All

Description

It splits the incoming flow into two flows:

$$Q_{out,2} = Q_{in} - Q_{out,1}$$

$$f_{out,1} = \frac{f_{out,1}}{f_{out,1} + f_{out,2}}$$

where:

- Q_{in}, $Q_{out,1}$ and $Q_{out,2}$ denote the influent-, effluent #1 and effluent #2 flow rates (m3/d)
- $f_{out,1}$ and $f_{out,2}$ denote the desired fraction (-) of the influent, diverted to effluent #1 and #2

Parameters

None

State Variables

Name	Description	Units
Actual_Q_Out1	Actual effluent flow no.1	m3/d
Actual_Q_Out2	Actual effluent flow no.2	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
f_Out_01	*in_2*	*Desired portion of flow to outflow #1*	*1*	---
f_Out_02	*in_2*	*Desired portion of flow to outflow #1*	*1*	---
Out_01	out_1	Outflow #01	---	g/d
Out_02	out_2	Outflow #02	---	g/d

SplitRel02s

Instances

IUWS1, IUWS2

Description

$$Q_{out,2} = Q_{in} - Q_{out,1}$$

$$f_{out,1} = \frac{f_{out,1}}{f_{out,1} + f_{out,2}}$$

where:

- Q_{in}, $Q_{out,1}$ and $Q_{out,2}$ denote the influent-, effluent #1 and effluent #2 flow rates (m3/d)
- $f_{out,1}$ and $f_{out,2}$ denote the desired fraction (-) of the influent, diverted to effluent #1 and #2

Parameters

None

State Variables

Name	Description	Units
Actual_Q_Out1	Actual effluent flow no.1	m3/d
Actual_Q_Out2	Actual effluent flow no.2	m3/d

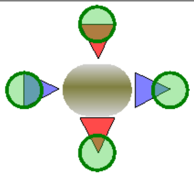
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
f_Out_01	*in_2*	*Desired portion of flow to outflow #1*	1	---
f_Out_02	*in_2*	*Desired portion of flow to outflow #2*	*1*	---
Out_01	out_1	Outflow #01	---	g/d
Out_02	out_2	Outflow #02	---	g/d

MULTI SPLITTERS / COMBINERS

	Palette Group	**Flow**
	Category	MixSplit
	Icon	Link

MixSplit.Rel10

Instances

All

Description

It simultaneously combines up to 10 incoming flows and splits the outgoing flow in up to 10 streams:

$$Q_{out,i} = \sum Q_{in,i} \cdot \frac{f_i}{\sum f_i}$$

where:

- $Q_{in,i}$ and $Q_{out,i}$ denote the *i*-th influent and effluent flow rate (m3/d)
- f_i indicates the portion of the influent flow directed to the *i*-th outflow

Parameters

None

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_In01 .. 10	Flow rate, inflow no.1 .. 10	m3/d
Q_Out01 .. 10	Flow rate, outflow no.1 .. 10	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
In_01 .. 10	in_1	Inflow no.1 .. 10	---	g/d
Out_01 .. 10	out_1	Outflow no.1 .. 10	---	g/d
f01 .. 10	*in_2*	*Portion of the influent to outflow no.1 .. 10*	*1*	---
Q_Out_01 .. 10	out_3	Flow rate, outflow no.1 .. 10	---	m3/d

MixSplit.Abs10

Instances

All

Description

It simultaneously combines up to 10 incoming flows and splits the outgoing flow in up to 10 streams:

$$Q_{out,i} = Q^*_{out,i}$$

where:

- $Q_{out,i}$ and $Q^*_{out,i}$ denote the i-th ‘actual’ and ‘desired’ effluent flow rates (m3/d).

Parameters

None

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_In01 .. 10	Flow rate, inflow no.1 .. 10	m3/d
Q_Out01 .. 10	Flow rate, outflow no.1 .. 10	m3/d

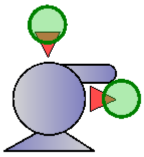
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
In_01 .. 10	in_1	Inflow no.1 .. 10	---	g/d
Out_01 .. 10	out_1	Outflow no.1 .. 10	---	g/d
Q01 .. 10	*in_2*	*Desired flow rate to outflow no. 1 to 10*	*0-10*	*m3/d*

PUMPS

	Palette Group	**Blowers and Pumps**
	Category	Pumps
	Icon Name	pump

SimpleQ

Instances

All

Description

This is very basic model of a pump which can deliver any flow rate, irrespective of the actual head losses.
Head losses are fixed and calculated as:

$$H = H_{syst} = H_{static} + H_{var}$$

where:

- H, H_{syst}, H_{static} and H_{var} denote the operating-, system-, static- head losses (m) and the friction and minor head losses (m) respectively

The actual flow rate that is delivered equals the desired (requested) flow rate – if the pump is active.

The energy and power consumption are calculated taking into consideration the density of the fluid (based on the solid concentration):

$$\rho = TSS + \left(1 + \frac{TSS}{\rho_{TSS}}\right) \cdot \rho_w$$

where:

- ρ, ρ_{TSS} and ρ_w denote the density (g/m3) of the fluid being pumped, of the solids and of water respectively
- TSS is the concentration of suspended solids (g/m3) in the fluid

The power consumption (kWh/d) and the cumulated energy consumption (kWh) are calculated as follows:

$$P_{pump} = \frac{\rho \cdot g \cdot H}{(3.6 \cdot 10^9) \cdot \eta_{tot}} \cdot Q_{out}$$

$$E_{pump} = \frac{1}{24} \cdot \int P_{pump}$$

where:

- g is the gravity acceleration (m/s2)
- Q_{out} is the flow rate delivered by the pump (m3/d)
- η_{tot} is the overall efficiency of the pump

Parameters

Name	Description	Value	Units
H_TS	Static head loss	5	m
H_F	Friction and minor head loss	1	m
Eta	Efficiency of the pump	0.667	---

State Variables

Name	Description	Units
H_System	Total head losses of the system	m
H	Operating head at Q_Out	m
Eta_Total	Total efficiency	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d

CF_Q_Throttle

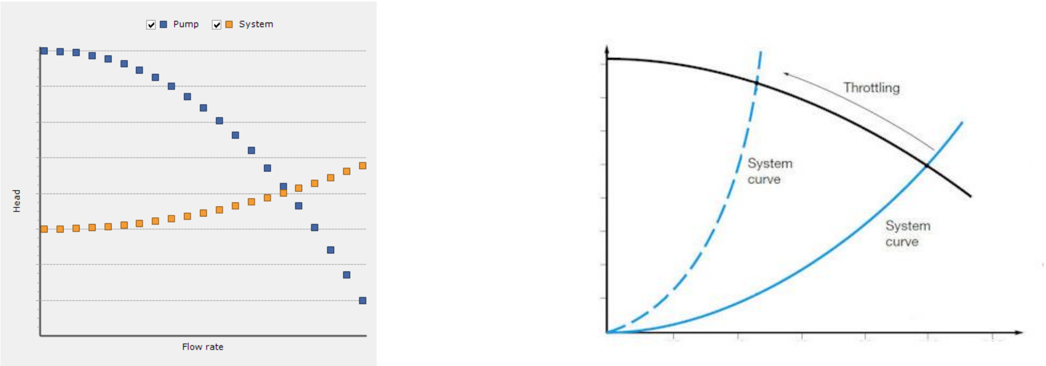
Instances

All

Description

This is a model of a pump whose performance follows a given pump curve i.e., a relationship between the flow rate delivered and the pumping head.

A way to control the flow rate generated by a centrifugal pump is to install a valve on the outlet: by adjusting the position of the valve, one changes the system head. In other words: the change in head resulting from a change in flow rate follows the pump curve.
This control mechanism is termed “throttling” and is shown in the figure below.



Characteristic pump- vs. system curves (left) and throttling control mechanism (right), for a generic centrifugal pump

The model constructs a pump curve as a continuous function based on three (Q, H) pairs following a power law:

$$H_{pump} = A - B \cdot Q^{C}$$

where A, B and C are constant coefficients.
If three (Q, H) pairs are not available, it is sufficient to supply a single design operating point (Q2,H2). The model constructs the two other points by assuming a shut-off head at zero flow equal to 133% of the design head and a maximum flow at zero head equal to twice the design flow (Rossman, 2000).

The total system head to be overcome by the pump is the sum of the static head of the pump flow, due to elevation and the dynamic head due to friction losses in the system, from piping, valves, etc.:

$$H = H_{static} + H_{var} = H_{static} + \left(H_{pipe} + H_{minor} + H_{inline}\right) + H_{ext}$$

$$H_{pipe} = f \cdot \frac{v^2}{2g} \cdot \frac{L}{d}$$

$$H_{minor} = H_{pipe} \cdot \frac{L_{eq}}{L}$$

where:

- H, H_{static} and H_{var} denote the total-, the static- and the variable head losses (m) respectively
- H_{pipe} indicates the friction head losses (m) due to flow through the pipe

- H_{minor} and H_{inline} indicate the head losses (m) due to elbows, inlet, outlet, etc.; and to in-line equipment such as control valves and flow sensors
- H_{ext} is the head loss (m) due to external factors
- f indicates the friction factor (-)
- v is the velocity (m/s) of the fluid in the pipe
- L, L_{eq} and d denote the length (m), the equivalent length (m) and the diameter (m) of the pipe

The friction factor f (-) is calculated with the Swamee-Jain equation, for turbulent regimes and for Newtonian fluids:

$$f = 0.25 \cdot \left(\log \left(\frac{\varepsilon}{3.7 \cdot d} + \frac{5.74}{Re^{0.9}} \right) \right)^{-2}$$

and as follows, for non-Newtonian fluids (superscript '*'):

- for laminar flow regime: $f^* = \frac{64}{Re^*}$
- for turbulent flow regime: $f^* = 0.3168 \cdot \frac{n^{0.675}}{Re^{*0.25}}$

where:

- ε is the absolute internal roughness of the pipe (-)

Note: it is assumed that the fluid can be considered non-Newtonian when the solid concentration (as TSS) exceeds 8,000 g/m3.

The Reynolds number, for Newtonian and non-Newtonian fluids respectively, can be calculated as follows:

$$Re = \frac{\rho_w \cdot v \cdot d}{\mu_w}$$

$$Re^* = \frac{\rho^* \cdot v \cdot d}{\mu^*}$$

where:

- ρ, v and μ denote the density (g/m3), the velocity (m/s) and the viscosity (Pa·d) of the fluid being pumped (subscript 'w' indicates water)

The density of the fluid is computed as:

$$\rho = TSS + \left(1 - \frac{TSS}{\rho_{TSS}}\right) \cdot \rho_w$$

where:

- ρ, ρ_{TSS} and ρ_w denote the density (g/m3) of the fluid being pumped, of the solids and of water respectively
- TSS is the concentration of suspended solids (g/m3) in the fluid

The viscosity of a non-Newtonian fluid is computed as:

$$\mu^* = k \cdot \left(0.75 + \frac{0.25}{n}\right)^n \cdot \left(\frac{8 \cdot v}{d}\right)^{n-1}$$

with:

$$k = 0.001 \cdot \exp\,(2 \cdot TSS^{0.41})$$

$$n = 1 - 0.23 \cdot TSS^{0.37}$$

(TSS in kg/m3)

The overall efficiency of a throttling-controlled centrifugal pump is calculated as:

$$\eta_{TOT} = \eta_p \cdot \eta_{motor}$$

where:

- η_p and η_{motor} denote the efficiency (-) of the pump and of the motor

A parabolic function is proposed to describe the change in efficiency for a generic pump operating at its normal speed:

$$\eta_p = -\left(\eta_{p,max} - \eta_{p,min}\right) \cdot \frac{Q^2}{Q_{BEP}^2} + \left(\eta_{p,max} - \eta_{p,min}\right) \cdot \frac{Q}{Q_{BEP}} + \eta_{p,min}$$

where:

- Q and Q_{BEP} indicate the actual- and Best Efficiency Point flow rate (m3/d)
- $\eta_{p,max}$ and $\eta_{p,min}$ denote the maximum and minimum pump efficiency (-)

The power consumption (kWh/d) and the cumulated energy consumption (kWh) are calculated as follows:

$$P_{pump} = \frac{\rho \cdot g \cdot H}{(3.6 \cdot 10^9) \cdot \eta_{tot}} \cdot Q_{out}$$

$$E_{pump} = \frac{1}{24} \cdot \int P_{pump}$$

where:

- g is the gravity acceleration (m/s2)
- Q_{out} is the flow rate delivered by the pump (m3/d)
- η_{tot} is the overall efficiency of the pump

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Pump_Max	Maximum efficiency of the pump (at Q_BEP)	0.9	---

Name	Description	Value	Units
Eta_Pump_Min	Minimum efficiency of the pump	0	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
Pipe_D	Diameter of pipes that conduct the pumped fluid	0.5	m
Pipe_L	Length of pipes that conduct the pumped fluid	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
Pipe_e	Absolute internal roughness of the pipes	0.00015	m
dH_InLine	Head losses due to control valves, flow sensors, …	0	m
visc_H20	Dynamic viscosity of water	1.5972E-08	Pa*d
H_1	Shutoff head (if unknown: -1)	-1	m
H_2	Design head	10	m
H_3	Point (head) on the pump curve (if unknown: -1)	-1	m
Q_2	Design flow rate	10	m3/d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m3/d

State Variables

Name	Description	Units
Eta_Total	Total efficiency	---
FluidVelocity	Velocity of the pumped fluid	m/d
FluidViscosity	Dynamic viscosity of the pumped fluid	Pa*d
Friction	Darcy-Weisbach friction factor f (depends on the Reynolds nr)	---
Friction_MinorLosses	Head losses due to elbows, inlet, outlet, ..	m
Friction_Pipe	Friction head losses due to flow through pipes	m
ReynoldsNr	Reynolds number of the pipes	---
H	Operating head at Q_Out	m
H_Pump	Operating head at Q_Out according to pump curve	m
H_System	Total head losses of the system	m
Q_Max	Maximum flow rate in the specified system	m3/d
Q_Min	Minimum flow rate in the specified system	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_e	*in_2*	*Elevation head to be overcome*	*10*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*10*	*m*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d

CF_Q_VFD

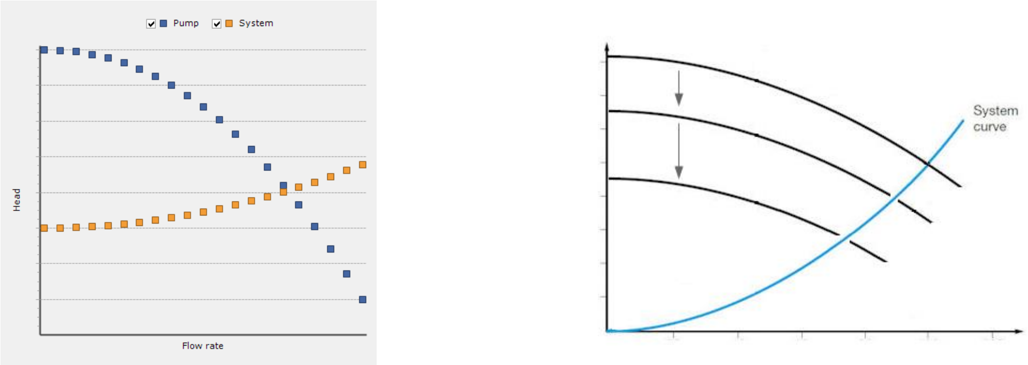
Instances

All

Description

This is a model of a pump whose performance follows a given pump curve, i.e. a relationship between the flow rate delivered and the pumping head.

A way to control the flow rate generated by a centrifugal pump is to vary the pump speed, i.e. the impeller speed, by means of an inverter. With this control strategy, the system curve is left unchanged while the operating point shifts towards the desired Q (on the pump curve). In other words: the change in head resulting from a change in flow rate follows the system curve.
This control mechanism is termed “Variable Frequency Drive” (VFD) and is shown in the figure below.



Characteristic pump- vs. system curves (left) and VFD control mechanism (right), for a generic centrifugal pump

The model constructs a pump curve as a continuous function based on three (Q, H) pairs following a power law (N=1):

$$H_{pump} = A - B \cdot Q^{C}$$

where A, B and C are constant coefficients.

By using the affinity law:

$$\frac{N_1}{N_2} = \sqrt{\frac{H_1}{H_2}}$$

a generic pump curve function can be obtained for any value of N:

$$H_{pump} = A \cdot N^{2} - B \cdot Q^{C} \cdot N^{2-C}$$

If three (Q, H) pairs are not available, it is sufficient to supply a single design operating point (Q2,H2). The model constructs the two other points by assuming a shut-off head at zero flow equal to 133% of the design head and a maximum flow at zero head equal to twice the design flow (Rossman, 2000).

The total system head to be overcome by the pump is the sum of the static head of the pump flow, due to elevation and the dynamic head due to friction losses in the system, from piping, valves, etc.:

$$H = H_{static} + H_{var} = H_{static} + \left(H_{pipe} + H_{minor} + H_{inline}\right) + H_{ext}$$

$$H_{pipe} = f \cdot \frac{v^2}{2g} \cdot \frac{L}{d}$$

$$H_{minor} = H_{pipe} \cdot \frac{L_{eq}}{L}$$

where:

- H, H_{static} and H_{var} denote the total-, the static- and the variable head losses (m) respectively
- H_{pipe} indicates the friction head losses (m) due to flow through the pipe
- H_{minor} and H_{inline} indicate the head losses (m) due to elbows, inlet, outlet, etc.; and to in-line equipment such as control valves and flow sensors
- H_{ext} is the head loss (m) due to external factors
- f indicates the friction factor (-)
- v is the velocity (m/s) of the fluid in the pipe
- L, L_{eq} and d denote the length (m), the equivalent length (m) and the diameter (m) of the pipe

The friction factor f (-) is calculated with the Swamee-Jain equation, for turbulent regimes and for Newtonian fluids:

$$f = 0.25 \cdot \left(\log\left(\frac{\varepsilon}{3.7 \cdot d} + \frac{5.74}{Re^{0.9}}\right)\right)^{-2}$$

and as follows, for non-Newtonian fluids (superscript ‘*’):

- for laminar flow regime: $f^* = \frac{64}{Re^*}$
- for turbulent flow regime: $f^* = 0.3168 \cdot \frac{n^{0.675}}{Re^{*0.25}}$

where:

- ε is the absolute internal roughness of the pipe (-)

Note: it is assumed that the fluid can be considered non-Newtonian when the solid concentration (as TSS) exceeds 8,000 g/m3.

The Reynolds number, for Newtonian and non-Newtonian fluids respectively, can be calculated as follows:

$$Re = \frac{\rho_w \cdot v \cdot d}{\mu_w}$$

$$Re^* = \frac{\rho^* \cdot v \cdot d}{\mu^*}$$

where:

- ρ, v and μ denote the density (g/m3), the velocity (m/s) and the viscosity (Pa·d) of the fluid being pumped (subscript ‘w’ indicates water)

The density of the fluid is computed as:

$$\rho = TSS + \left(1 - \frac{TSS}{\rho_{TSS}}\right) \cdot \rho_w$$

where:

- ρ, ρ_{TSS} and ρ_w denote the density (g/m3) of the fluid being pumped, of the solids and of water respectively
- TSS is the concentration of suspended solids (g/m3) in the fluid

The viscosity of a non-Newtonian fluid is computed as:

$$\mu^* = k \cdot \left(0.75 + \frac{0.25}{n}\right)^n \cdot \left(\frac{8 \cdot v}{d}\right)^{n-1}$$

with:

$$k = 0.001 \cdot \exp\left(2 \cdot TSS^{0.41}\right)$$

$$n = 1 - 0.23 \cdot TSS^{0.37}$$

(TSS in kg/m3)

The overall efficiency of a VFD-controlled centrifugal pump is calculated as:

$$\eta_{TOT} = \eta_p \cdot \eta_{motor} \cdot \eta_{VFD}$$

where:

- η_p, η_{motor} and η_{VFD} denote the efficiency (-) of the pump, of the motor and of the variable frequency drives

A parabolic function is proposed to describe the change in efficiency for a generic pump operating at its normal speed:

$$\eta_p = -\left(\eta_{p,max} - \eta_{p,min}\right) \cdot \frac{(Q/N)^2}{Q_{BEP}^2} + \left(\eta_{p,max} - \eta_{p,min}\right) \cdot \frac{(Q/N)}{Q_{BEP}} + \eta_{p,min}$$

where:

- Q and Q_{BEP} indicate the actual- and Best Efficiency Point flow rate (m3/d);
- $\eta_{p,max}$ and $\eta_{p,min}$ denote the maximum and minimum pump efficiency (-)

Following Walski *et al.* (2003), an empirical fourth order function is proposed, scalable with parameter pairs for minimum and maximum N and variable frequency drives efficiency:

$$\eta_{VFD} = \left(\eta_{VFD,max} - \eta_{VFD,min}\right) \cdot \frac{N^4 - N_{min}^4}{N_{max}^4 - N_{min}^4} + \eta_{VFD,min}$$

where:

- N_{min} and N_{max} are set to 0.5 and 1.0 respectively

The power consumption (kWh/d) and the cumulated energy consumption (kWh) are calculated as follows:

$$P_{pump} = \frac{\rho \cdot g \cdot H}{(3.6 \cdot 10^9) \cdot \eta_{tot}} \cdot Q_{out}$$

$$E_{pump} = \frac{1}{24} \cdot \int P_{pump}$$

where:

- g is the gravity acceleration (m/s2)
- Q_{out} is the flow rate delivered by the pump (m3/d)
- η_{tot} is the overall efficiency of the pump

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Pump_Max	Maximum efficiency of the pump (at Q_BEP)	0.9	---
Eta_Pump_Min	Minimum efficiency of the pump	0	---
Eta_VFD_Half	Efficiency of the VFD at half speed (N=0.5)	0.89	---
Eta_VFD_Max	Efficiency of the VFD at full speed (N=1)	0.95	---
N_max	Max relative pump speed for VFD controlled pumps	1	---
N_min	Min relative pump speed for VFD controlled pumps	0.6	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
Pipe_D	Diameter of pipes that conduct the pumped fluid	0.5	m
Pipe_L	Length of pipes that conduct the pumped fluid	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
Pipe_e	Absolute internal roughness of the pipes	0.00015	m
dH_InLine	Head losses due to control valves, flow sensors, …	0	m
visc_H20	Dynamic viscosity of water	1.5972E-08	Pa*d
H_1	Shutoff head (if unknown: -1)	-1	m
H_2	Design head	10	m
H_3	Point (head) on the pump curve (if unknown: -1)	-1	m
Q_2	Design flow rate	10	m3/d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m3/d

State Variables

Name	Description	Units
Eta_Total	Total efficiency	---
Eta_VFD	Efficiency of the VFD	---
FluidVelocity	Velocity of the pumped fluid	m/d

FluidViscosity	Dynamic viscosity of the pumped fluid	Pa*d
Friction	Darcy-Weisbach friction factor f (depends on the Reynolds nr)	---
Friction_MinorLosses	Head losses due to elbows, inlet, outlet, ..	m
Friction_Pipe	Friction head losses due to flow through pipes	m
ReynoldsNr	Reynolds number of the pipes	---
H	Operating head at Q_Out	m
H_MaxVFD_Duty	Operating head at Q_MaxVFD_Duty for given pump and system	m
H_MinVFD_Duty	Operating head at to Q_MinVFD_Duty for given pump and system	m
H_Pump	Operating head at Q_Out according to pump curve	m
H_System	Total head losses of the system	m
Q_MaxVFD_Duty	Maximum flow rate for VFD pumps operating at N=Nmax	m3/d
Q_MinVFD_Duty	Minimum flow rate for VFD pumps operating at N=Nmin	m3/d
Q_Max	Maximum flow rate in the specified system	m3/d
Q_Min	Minimum flow rate in the specified system	m3/d

Derived State Variables

None

Interface Variables

Name	**Terminal**	**Description**	**Value**	**Units**
H_e	*in_2*	*Elevation head to be overcome*	*10*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*10*	*m*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
N	out_2	Actual / nominal relative pump speed	---	---
Q_Out	out_2	Actual flow rate	---	m3/d

CF_HQ_VFD

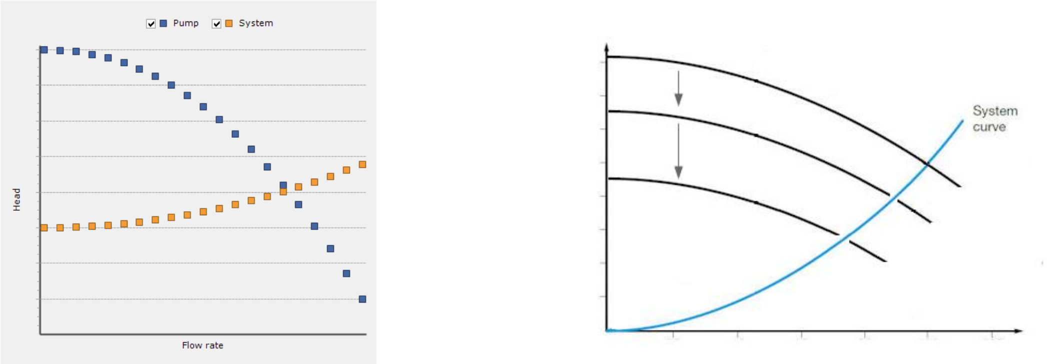
Instances

All

Description

The model calculates the power consumption of a centrifugal (CF) pump controlled with Variable Frequency Drive (VFD). The calculation is based on the air flow rate, Q, and the head, H.

A way to control the flow rate generated by a centrifugal pump is to vary the pump speed, i.e. the impeller speed, by means of an inverter. With this control strategy, the system curve is left unchanged while the operating point shifts towards the desired Q (on the pump curve). In other words: the change in head resulting from a change in flow rate follows the system curve.
This control mechanism is termed "Variable Frequency Drive" (VFD) and is shown in the figure below.



Characteristic pump- vs. system curves (left) and VFD control mechanism (right), for a generic centrifugal pump

The model constructs a pump curve as a continuous function based on three (Q, H) pairs following a power law (N=1):

$$H_{pump} = A - B \cdot Q^{C}$$

where A, B and C are constant coefficients.

The power consumption (kWh/d) and the cumulated energy consumption (kWh) are calculated as follows:

$$P_{pump} = \frac{\rho \cdot g \cdot H}{(3.6 \cdot 10^{9}) \cdot \eta_{tot}} \cdot Q_{out}$$

$$E_{pump} = \frac{1}{24} \cdot \int P_{pump}$$

where:

- g is the gravity acceleration (m/s2)
- Q_{out} is the flow rate delivered by the pump (m3/d)
- η_{tot} is the overall efficiency of the pump

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Pump_Max	Maximum efficiency of the pump (at Q_BEP)	0.9	---
Eta_Pump_Min	Minimum efficiency of the pump	0	---
Eta_VFD_Half	Efficiency of the VFD at half speed (N=0.5)	0.89	---
Eta_VFD_Max	Efficiency of the VFD at full speed (N=1)	0.95	---
N_max	Max relative pump speed for VFD controlled pumps	1	---
N_min	Min relative pump speed for VFD controlled pumps	0.6	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
H_1	Shutoff head (if unknown: -1)	-1	m
H_2	Design head	10	m
H_3	Point (head) on the pump curve (if unknown: -1)	-1	m
Q_2	Design flow rate	10	m3/d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m3/d

State Variables

Name	Description	Units
Nvector	Dummy vector containing n Relative Pump Speed (N) values	---
Eta_Total	Total efficiency	---
Eta_VFD	Efficiency of the VFD	---
H	Operating head at Q_Out	m
H_System	Total head losses of the system	m
Q_Min	Minimum flow rate in the specified system	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_Op	*in_2*	*Operating head*	*1*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
N	out_2	Actual / nominal relative pump speed	---	---
Q_Out	out_2	Actual flow rate	---	m3/d

CF_HN_VFD

Instances

All

Description

The model calculates the power consumption of a centrifugal (CF) pump controlled with Variable Frequency Drive (VFD). The calculation is based on the relative pump speed, N, and the head, H.

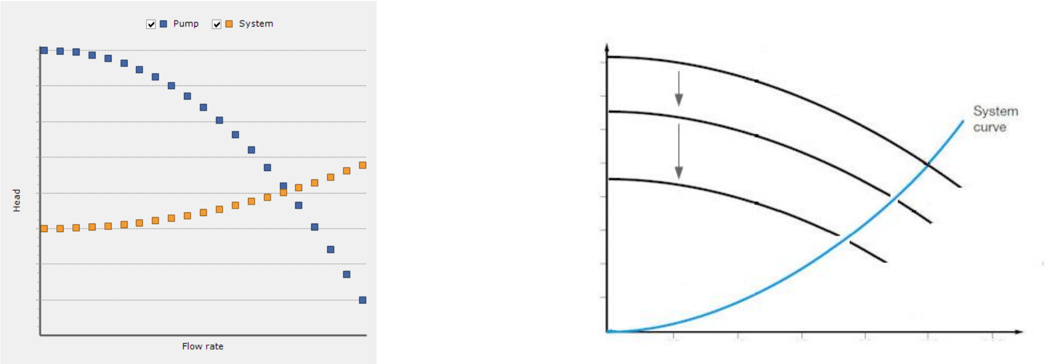
The pump curve can be written in terms of H, N and Q:

$$H_1 = N^2 A - B N^{2-C} Q_1^C$$

where A, B and C are constant coefficients.
With the equation Q can be found.

In this way the relative pump speed can be the control signal instead of the flow rate.

A way to control the flow rate generated by a centrifugal pump is to vary the pump speed, i.e. the impeller speed, by means of an inverter. With this control strategy, the system curve is left unchanged while the operating point shifts towards the desired Q (on the pump curve). In other words: the change in head resulting from a change in flow rate follows the system curve.
This control mechanism is termed "Variable Frequency Drive" (VFD) and is shown in the figure below.



Characteristic pump- vs. system curves (left) and VFD control mechanism (right), for a generic centrifugal pump

The power consumption (kWh/d) and the cumulated energy consumption (kWh) are calculated as follows:

$$P_{pump} = \frac{\rho \cdot g \cdot H}{(3.6 \cdot 10^9) \cdot \eta_{tot}} \cdot Q_{out}$$

$$E_{pump} = \frac{1}{24} \cdot \int P_{pump}$$

where:

- g is the gravity acceleration (m/s2)
- Q_{out} is the flow rate delivered by the pump (m3/d)
- η_{tot} is the overall efficiency of the pump

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Pump_Max	Maximum efficiency of the pump (at Q_BEP)	0.9	---
Eta_Pump_Min	Minimum efficiency of the pump	0	---
Eta_VFD_Half	Efficiency of the VFD at half speed (N=0.5)	0.89	---
Eta_VFD_Max	Efficiency of the VFD at full speed (N=1)	0.95	---
N_max	Max relative pump speed for VFD controlled pumps	1	---
N_min	Min relative pump speed for VFD controlled pumps	0.6	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
H_1	Shutoff head (if unknown: -1)	-1	m
H_2	Design head	10	m
H_3	Point (head) on the pump curve (if unknown: -1)	-1	m
Q_2	Design flow rate	10	m3/d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m3/d

State Variables

Name	Description	Units
Eta_Total	Total efficiency	---
Eta_VFD	Efficiency of the VFD	---
H	Operating head at Q_Out	m
H_System	Total head losses of the system	m

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_Op	*in_2*	*Operating head*	*1*	*m*
N_Op	*in_2*	*Desired pump speed as a fraction of max*	*0.6*	---
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
N	out_2	Actual / nominal relative pump speed	---	---
Q_Out	out_2	Actual flow rate	---	m3/d

CF_N_VFD

Instances

All

Description

The model calculates the power consumption of a centrifugal (CF) pump controlled with Variable Frequency Drive (VFD). The calculation is based on the relative pump speed, N.

For each value of N, the pump curve can be written in terms of H and Q by:

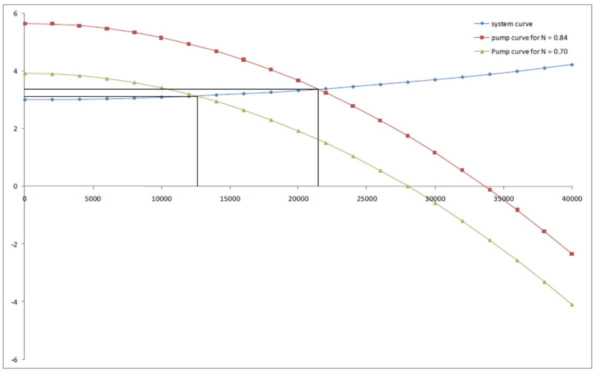
$$H_1 = N^2 A - BN^{2-C} Q_1^C$$

where A, B and C are constant coefficients.

The operating point can be found as the intersection of this pump curve with the system curve expressed by:

$$H_S = K_S Q^2 + K_{TS}$$

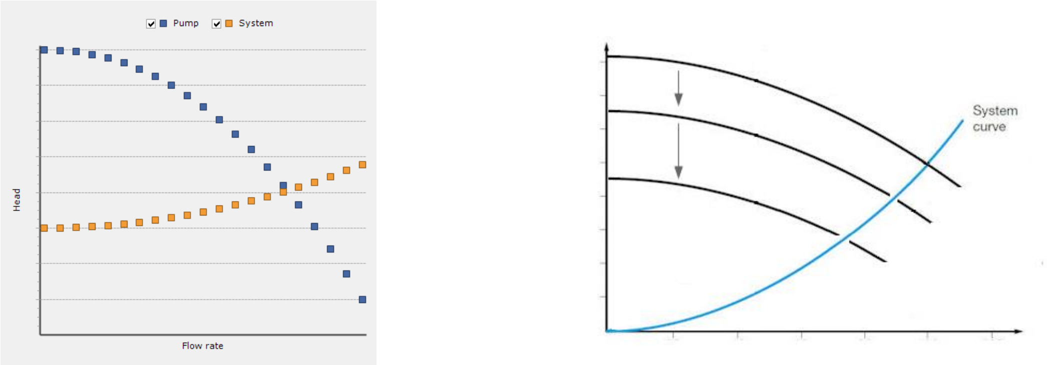
This gives two equations and two unknows, H and Q, but it cannot be solved analytically. Therefor Hsystem and Hpump are calculated for a number of Q-values and linear interpolation between the nearest two points is used to approximate the intersection of the curves.



Discretized system curve and pump curve for two different values of the relative pump speed, N.

In this way the relative pump speed can be the control signal instead of the flow rate.

A way to control the flow rate generated by a centrifugal pump is to vary the pump speed, i.e. the impeller speed, by means of an inverter. With this control strategy, the system curve is left unchanged while the operating point shifts towards the desired Q (on the pump curve). In other words: the change in head resulting from a change in flow rate follows the system curve.
This control mechanism is termed “Variable Frequency Drive” (VFD) and is shown in the figure below.



Characteristic pump- vs. system curves (left) and VFD control mechanism (right), for a generic centrifugal pump

The power consumption (kWh/d) and the cumulated energy consumption (kWh) are calculated as follows:

$$P_{pump} = \frac{\rho \cdot g \cdot H}{(3.6 \cdot 10^9) \cdot \eta_{tot}} \cdot Q_{out}$$

$$E_{pump} = \frac{1}{24} \cdot \int P_{pump}$$

where:

- g is the gravity acceleration (m/s2)
- Q_{out} is the flow rate delivered by the pump (m3/d)
- η_{tot} is the overall efficiency of the pump

Parameters

Name	**Description**	**Value**	**Units**
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Pump_Max	Maximum efficiency of the pump (at Q_BEP)	0.9	---
Eta_Pump_Min	Minimum efficiency of the pump	0	---
Eta_VFD_Half	Efficiency of the VFD at half speed (N=0.5)	0.89	---
Eta_VFD_Max	Efficiency of the VFD at full speed (N=1)	0.95	---
N_max	Max relative pump speed for VFD controlled pumps	1	---
N_min	Min relative pump speed for VFD controlled pumps	0.6	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
Pipe_D	Diameter of pipes that conduct the pumped fluid	0.5	m
Pipe_L	Length of pipes that conduct the pumped fluid	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
Pipe_e	Absolute internal roughness of the pipes	0.00015	m
dH_InLine	Head losses due to control valves, flow sensors, …	0	m
visc_H20	Dynamic viscosity of water	1.5972E-08	Pa*d
H_1	Shutoff head (if unknown: -1)	-1	m
H_2	Design head	10	m
H_3	Point (head) on the pump curve (if unknown: -1)	-1	m
Q_2	Design flow rate	10	m3/d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m3/d

State Variables

Name	Description	Units
Eta_Total	Total efficiency	---
Eta_VFD	Efficiency of the VFD	---
H	Operating head at Q_Out	m
H_System	Total head losses of the system	m

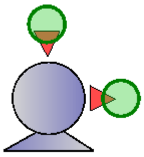
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_e	*in_2*	*Elevation head to be overcome*	*10*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
N_Op	*in_2*	*Desired pump speed as a fraction of max*	*0.6*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*10*	*m*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
N	out_2	Actual / nominal relative pump speed	---	---
Q_Out	out_2	Actual flow rate	---	m3/d

BLOWERS

	Palette Group	**Blowers and Pumps**
	Category	Blowers
	Icon Name	blower

CF_Q_VFD

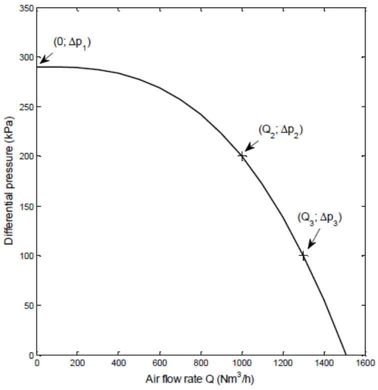
Instances

All

Description

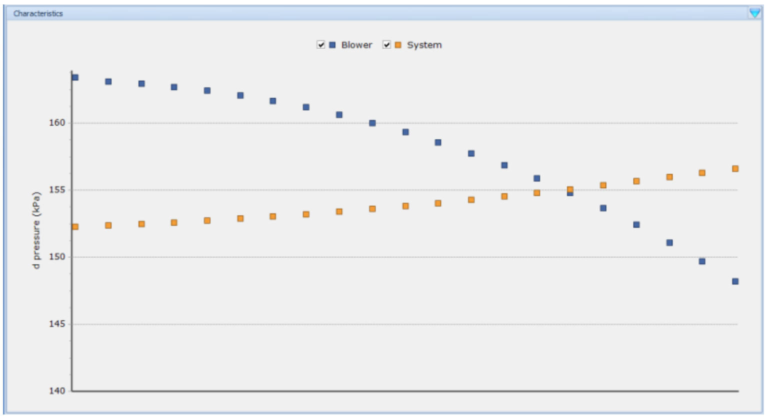
The model calculates the power consumption of a centrifugal (CF) blower controlled with Variable Frequency Drive (VFD). The calculation is based on the air flow rate, Q.

The differential pressure vs. flow rate for a centrifugal blower follows a power-law based on combinations between flow and pressure, (Q_1,dp1) (Q_2,dp2) (Q_3,dp3):



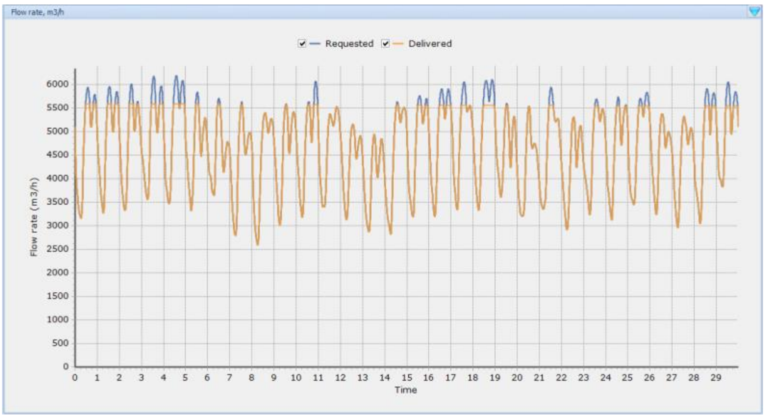
Blower curve following a power law based on three flow-pressure combinations, (Q,dp)

For centrifugal blowers the operating point is found as the intersection between the curves of the differential pressure of the blower and the differential pressure of the system.



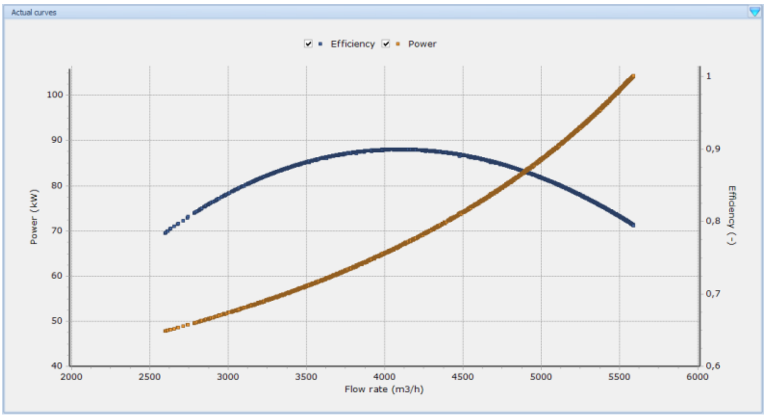
Differential pressure of the blower and the system.

The desired flow rate, Q_Op, is the key input in the model. The model can not necessarily deliver the requested flow.



Requested and delivered flow rate vs. time.

The efficiency of a centrifugal blower in function of the flow rate follows a parabolic trend.



Efficiency and power vs. flow rate.

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Blower_Max	Maximum efficiency of the blower (at Q_BEP)	0.9	---
Eta_Blower_Min	Minimum efficiency of the blower	0	---
Eta_VFD_Half	Efficiency of the VFD at half speed (N=0.5)	0.89	---
Eta_VFD_Max	Efficiency of the VFD at full speed (N=1)	0.95	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
Pipe_D	Diameter of pipes that conduct the air	0.25	m
Pipe_L	Length of pipes that conduct the air	30	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
A_Diff	Total surface area of diffuser's membrane	70	m2
H_Cutoff	Diffuser's membrane's min pressure loss at zero flow	150	mm
f_P_Loss	Linear pressure loss factor (head loss due to scale build-up on the membrane)	0.5	mm/ (m3/h/m2)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m3/d
N_Valves	Number of valves characterised by Kv	0	---
dt_clean	Interval between two cleanings of the membrane	250	d
f_Foul_Max	Max pressure increase due to fouling (1 = clean)	2	---
dp1	Shutoff differential pressure, full speed and zero flow (if unknow: -1.0)	-1	Pa
dp2	Design differential pressure corresponding to Q_2	100	Pa
dp3	Differential pressure on the blower curve at Q_3 (if unknown: -1.0)	-1	Pa

Name	Description	Value	Units
Q_1	Shutoff flow rate corresponding to dp1	0	m3/d
Q_2	Design flow rate corresponding to dp2	2000	m3/d
Q_3	Flow rate on the blower curve at dp3 (if unknown: -1.0)	-1	m3/d

State Variables

Name	Description	Units
Eta_Blower	Efficiency of the blower	---
Eta_VFD	Efficiency of the VFD	---
P_Duty	Operating pressure at max flow rate Q_NoCtl	Pa
P_System_Duty	Actual operating pressure at Q_In (via system curve)	Pa
Q_Duty	Maximum flow rate	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
dp_DWP	Friction losses due to the diffuser	Pa
dp_line	Friction losses in the air line	Pa
f_Foul	Relative pressure increase due to fouling (1 = clean)	---
t_clean_last	Time of last cleaning of diffuser's membrane	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_h2o	*in_2*	*Water height above diffusers*	*5*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
Temp	*in_2*	*Ambient air temperature*	*15*	*°C*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
N	out_2	Relative blower speed: actual/nominal speed	---	---
P_Out	out_2	Absolute output pressure	---	Pa
dP_Out	out_2	Differential output pressure	---	Pa

CF_HQ_VFD

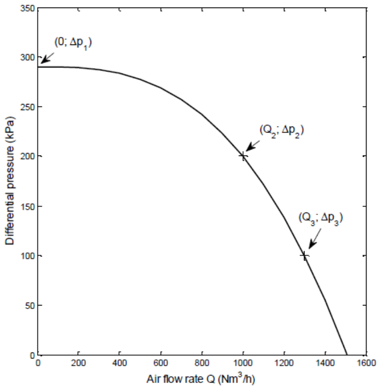
Instances

All

Description

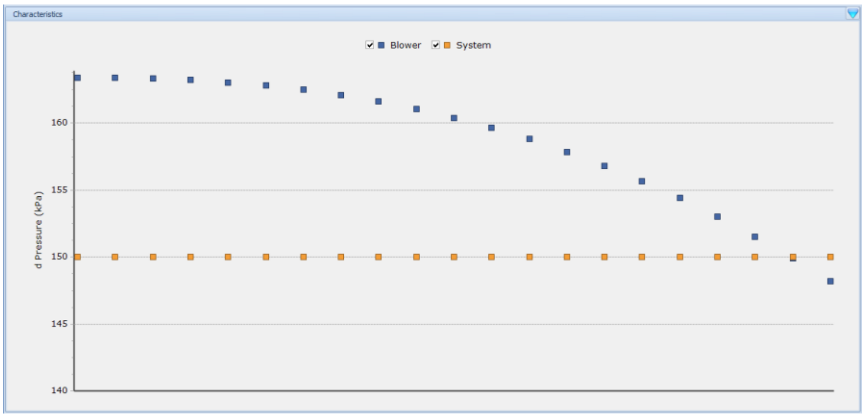
The model calculates the power consumption of a centrifugal (CF) blower controlled with Variable Frequency Drive (VFD). The calculation is based on air flow rate, Q, and pressure.

The differential pressure vs. flow rate for a centrifugal blower follows a power-law based on combinations between flow and pressure, (Q_1,dp1) (Q_2,dp2) (Q_3,dp3):



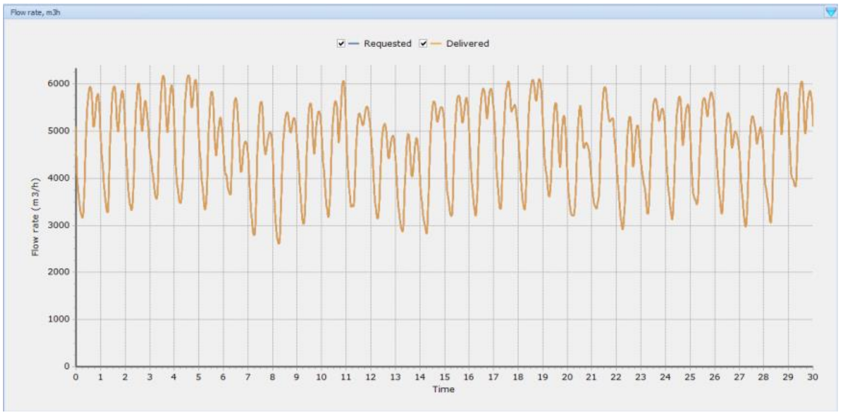
Blower curve following a power law based on three flow-pressure combinations, (Q,dp)

For centrifugal blowers the operating point is found as the intersection between the curves of the differential pressure of the blower and the differential pressure of the system.



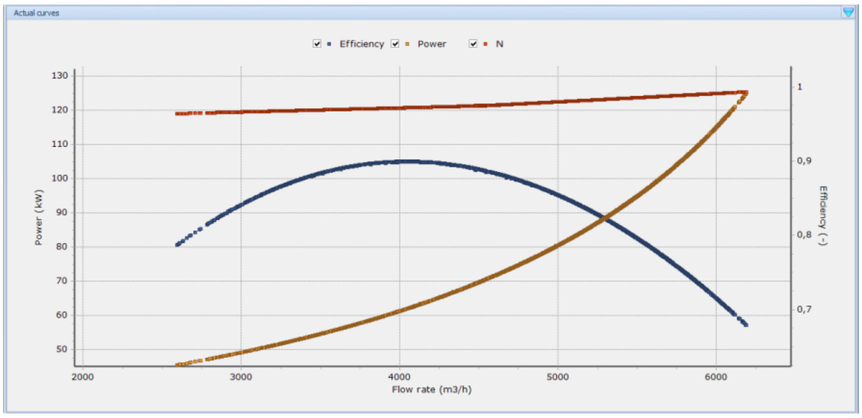
Differential pressure of the blower and the system.

Q_Op is the desired flow rate and is the key input in the model.



Requested and delivered flow rate vs. time.

The efficiency of a centrifugal blower in function of the flow rate follows a parabolic trend.



Efficiency and power vs. flow rate. N is the relative blower speed

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Blower_Max	Maximum efficiency of the blower (at Q_BEP)	0.9	---
Eta_Blower_Min	Minimum efficiency of the blower	0	---
Eta_VFD_Half	Efficiency of the VFD at half speed (N=0.5)	0.89	---
Eta_VFD_Max	Efficiency of the VFD at full speed (N=1)	0.95	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
N_Max	Maximum blower speed	1	---
N_Min	Minimum blower speed	0.5	---
H_sl	Altitude above sea level	0	m
dp1	Shutoff differential pressure, full speed and zero flow (if unknow: -1.0)	-1	Pa
dp2	Design differential pressure corresponding to Q_2	100	Pa
dp3	Differential pressure on the blower curve at Q_3 (if unknown: -1.0)	-1	Pa
Q_1	Shutoff flow rate corresponding to dp1	0	m3/d
Q_2	Design flow rate corresponding to dp2	2000	m3/d
Q_3	Flow rate on the blower curve at dp3 (if unknown: -1.0)	-1	m3/d

State Variables

Name	Description	Units
Eta_Blower	Efficiency of the blower	---
Eta_VFD	Efficiency of the VFD	---

Name	Description	Units
P_Duty	Operating pressure at max flow rate Q_NoCtl	Pa
Q_Duty	Maximum flow rate	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
Q_Min	Minimum operating flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
P_Op	*in_2*	*Absolute operating pressure (= Pin + diff press)*	*0*	*Pa*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
N	out_2	Relative blower speed: actual/nominal speed	---	---

CF_Q_IGV

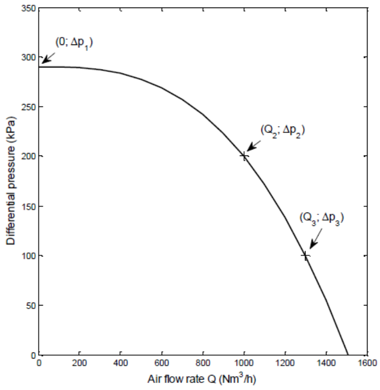
Instances

All

Description

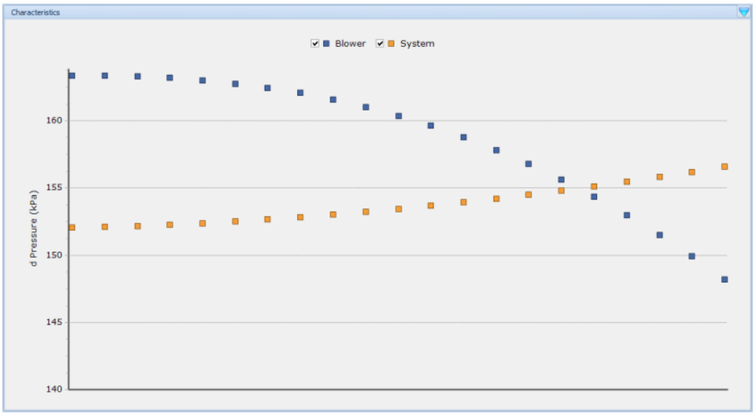
The model calculates the power consumption of a centrifugal (CF) blower controlled with variable Inlet Guide Vane (IGV). The calculation is based on the air flow rate, Q.

The differential pressure vs. flow rate for a centrifugal blower follows a power-law based on combinations between flow and pressure, (Q_1,dp1) (Q_2,dp2) (Q_3,dp3):



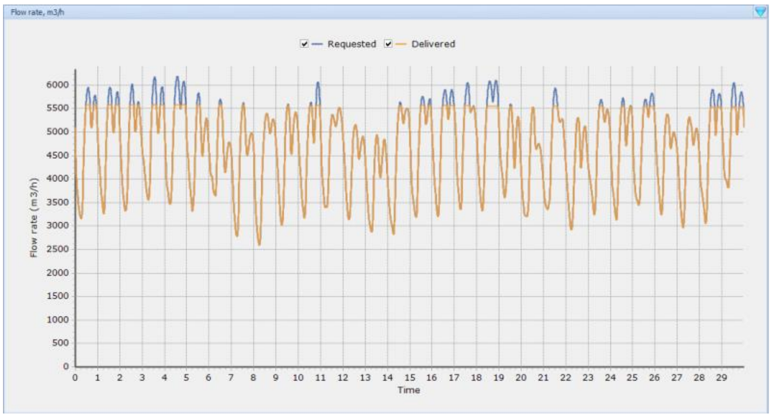
Blower curve following a power law based on three flow-pressure combinations, (Q,dp)

For centrifugal blowers the operating point is found as the intersection between the curves of the differential pressure of the blower and the differential pressure of the system.



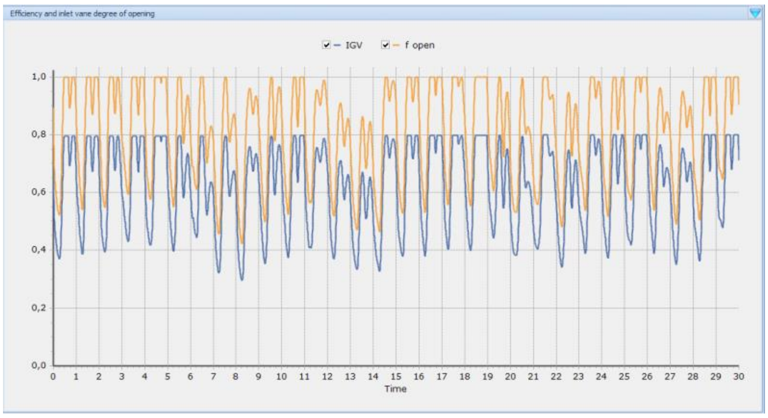
Differential pressure of the blower and the system.

The desired flow rate, Q_Op, is the key input in the model. The model can not necessarily deliver the requested flow.



Requested and delivered flow rate vs. time.

The efficiency of the IGV controlled blower depends on the inlet vane degree of opening.



Efficiency of the blower (IGV) vs. the degree of opening of the inlet vane (f open).

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
Eta_Blower_Max	Maximum efficiency of the blower (at Q_BEP)	0.9	---
Eta_Blower_Min	Minimum efficiency of the blower	0	---
Q_BEP	Flow rate at Best Efficiency Point	1,000	m3/d
H_sl	Altitude above sea level	0	m
Alpha	Scaling factor for the blower efficiency curve	1	---
Beta	Scaling factor for the blower efficiency curve	1	---
k	Scaling factor for the blower efficiency curve	1	---
A_Diff	Total surface area of diffuser's membrane	70	m2
H_Cutoff	Diffuser's membrane's min pressure loss at zero flow	150	mm
Pipe_D	Diameter of pipes that conduct the air	0.25	m
Pipe_L	Length of pipes that conduct the air	30	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
f_P_Loss	Linear pressure loss factor (head loss due to scale build-up on the membrane)	0.5	mm/ (m3/h/m2)
Kv	Valve flow factor to quantify friction loss	300,000	m3/d
N_Valves	Number of valves characterised by Kv	0	---
dt_clean	Interval between two cleanings of the diffuser's membrane	250	d
f_Foul_Max	Max pressure increase due to fouling (1 = clean)	2	---
dp1	Shutoff differential pressure, full speed and zero flow (if unknow: -1.0)	-1	Pa
dp2	Design differential pressure corresponding to Q_2	100	Pa

Name	Description	Value	Units
dp3	Differential pressure on the blower curve at Q_3 (if unknown: -1.0)	-1	Pa
Q_1	Shutoff flow rate corresponding to dp1	0	m3/d
Q_2	Design flow rate corresponding to dp2	2000	m3/d
Q_3	Flow rate on the blower curve at dp3 (if unknown: -1.0)	-1	m3/d

State Variables

Name	Description	Units
Eta_IGV	Efficiency of Inlet Guide Vane-controlled blower	---
P_Duty	Operating pressure at max flow rate Q_NoCtl	Pa
P_System_Duty	Actual operating pressure at Q_In (via system curve)	Pa
Q_Duty	Maximum flow rate	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
dp_DWP	Friction losses due to the diffuser	Pa
dp_line	Friction losses in the air line	Pa
f_Foul	Relative pressure increase due to fouling (1 = clean)	---
t_clean_last	Time of last cleaning of diffuser’s membrane	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_h2o	*in_2*	*Water height above diffusers*	*5*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
Temp	*in_2*	*Ambient air temperature*	*15*	*°C*
f_IGV	out_2	Opening of the inlet vanes: 0=closed, 1=open	---	---
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
P_Out	out_2	Absolute output pressure	---	Pa
dP_Out	out_2	Differential output pressure	---	Pa

PD_Q_VFD

Instances

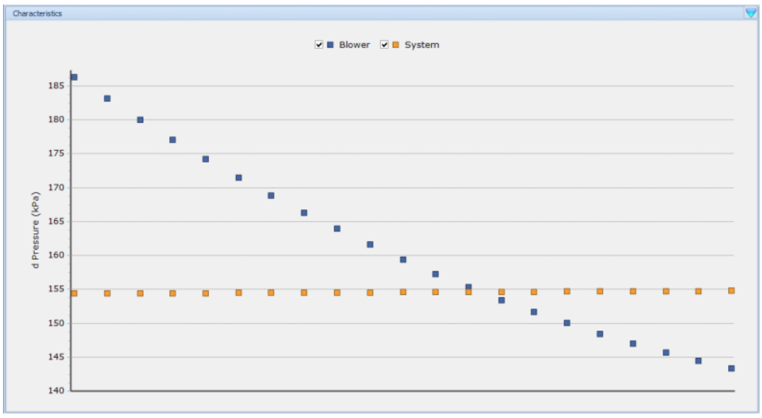
All

Description

The model calculates the power consumption of a positive displacement (PD) blower controlled with Variable Frequency Drive (VFD). The calculation is based on the air flow rate, Q.

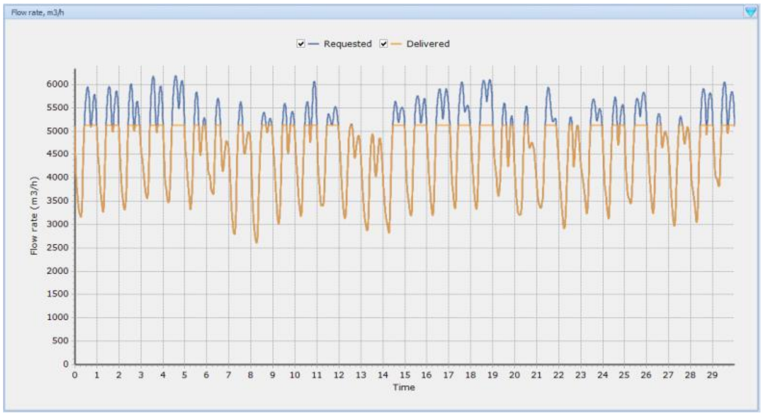
The efficiency of a PD blower takes the friction power loss at actual operating conditions into account.

The blower curve for a PD blower is constructed by using a quadratic function and three flow-pressure combination, (Q_1,dp1) (Q_2,dp2) (Q_3,dp3).



Differential pressure of the blower and the system.

The desired flow rate, Q_Op, is the key input in the model. The model can not necessarily deliver the requested flow.



Requested and delivered flow rate vs. time.

Parameters

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
dPower_Friction	Friction power losses (rel to max power consumption)	0.05	---
Pipe_D	Diameter of pipes that conduct the air	0.25	m
Pipe_L	Length of pipes that conduct the air	30	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m

Name	Description	Value	Units
A_Diff	Total surface area of diffuser’s membrane	70	m2
H_Cutoff	Diffuser’s membrane’s min pressure loss at zero flow	150	mm
f_P_Loss	Linear pressure loss factor (head loss due to scale build-up on the membrane)	0.5	mm/ (m3/h/m2)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m3/d
N_Valves	Number of valves characterised by Kv	0	---
dt_clean	Interval between two cleanings of the membrane	250	d
f_Foul_Max	Max pressure increase due to fouling (1 = clean)	2	---
dp1	Shutoff differential pressure, full speed and zero flow (if unknow: -1.0)	-1	Pa
dp2	Design differential pressure corresponding to Q_2	100	Pa
dp3	Differential pressure on the blower curve at Q_3 (if unknown: -1.0)	-1	Pa
Q_1	Minimum flow rate at full speed and maximum pressure	100,000	m3/d
Q_2	Design flow rate corresponding to dp2	2000	m3/d
Q_3	Flow rate on the blower curve at dp3 (>Q_2) (if unknown: -1.0)	-1	m3/d

State Variables

Name	Description	Units
Q_0	Flow rate at full speed and Pout=Pin (extrapolated value)	m3/d
P_Duty	Operating pressure at max flow rate Q_NoCtl	Pa
P_System_Duty	Actual operating pressure at Q_In (via system curve)	Pa
Q_Duty	Maximum flow rate	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
dp_DWP	Friction losses due to the diffuser	Pa
dp_line	Friction losses in the air line	Pa
f_Foul	Relative pressure increase due to fouling (1 = clean)	---
t_clean_last	Time of last cleaning of diffuser’s membrane	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
H_h2o	*in_2*	*Water height above diffusers*	*5*	*m*
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
Temp	*in_2*	*Ambient air temperature*	*15*	*°C*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
N	out_2	Relative blower speed: actual/nominal speed	---	---
P_Out	out_2	Absolute output pressure	---	Pa
dP_Out	out_2	Differential output pressure	---	Pa

PD_HQ_VFD

Instances

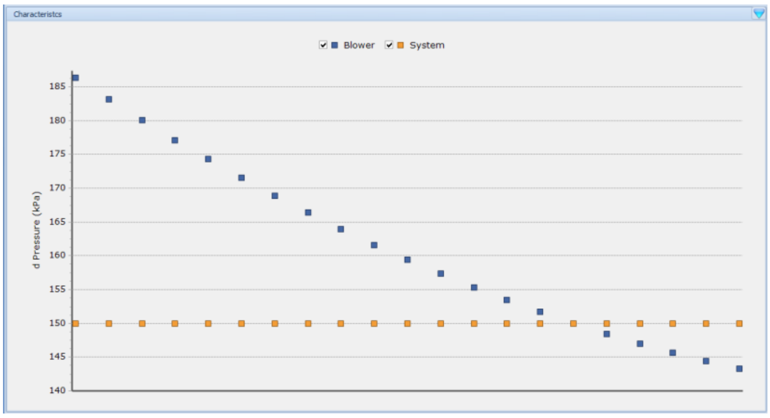
All

Description

The model calculates the power consumption of a positive displacement (PD) blower controlled with Variable Frequency Drive (VFD). The calculation is based on air flow rate and pressure.

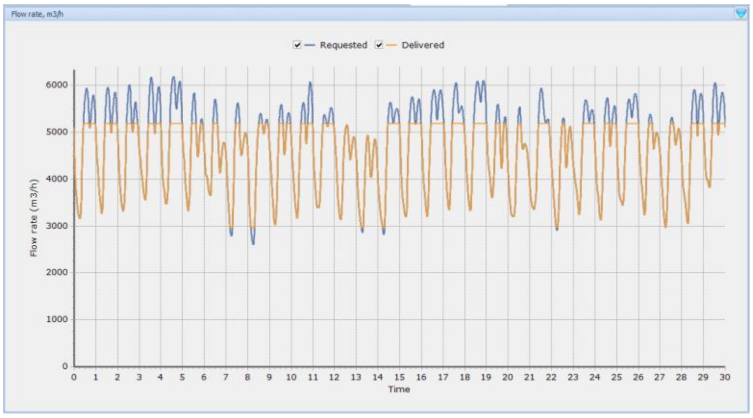
The efficiency of a PD blower takes the friction power loss at actual operating conditions into account.

The blower curve for a PD blower is constructed by using a quadratic function and three flow-pressure combination, (Q_1,dp1) (Q_2,dp2) (Q_3,dp3).



Differential pressure of the blower and the system.

The desired flow rate, Q_Op, is the key input in the model. The model can not necessarily deliver the requested flow.



Requested and delivered flow rate vs. time.

Parameters

Name	Description	Value	Units
N_Min	Minimum blower speed	0.6	---

Name	Description	Value	Units
Eta_Motor	Efficiency of the motor	0.9	---
dPower_Friction	Friction power losses (rel to max power consumption)	0.05	---

Name	Description	Value	Units
N_Min	Minimum blower speed	0.6	---
H_sl	Altitude above sea level	0	m
dp1	Shutoff differential pressure, full speed and zero flow (if unknow: -1.0)	-1	Pa
dp2	Design differential pressure corresponding to Q_2	100	Pa
dp3	Differential pressure on the blower curve at Q_3 (if unknown: -1.0)	-1	Pa
Q_1	Minimum flow rate at full speed and maximum pressure	0	m3/d
Q_2	Design flow rate corresponding to dp2	2000	m3/d
Q_3	Flow rate on the blower curve at dp3 (>Q_2) (if unknown: -1.0)	-1	m3/d

State Variables

Name	Description	Units
Q_0	Flow rate at full speed and Pout=Pin (extrapolated value)	m3/d
P_Duty	Operating pressure at max flow rate Q_NoCtl	Pa
Q_Duty	Maximum flow rate	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
Q_Min	Minimum operating flow rate	m3/d

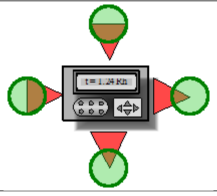
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
IsOn	*in_2*	*Control signal: 0=off, 1=on*	*1*	---
P_Op	*in_2*	*Absolute operating pressure (= Pin + diff press)*	*0*	*Pa*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
N	out_2	Relative blower speed: actual/nominal speed	---	---

PUMP CONTROLLERS

	Palette Group	**Blowers and Pumps**
	Category	Pumps
	Icon Name	controller_pump

Separate10_CFQThrottle

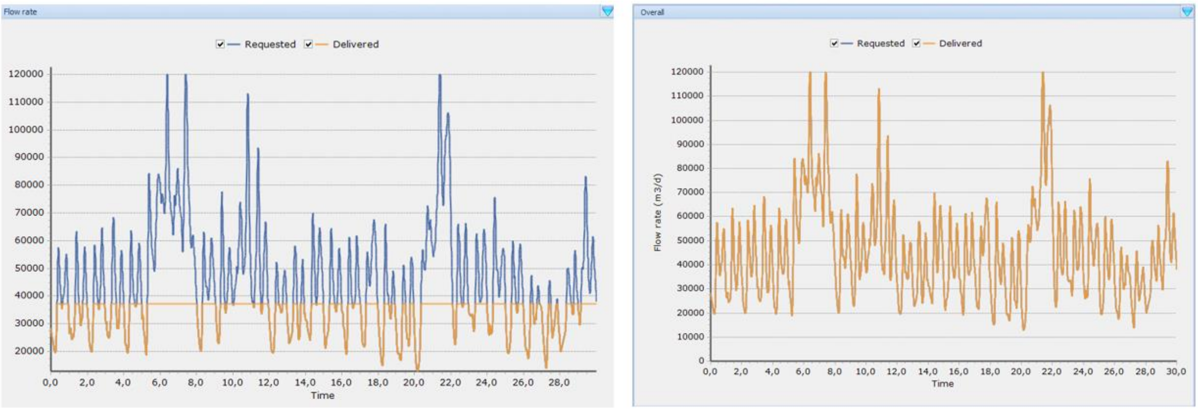
Instances

All

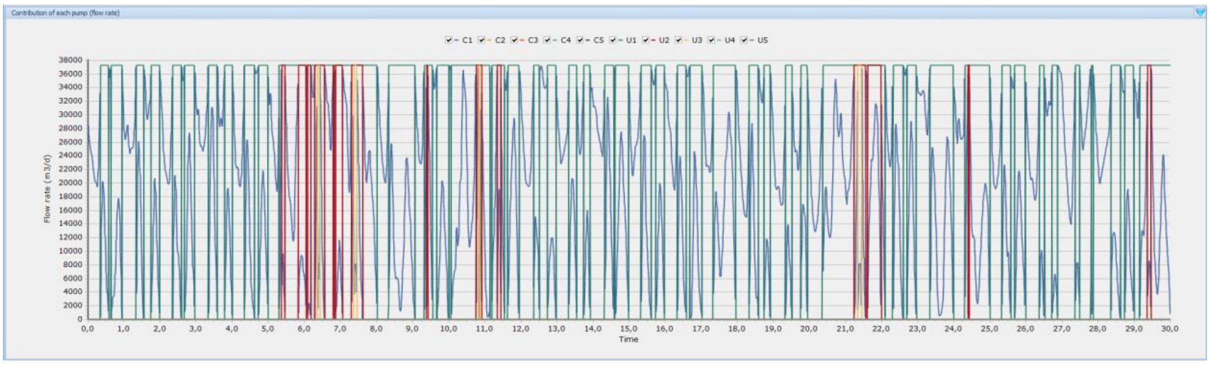
Description

The model describes a group of 10 centrifugal (CF) pumps, each pump on its own discharge pipe.
Five pumps are controlled by throttling and five have a fixed rate (uncontrolled).
The model is based on the flow rate.

The pump group controller is used when one pump is not enough to reach the requested flowrate. The controller will first activate the uncontrolled pumps and then the controlled pumps to regulate the flowrate to reach the requested flow.



Comparison between the case of a single pump (left) and that of multiple pumps (right): the single pump cannot deliver the total flow that is requested, while the combination of pumps can deliver it.



The flowrate for each pump of the group. Three uncontrolled pumps (U1, U2, U3) and one controlled pump (C1) are activated to reach the requested flow.

Parameters

Name	Description	Value	Units
Is_PC01	Controllable pump #1 present (1) or not (0)	1	---
Is_PC02	Controllable pump #2 present (1) or not (0)	1	---
Is_PC03	Controllable pump #3 present (1) or not (0)	1	---
Is_PC04	Controllable pump #4 present (1) or not (0)	1	---
Is_PC05	Controllable pump #5 present (1) or not (0)	1	---
Is_PU01	Unregulated pump #1 present (1) or not (0)	1	---
Is_PU02	Unregulated pump #2 present (1) or not (0)	1	---
Is_PU03	Unregulated pump #3 present (1) or not (0)	1	---
Is_PU04	Unregulated pump #4 present (1) or not (0)	1	---

Name	Description	Value	Units
Is_PU05	Unregulated pump #5 present (1) or not (0)	1	---

State Variables

Name	Description	Units
IsOnPC01	Controllable pump #1 is active (1) or not (0)	---
IsOnPC02	Controllable pump #2 is active (1) or not (0)	---
IsOnPC03	Controllable pump #3 is active (1) or not (0)	---
IsOnPC04	Controllable pump #4 is active (1) or not (0)	---
IsOnPC05	Controllable pump #5 is active (1) or not (0)	---
IsOnPU01	Unregulated pump #1 is active (1) or not (0)	---
IsOnPU02	Unregulated pump #2 is active (1) or not (0)	---
IsOnPU03	Unregulated pump #3 is active (1) or not (0)	---
IsOnPU04	Unregulated pump #4 is active (1) or not (0)	---
IsOnPU05	Unregulated pump #5 is active (1) or not (0)	---
PC01_Qmax	Maximum flow rate attainable by PC #1	m3/d
PC01_Qmin	Minimum flow rate attainable by PC #1	m3/d
PC02_Qmax	Maximum flow rate attainable by PC #2	m3/d
PC02_Qmin	Minimum flow rate attainable by PC #2	m3/d
PC03_Qmax	Maximum flow rate attainable by PC #3	m3/d
PC03_Qmin	Minimum flow rate attainable by PC #3	m3/d
PC04_Qmax	Maximum flow rate attainable by PC #4	m3/d
PC04_Qmin	Minimum flow rate attainable by PC #4	m3/d
PC05_Qmax	Maximum flow rate attainable by PC #5	m3/d
PC05_Qmin	Minimum flow rate attainable by PC #5	m3/d
PU01_Qmax	Maximum flow rate attainable by PU #1	m3/d
PU02_Qmax	Maximum flow rate attainable by PU #2	m3/d
PU03_Qmax	Maximum flow rate attainable by PU #3	m3/d
PU04_Qmax	Maximum flow rate attainable by PU #4	m3/d
PU05_Qmax	Maximum flow rate attainable by PU #5	m3/d

Derived State Variables

None

Sub-models

Name	Class Name
PC01	CF_Q_Throttle.Model
PC02	CF_Q_Throttle.Model
PC03	CF_Q_Throttle.Model
PC04	CF_Q_Throttle.Model
PC05	CF_Q_Throttle.Model
PU01	CF_Q_Throttle.Model
PU02	CF_Q_Throttle.Model
PU03	CF_Q_Throttle.Model
PU04	CF_Q_Throttle.Model
PU05	CF_Q_Throttle.Model

Interface Variables

Name	Terminal	Description	Value	Units
H_e	*in_2*	*Elevation head to be overcome*	*0*	*m*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*0*	*m*
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3

PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d

Separate10_CFQVFD

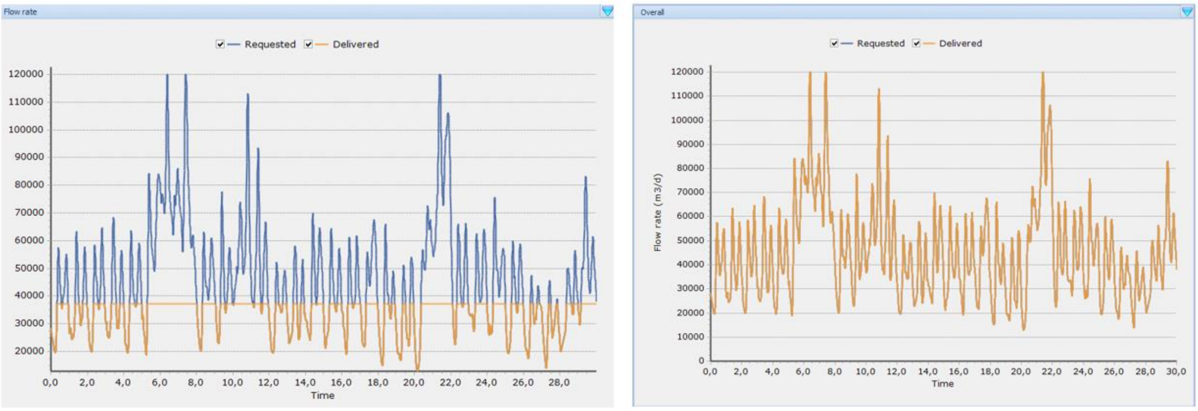
Instances

All

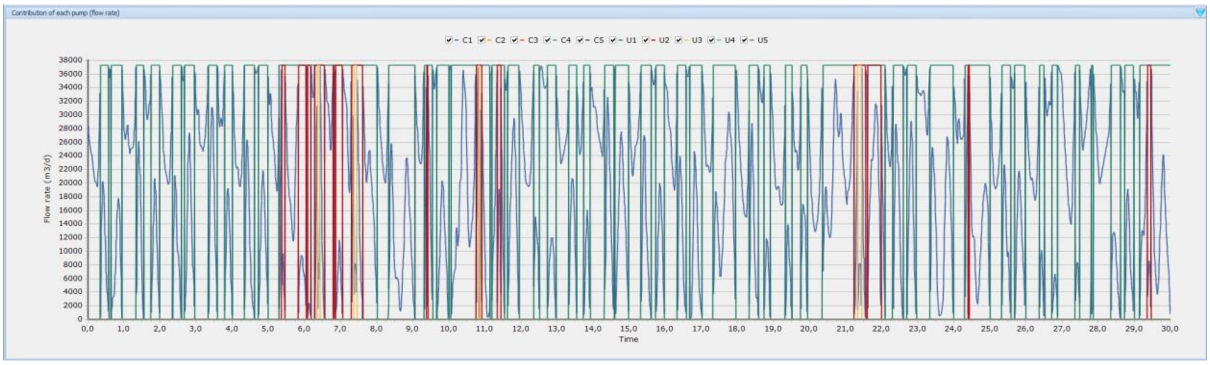
Description

The model describes a group of 10 centrifugal (CF) pumps, each pump on its own discharge pipe. Five pumps are controlled by Variable Frequency Drive (VFD) and five have a fixed rate (uncontrolled). The model is based on the flow rate.

The pump group controller is used when one pump is not enough to reach the requested flowrate. The controller will first activate the uncontrolled pumps and then the controlled pumps to regulate the flowrate to reach the requested flow.



Comparison between the case of a single pump (left) and that of multiple pumps (right): the single pump cannot deliver the total flow that is requested, while the combination of pumps can deliver it.



The flowrate for each pump of the group. Three uncontrolled pumps (U1, U2, U3) and one controlled pump (C1) are activated to reach the requested flow.

Parameters

Name	Description	Value	Units
Is_PC01	Controllable pump #1 present (1) or not (0)	1	---
Is_PC02	Controllable pump #2 present (1) or not (0)	1	---
Is_PC03	Controllable pump #3 present (1) or not (0)	1	---
Is_PC04	Controllable pump #4 present (1) or not (0)	1	---
Is_PC05	Controllable pump #5 present (1) or not (0)	1	---
Is_PU01	Unregulated pump #1 present (1) or not (0)	1	---
Is_PU02	Unregulated pump #2 present (1) or not (0)	1	---
Is_PU03	Unregulated pump #3 present (1) or not (0)	1	---
Is_PU04	Unregulated pump #4 present (1) or not (0)	1	---

Name	Description	Value	Units
Is_PU05	Unregulated pump #5 present (1) or not (0)	1	---

State Variables

Name	Description	Units
IsOnPC01	Controllable pump #1 is active (1) or not (0)	---
IsOnPC02	Controllable pump #2 is active (1) or not (0)	---
IsOnPC03	Controllable pump #3 is active (1) or not (0)	---
IsOnPC04	Controllable pump #4 is active (1) or not (0)	---
IsOnPC05	Controllable pump #5 is active (1) or not (0)	---
IsOnPU01	Unregulated pump #1 is active (1) or not (0)	---
IsOnPU02	Unregulated pump #2 is active (1) or not (0)	---
IsOnPU03	Unregulated pump #3 is active (1) or not (0)	---
IsOnPU04	Unregulated pump #4 is active (1) or not (0)	---
IsOnPU05	Unregulated pump #5 is active (1) or not (0)	---
PC01_Qmax	Maximum flow rate attainable by PC #1	m3/d
PC01_Qmin	Minimum flow rate attainable by PC #1	m3/d
PC02_Qmax	Maximum flow rate attainable by PC #2	m3/d
PC02_Qmin	Minimum flow rate attainable by PC #2	m3/d
PC03_Qmax	Maximum flow rate attainable by PC #3	m3/d
PC03_Qmin	Minimum flow rate attainable by PC #3	m3/d
PC04_Qmax	Maximum flow rate attainable by PC #4	m3/d
PC04_Qmin	Minimum flow rate attainable by PC #4	m3/d
PC05_Qmax	Maximum flow rate attainable by PC #5	m3/d
PC05_Qmin	Minimum flow rate attainable by PC #5	m3/d
PU01_Qmax	Maximum flow rate attainable by PU #1	m3/d
PU02_Qmax	Maximum flow rate attainable by PU #2	m3/d
PU03_Qmax	Maximum flow rate attainable by PU #3	m3/d
PU04_Qmax	Maximum flow rate attainable by PU #4	m3/d
PU05_Qmax	Maximum flow rate attainable by PU #5	m3/d

Derived State Variables

None

Sub-models

Name	Class Name
PC01	CF_Q_VFD
PC02	CF_Q_VFD
PC03	CF_Q_VFD
PC04	CF_Q_VFD
PC05	CF_Q_VFD
PU01	CF_Q_VFD
PU02	CF_Q_VFD
PU03	CF_Q_VFD
PU04	CF_Q_VFD
PU05	CF_Q_VFD

Interface Variables

Name	Terminal	Description	Value	Units
H_e	*in_2*	*Elevation head to be overcome*	*0*	*m*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*0*	*m*
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3

PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d

Common10_CFHQVFD

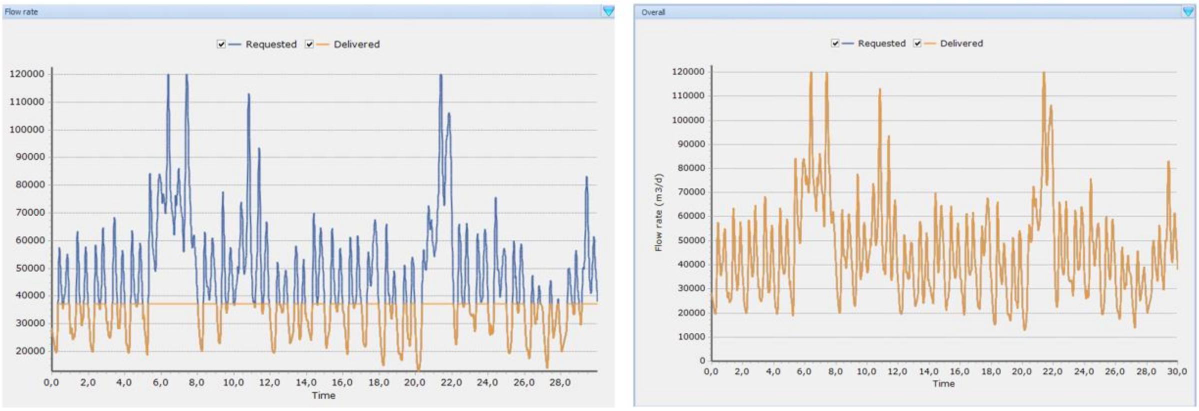
Instances

All

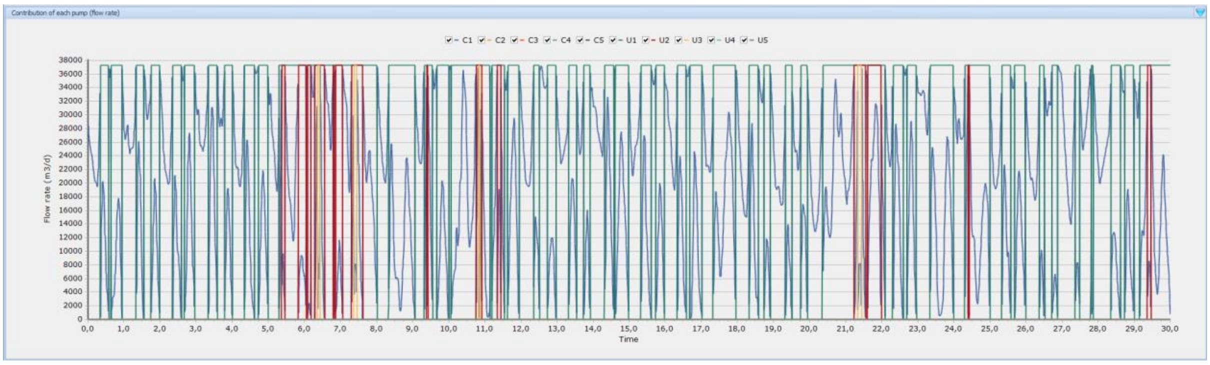
Description

The model describes a group of 10 centrifugal (CF) pumps, all operating on a common pipe.
Five pumps are controlled by Variable Frequency Drive (VFD) and five have a fixed rate (uncontrolled).
The model is based on head and flow rate.

The pump group controller is used when one pump is not enough to reach the requested flowrate. The controller will first activate the uncontrolled pumps and then the controlled pumps to regulate the flowrate to reach the requested flow.



Comparison between the case of a single pump (left) and that of multiple pumps (right): the single pump cannot deliver the total flow that is requested, while the combination of pumps can deliver it.



The flowrate for each pump of the group. Three uncontrolled pumps (U1, U2, U3) and one controlled pump (C1) are activated to reach the requested flow.

Parameters

Name	Description	Value	Units
Is_PC01	Controllable pump #1 present (1) or not (0)	1	---
Is_PC02	Controllable pump #2 present (1) or not (0)	1	---
Is_PC03	Controllable pump #3 present (1) or not (0)	1	---
Is_PC04	Controllable pump #4 present (1) or not (0)	1	---
Is_PC05	Controllable pump #5 present (1) or not (0)	1	---
Is_PU01	Unregulated pump #1 present (1) or not (0)	1	---
Is_PU02	Unregulated pump #2 present (1) or not (0)	1	---
Is_PU03	Unregulated pump #3 present (1) or not (0)	1	---
Is_PU04	Unregulated pump #4 present (1) or not (0)	1	---

Name	Description	Value	Units
Is_PU05	Unregulated pump #5 present (1) or not (0)	1	---
Pipe_D	Diameter of pipes that conduct the pumped fluid	0.5	m
Pipe_L	Length of pipes that conduct the pumped fluid	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
Pipe_e	Absolute internal roughness of the pipes	0.00015	m
dH_InLine	Head losses due to control valves, flow sensors, …	0	m
visc_H20	Dynamic viscosity of water	1.5972E-08	Pa*d

State Variables

Name	Description	Units
IsOnPC01	Controllable pump #1 is active (1) or not (0)	---
IsOnPC02	Controllable pump #2 is active (1) or not (0)	---
IsOnPC03	Controllable pump #3 is active (1) or not (0)	---
IsOnPC04	Controllable pump #4 is active (1) or not (0)	---
IsOnPC05	Controllable pump #5 is active (1) or not (0)	---
IsOnPU01	Unregulated pump #1 is active (1) or not (0)	---
IsOnPU02	Unregulated pump #2 is active (1) or not (0)	---
IsOnPU03	Unregulated pump #3 is active (1) or not (0)	---
IsOnPU04	Unregulated pump #4 is active (1) or not (0)	---
IsOnPU05	Unregulated pump #5 is active (1) or not (0)	---
PC01_Qmax	Maximum flow rate attainable by PC #1	m3/d
PC01_Qmin	Minimum flow rate attainable by PC #1	m3/d
PC02_Qmax	Maximum flow rate attainable by PC #2	m3/d
PC02_Qmin	Minimum flow rate attainable by PC #2	m3/d
PC03_Qmax	Maximum flow rate attainable by PC #3	m3/d
PC03_Qmin	Minimum flow rate attainable by PC #3	m3/d
PC04_Qmax	Maximum flow rate attainable by PC #4	m3/d
PC04_Qmin	Minimum flow rate attainable by PC #4	m3/d
PC05_Qmax	Maximum flow rate attainable by PC #5	m3/d
PC05_Qmin	Minimum flow rate attainable by PC #5	m3/d
PU01_Qmax	Maximum flow rate attainable by PU #1	m3/d
PU02_Qmax	Maximum flow rate attainable by PU #2	m3/d
PU03_Qmax	Maximum flow rate attainable by PU #3	m3/d
PU04_Qmax	Maximum flow rate attainable by PU #4	m3/d
PU05_Qmax	Maximum flow rate attainable by PU #5	m3/d
FluidVelocity	Velocity of pumped fluid	m/d
FluidViscosity	Dynamic viscosity of the pumped fluid	Pa*d
Friction	Darcy-Weisbach friction factor f (depends on Reynolds nr)	---
Friction_MinorLosses	Head losses due to elbows, inlet, outlet, ..	m
Friction_Pipe	Friction head losses due to flow through pipes	m
ReynoldsNr	Reynolds number of the pipes	---
H_System	Total head losses of the system	m

Derived State Variables

None

Sub-models

Name	Class Name
PC01	CF_HQ_VFD
PC02	CF_HQ_VFD
PC03	CF_HQ_VFD
PC04	CF_HQ_VFD
PC05	CF_HQ_VFD
PU01	CF_HQ_VFD

Name	Class Name
PU02	CF_HQ_VFD
PU03	CF_HQ_VFD
PU04	CF_HQ_VFD
PU05	CF_HQ_VFD

Interface Variables

Name	Terminal	Description	Value	Units
H_e	*in_2*	*Elevation head to be overcome*	*0*	*m*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*0*	*m*
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d

Common10_CFHNVFD

Instances

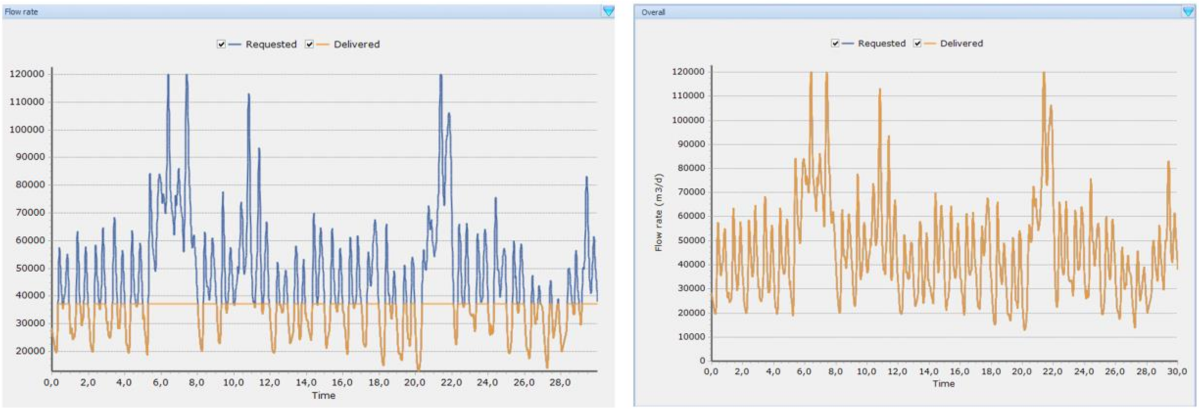
All

Description

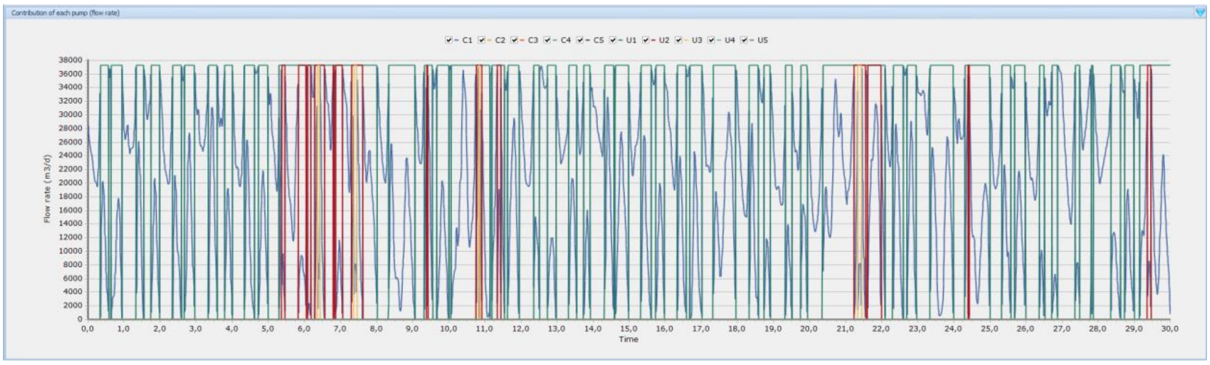
Description

The model describes a group of 10 centrifugal (CF) pumps, all operating on a common pipe.
Five pumps are controlled by Variable Frequency Drive (VFD) and five have a fixed rate (uncontrolled).
The model is based on head and relative pump speed.

The pump group controller is used when one pump is not enough to reach the requested flowrate. The controller will first activate the uncontrolled pumps and then the controlled pumps to regulate the flowrate to reach the requested flow.



Comparison between the case of a single pump (left) and that of multiple pumps (right): the single pump cannot deliver the total flow that is requested, while the combination of pumps can deliver it.



The flowrate for each pump of the group. Three uncontrolled pumps (U1, U2, U3) and one controlled pump (C1) are activated to reach the requested flow.

Parameters

Name	Description	Value	Units
Is_PC01	Controllable pump #1 present (1) or not (0)	1	---
Is_PC02	Controllable pump #2 present (1) or not (0)	1	---
Is_PC03	Controllable pump #3 present (1) or not (0)	1	---
Is_PC04	Controllable pump #4 present (1) or not (0)	1	---
Is_PC05	Controllable pump #5 present (1) or not (0)	1	---
Is_PU01	Unregulated pump #1 present (1) or not (0)	1	---
Is_PU02	Unregulated pump #2 present (1) or not (0)	1	---

Name	Description	Value	Units
Is_PU03	Unregulated pump #3 present (1) or not (0)	1	---
Is_PU04	Unregulated pump #4 present (1) or not (0)	1	---
Is_PU05	Unregulated pump #5 present (1) or not (0)	1	---
Pipe_D	Diameter of pipes that conduct the pumped fluid	0.5	m
Pipe_L	Length of pipes that conduct the pumped fluid	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
Pipe_e	Absolute internal roughness of the pipes	0.00015	m
dH_InLine	Head losses due to control valves, flow sensors, …	0	m
visc_H20	Dynamic viscosity of water	1.5972E-08	Pa*d

State Variables

Name	Description	Units
IsOnPC01	Controllable pump #1 is active (1) or not (0)	---
IsOnPC02	Controllable pump #2 is active (1) or not (0)	---
IsOnPC03	Controllable pump #3 is active (1) or not (0)	---
IsOnPC04	Controllable pump #4 is active (1) or not (0)	---
IsOnPC05	Controllable pump #5 is active (1) or not (0)	---
IsOnPU01	Unregulated pump #1 is active (1) or not (0)	---
IsOnPU02	Unregulated pump #2 is active (1) or not (0)	---
IsOnPU03	Unregulated pump #3 is active (1) or not (0)	---
IsOnPU04	Unregulated pump #4 is active (1) or not (0)	---
IsOnPU05	Unregulated pump #5 is active (1) or not (0)	---
PC01_N	Actual relative pump speed of controllable pump #1	---
PC02_N	Actual relative pump speed of controllable pump #2	---
PC03_N	Actual relative pump speed of controllable pump #3	---
PC04_N	Actual relative pump speed of controllable pump #4	---
PC05_N	Actual relative pump speed of controllable pump #5	---
PU01_N	Actual relative pump speed of uncontrollable pump #1	---
PU02_N	Actual relative pump speed of uncontrollable pump #2	---
PU03_N	Actual relative pump speed of uncontrollable pump #3	---
PU04_N	Actual relative pump speed of uncontrollable pump #4	---
PU05_N	Actual relative pump speed of uncontrollable pump #5	---

Derived State Variables

None

Sub-models

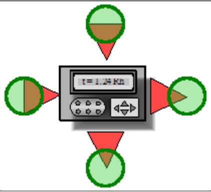
Name	Class Name
PC01	CF_HN_VFD
PC02	CF_HN_VFD
PC03	CF_HN_VFD
PC04	CF_HN_VFD
PC05	CF_HN_VFD
PU01	CF_HN_VFD
PU02	CF_HN_VFD
PU03	CF_HN_VFD
PU04	CF_HN_VFD
PU05	CF_HN_VFD

Interface Variables

Name	Terminal	Description	Value	Units
H_e	*in_2*	*Elevation head to be overcome*	*0*	*m*
PC01_Nop	*in_2*	*Desired relative speed of controllable pump #1*	*0.6*	---

Name	Terminal	Description	Value	Units
PC02_Nop	*in_2*	*Desired relative speed of controllable pump #2*	*0.6*	---
PC03_Nop	*in_2*	*Desired relative speed of controllable pump #3*	*0.6*	---
PC04_Nop	*in_2*	*Desired relative speed of controllable pump #4*	*0.6*	---
PC05_Nop	*in_2*	*Desired relative speed of controllable pump #5*	*0.6*	---
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
TSS	*in_2*	*TSS concentration in the pumped liquid*	*3,000*	*g/m3*
dH_Ext	*in_2*	*Head loss due to external factors (optional)*	*0*	*m*
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d

BLOWER CONTROLLERS

	Palette Group	**Blowers and Pumps**
	Category	Blowers
	Icon Name	controller_blower

Common10_CFHQVFD

Instances

All

Description

The model describes a group of 10 centrifugal (CF) blowers, all operating on a common pipe.
Five blowers are controlled by Variable Frequency Drive (VFD) and five have a fixed rate (uncontrolled).
The model is based on head and flow rate.

The blower group controller is used when one blower is not enough to reach the requested flowrate. The controller will first activate the uncontrolled blowers and then the controlled blowers to regulate the flowrate to reach the requested flow.

Parameters

Name	Description	Value	Units
Is_BC01	Controllable blower #1 present (1) or not (0)	1	---
Is_BC02	Controllable blower #2 present (1) or not (0)	0	---
Is_BC03	Controllable blower #3 present (1) or not (0)	0	---
Is_BC04	Controllable blower #4 present (1) or not (0)	0	---
Is_BC05	Controllable blower #5 present (1) or not (0)	0	---
Is_BU01	Unregulated blower #1 present (1) or not (0)	1	---
Is_BU02	Unregulated blower #2 present (1) or not (0)	0	---
Is_BU03	Unregulated blower #3 present (1) or not (0)	0	---
Is_BU04	Unregulated blower #4 present (1) or not (0)	0	---
Is_BU05	Unregulated blower #5 present (1) or not (0)	0	---
Pipe_D	Diameter of pipes that conduct the air	0.5	m
Pipe_L	Length of pipes that conduct the air	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
A_Diff	Total surface area of diffuser’s membrane	70	m2
H_Cutoff	Diffuser’s membrane’s min pressure loss at zero flow	150	mm
f_P_Loss	Linear pressure loss factor (head loss due to scale build-up on the membrane)	0.5	mm/ (m3/h/m2)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m3/d
N_Lines	Nr of identical aeration lines connected to the header	3	---
N_Valves	Number of valves characterised by Kv	0	---
P_sp	Absolute pressure set-point in the common header	111,325	Pa
dP_sp	(Over)pressure set-point in the common header	10,000	Pa
dt_clean	Interval between two cleanings of the membrane	250	d
f_Foul_Max	Max pressure increase due to fouling (1 = clean)	2	---

State Variables

Name	Description	Units
BC01_Qmax	Maximum flow rate attainable by BC #1	m3/d
BC01_Qmin	Minimum flow rate attainable by BC #1	m3/d
BC02_Qmax	Maximum flow rate attainable by BC #2	m3/d
BC02_Qmin	Minimum flow rate attainable by BC #2	m3/d
BC03_Qmax	Maximum flow rate attainable by BC #3	m3/d
BC03_Qmin	Minimum flow rate attainable by BC #3	m3/d
BC04_Qmax	Maximum flow rate attainable by BC #4	m3/d
BC04_Qmin	Minimum flow rate attainable by BC #4	m3/d
BC05_Qmax	Maximum flow rate attainable by BC #5	m3/d

Name	Description	Units
BC05_Qmin	Minimum flow rate attainable by BC #5	m3/d
BU01_Qmax	Maximum flow rate attainable by BU #1	m3/d
BU02_Qmax	Maximum flow rate attainable by BU #2	m3/d
BU03_Qmax	Maximum flow rate attainable by BU #3	m3/d
BU04_Qmax	Maximum flow rate attainable by BU #4	m3/d
BU05_Qmax	Maximum flow rate attainable by BU #5	m3/d
P_Min	Actual pressure at maximum flow rate	Pa
Q_Blower_Psp	Maximum achievable flow rate at pressure set-poin	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
Q_System_Psp	Flow rate at pressure set-point on system curve	m3/d
t_clean_last	Time of last cleaning of diffuser’s membrane	d

Derived State Variables

None

Sub-models

Name	Class Name
BC01	CF_HQ_VFD
BC02	CF_HQ_VFD
BC03	CF_HQ_VFD
BC04	CF_HQ_VFD
BC05	CF_HQ_VFD
BU01	CF_HQ_VFD
BU02	CF_HQ_VFD
BU03	CF_HQ_VFD
BU04	CF_HQ_VFD
BU05	CF_HQ_VFD

Interface Variables

Name	Terminal	Description	Value	Units
IsOn_BC01	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC02	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC03	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC04	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC05	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU01	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU02	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU03	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU04	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU05	in_2	Blower is running (1) or not (0)?	---	---
H_h2o	*in_2*	*Water height above diffusers*	*5*	*m*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
Temp	*in_2*	*Ambient air temperature*	*15*	*°C*
P_Op	out_1	Actual absolute header pressure	---	Pa
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
f_Foul	out_2	Relative pressure increase due to fouling (1 clean membrane)	---	---

Common10_PDHQVFD

Instances
All

Description
The model describes a group of 10 positive displacement (PD) blowers, all operating on a common pipe.
Five blowers are controlled by Variable Frequency Drive (VFD) and five have a fixed rate (uncontrolled).
The model is based on head and flow rate.

The blower group controller is used when one blower is not enough to reach the requested flowrate. The controller will first activate the uncontrolled blowers and then the controlled blowers to regulate the flowrate to reach the requested flow.

Parameters

Name	Description	Value	Units
Is_BC01	Controllable blower #1 present (1) or not (0)	1	---
Is_BC02	Controllable blower #2 present (1) or not (0)	0	---
Is_BC03	Controllable blower #3 present (1) or not (0)	0	---
Is_BC04	Controllable blower #4 present (1) or not (0)	0	---
Is_BC05	Controllable blower #5 present (1) or not (0)	0	---
Is_BU01	Unregulated blower #1 present (1) or not (0)	1	---
Is_BU02	Unregulated blower #2 present (1) or not (0)	0	---
Is_BU03	Unregulated blower #3 present (1) or not (0)	0	---
Is_BU04	Unregulated blower #4 present (1) or not (0)	0	---
Is_BU05	Unregulated blower #5 present (1) or not (0)	0	---
Pipe_D	Diameter of pipes that conduct the air	0.5	m
Pipe_L	Length of pipes that conduct the air	60	m
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
A_Diff	Total surface area of diffuser’s membrane	70	m2
H_Cutoff	Diffuser’s membrane’s min pressure loss at zero flow	150	mm
f_P_Loss	Linear pressure loss factor (head loss due to scale build-up on the membrane)	0.5	mm/ (m3/h/m2)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m3/d
N_Lines	Nr of identical aeration lines connected to the header	3	---
N_Valves	Number of valves characterised by Kv	0	---
P_sp	Absolute pressure set-point in the common header	111,325	Pa
dP_Max	Maximum allowable (over)pressure in the header	10,000	Pa
dP_sp	(Over)pressure set-point in the common header	10,000	Pa
dt_clean	Interval between two cleanings of the membrane	250	d
f_Foul_Max	Max pressure increase due to fouling (1 = clean)	2	---

State Variables

Name	Description	Units
BC01_Qmax	Maximum flow rate attainable by BC #1	m3/d
BC01_Qmin	Minimum flow rate attainable by BC #1	m3/d
BC02_Qmax	Maximum flow rate attainable by BC #2	m3/d
BC02_Qmin	Minimum flow rate attainable by BC #2	m3/d
BC03_Qmax	Maximum flow rate attainable by BC #3	m3/d
BC03_Qmin	Minimum flow rate attainable by BC #3	m3/d
BC04_Qmax	Maximum flow rate attainable by BC #4	m3/d

Name	Description	Units
BC04_Qmin	Minimum flow rate attainable by BC #4	m3/d
BC05_Qmax	Maximum flow rate attainable by BC #5	m3/d
BC05_Qmin	Minimum flow rate attainable by BC #5	m3/d
BU01_Qmax	Maximum flow rate attainable by BU #1	m3/d
BU02_Qmax	Maximum flow rate attainable by BU #2	m3/d
BU03_Qmax	Maximum flow rate attainable by BU #3	m3/d
BU04_Qmax	Maximum flow rate attainable by BU #4	m3/d
BU05_Qmax	Maximum flow rate attainable by BU #5	m3/d
P_Min	Actual pressure at maximum flow rate	Pa
Q_Blower_Psp	Maximum achievable flow rate at pressure set-poin	m3/d
Q_Max	Maximum flow rate given the system curve	m3/d
Q_System_Psp	Flow rate at pressure set-point on system curve	m3/d
t_clean_last	Time of last cleaning of diffuser’s membrane	d

Derived State Variables

None

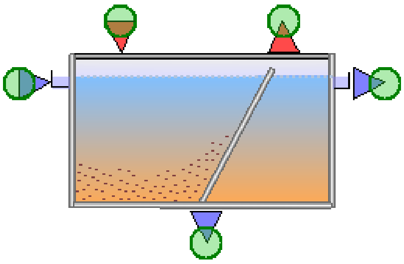
Sub-models

Name	Class Name
BC01	PD_HQ_VFD
BC02	PD_HQ_VFD
BC03	PD_HQ_VFD
BC04	PD_HQ_VFD
BC05	PD_HQ_VFD
BU01	PD_HQ_VFD
BU02	PD_HQ_VFD
BU03	PD_HQ_VFD
BU04	PD_HQ_VFD
BU05	PD_HQ_VFD

Interface Variables

Name	Terminal	Description	Value	Units
IsOn_BC01	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC02	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC03	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC04	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BC05	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU01	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU02	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU03	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU04	in_2	Blower is running (1) or not (0)?	---	---
IsOn_BU05	in_2	Blower is running (1) or not (0)?	---	---
H_h2o	*in_2*	*Water height above diffusers*	*5*	*m*
Q_Op	*in_2*	*Desired operating flow rate*	*20,000*	*m3/d*
Temp	*in_2*	*Ambient air temperature*	*15*	*°C*
P_Op	out_1	Actual absolute header pressure	---	Pa
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m3
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m3/d
f_Foul	out_2	Relative pressure increase due to fouling (1 clean membrane)	---	---

SCREENING

	Palette Group	**Pre-treatment**
	Category	ASM1, ASM2dISS, ASM2dMod
	Icon Name	screen

Screen_Ideal

Instances

All

Description

The model describes an ideal phase separator.

$$Q_{out} = Q_{in} - Q_{under}$$

$$(Q_{in} \leq Q_{under}): Q_{under} = Q_{in}$$
$$(Q_{in} > Q_{under}): Q_{under} = Q_{under}^{*}$$

where:

- Q_{in}, Q_{under} and Q_{in} denote the influent-, effluent- and underflow flow rates (m3/d) respectively
- Q_{under}^{*} is the desired underflow flow rate (m3/d)

The mass balance over the screen is as follows:

$$C_{out,S_i} = C_{in,S_i}$$

$$C_{out,X_i} = (1 - e_{tss}) \cdot C_{in,X_i}$$

$$C_{under,S_i} = C_{in,S_i}$$

$$C_{under,X_i} = e_{tss} \cdot C_{in,X_i}$$

where:

- C is the concentration of the *i*-th state component (g/m3) (suffixes S and X denotes soluble and particulate components)
- e_{tss} is fraction (-) of settleable solids

No conversion process occurs in the tank volume.

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
e_solids	Settleable fraction of particulate components	0.1	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
r_COD	Reduction in COD concentration	---
r_TSS	Reduction in TSS concentration	---

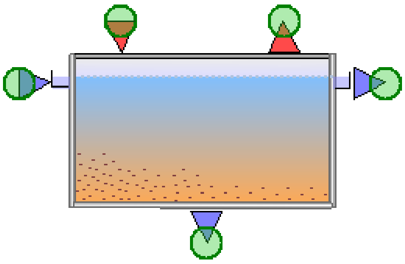
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

GRIT REMOVAL

	Palette Group	**Pre-treatment**
	Category	ASM1, ASM2dISS, ASM2dMod
	Icon	grit_chamber

Grit_Ideal

Instances

All

Description

The model describes an ideal phase separator.

$$Q_{out} = Q_{in} - Q_{under}$$

$$(Q_{in} \leq Q_{under}): Q_{under} = Q_{in}$$
$$(Q_{in} > Q_{under}): Q_{under} = Q_{under}^{*}$$

where:

- Q_{in}, Q_{under} and Q_{in} denote the influent-, effluent- and underflow flow rates (m3/d) respectively
- Q_{under}^{*} is the desired underflow flow rate (m3/d)

The mass balance over the tank is as follows:

$$C_{out,S_i} = C_{in,S_i}$$

$$C_{out,X_i} = \left(\left(1 - e_{inorg}\right) \cdot x_{i,inorg} + \left(1 - e_{org}\right) \cdot x_{i,org}\right) \cdot C_{in,X_i}$$

$$C_{under,S_i} = C_{in,S_i}$$

$$C_{under,X_i} = \left(e_{inorg} \cdot x_{i,inorg} + e_{org} \cdot x_{i,org}\right) \cdot C_{in,X_i}$$

where:

- C is the concentration of the *i*-th state component (g/m3) (suffixes S and X denotes soluble and particulate components)
- $x_{i,org}$ and $x_{i,inorg}$ denote the organic and the inorganic fraction (-) of each particulate component
- e_{org} and e_{inorg} denote the organic and the inorganic settleable fractions (-) respectively

No conversion process occurs in the tank volume.

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
e_org	Settleable fraction of organic components	0.05	---
e_inorg	Settleable fraction of inorganic components	0.5	---
i_COD_VSS	VSS to COD conversion	1.42	g VSS/g COD

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
r_COD	Reduction in COD concentration	---
r_TSS	Reduction in TSS concentration	---

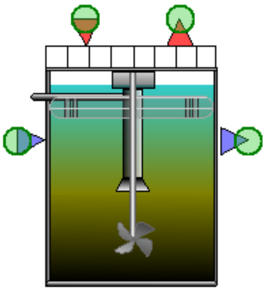
Derived State Variables

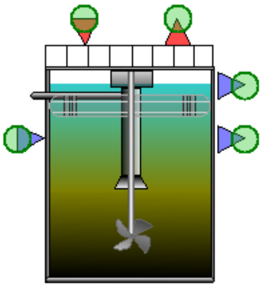
None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

BUFFER TANKS

	Palette Group	**Retention**
	Category	Tanks_Buffer
	Icon	buffer_tank

	Palette Group	**Retention**
	Category	Tanks_Buffer
	Icon Name	storm_tank

	Palette Group	**Retention**
	Category	Tanks_Buffer
	Icon	storm_tank_2

Tanks_Buffer.VolumeConstant

Instances

All

Description

The model describes an ideally mixed buffer tank with constant volume:

$$Q_{out} = Q_{in}$$

The power (kWh/d) required for mixing is estimated as follows:

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

where:

- E_{mix} indicates the mixing energy per unit volume (kWh/m3/d)
- V denotes the tank volume (m3)

Parameters

Name	Description	Value	Units
Vol	Volume of the tank	1000	m3

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
V_Tank	out_2	Volume of the (liquid in the) tank	---	m3
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kW/m3*

Tanks_Buffer.VolumeVariable

Instances

All

Description

The model describes an ideally mixed buffer tank with variable outflow:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_c}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_c is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

The power (kWh/d) required for mixing is estimated as follows:

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

where:

- E_{mix} indicates the mixing energy per unit volume (kWh/m3/d)
- V denotes the tank volume (m3)

Parameters

Name	Description	Value	Units
A	Surface area of the tank below the weirs	200	m2
N	Number of weirs	100	---
Alpha	Empirical factor function of weir type or width	1	---
Beta	Empirical factor function of weir design	1	---
Vol	Volume of the tank (under the weir)	2,000	m3

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d

P_Mix	out_2	Power consumption for mixing	---	kWh/d
V_Tank	out_2	Volume of the (liquid in the) tank	---	m3
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kW/m3*

Tanks_Buffer.VolumePumped

Instances

All

Description

The model describes an ideally mixed buffer/storm tank with pumped-regulated outflow:

$$V < V_{min}: Q_{out} = 0$$
$$V < (1 + f_{vol}) \cdot V_{min}: Q_{out} = min\left(Q_{in}, Q_p\right)$$
$$V < V_{max}: Q_{out} = Q_p$$
$$V \geq V_{max}: Q_{out} = Q_p$$

and possible overflow:

$$V < V_{max}: Q_{over} = 0$$
$$V \geq V_{max}: Q_{over} = max(0, Q_{in} - Q_{out})$$

where:

- V_{min} and V_{max} denote the minimum and maximum volume of the tank (m3)
- Q_p is the pump flow rate (m3/d)

The power (kWh/d) required for mixing and pumping is estimated as follows:

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

$$P_{Pump} = E_{pump} \cdot Q_{out}$$

where:

- E_{mix} and E_{pump} indicate the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow (kWh/m3) respectively
- V denotes the tank volume (m3)

Parameters

Name	Description	Value	Units
V_Max	Maximum volume of the tank	2,000	m3
V_Min	Minimum volume of the tank	10	m3
V0	Initial volume of the tank	1,000	m3
f_vol	Margin over V_Min to start the pump	0.1	-

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Over	Overflow flow rate	m3/d

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Overflow	out_3	Overflow (component vector)	---	g/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
P_Pump	out_2	Power consumption for pumping	---	kWh/d
V_Tank	out_2	Volume of the (liquid in the) tank	---	m3
Q01_Pump	*in_2*	*Desired effluent flow rate (pump #1)*	*100*	*m3*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kW/m3*
E_Pump_sp	*in_2*	*Pumping energy per unit volume*	*0.04*	*kWh/m3*

Tanks_Buffer.VolumePumped02

Instances

All

Description

The model describes an ideally mixed buffer/storm tank with pumped-regulated outflow, using 2 fix rate-pumps (or 1 variable rate-pump):

$$V < V_{min}: Q_{out} = 0$$
$$V < (1 + f_{vol}) \cdot V_{min}: Q_{out} = min\left(Q_{in}, Q_{p1}\right)$$
$$V < V_{02}: Q_{out} = Q_{p1}$$
$$V < (1 + f_{vol}) \cdot V_{02}: Q_{out} = min\left(Q_{in}, Q_{p1} + Q_{p2}\right)$$
$$V < V_{max}: Q_{out} = Q_{p1} + Q_{p2}$$
$$V \geq V_{max}: Q_{out} = Q_{p1} + Q_{p2}$$

and possible overflow:

$$V < V_{max}: Q_{over} = 0$$
$$V \geq V_{max}: Q_{over} = max(0, Q_{in} - Q_{out})$$

where:

- V_{min} and V_{max} denote the minimum and maximum volume of the tank (m3)
- Q_p is the pump flow rate (m3/d)

The power (kWh/d) required for mixing and pumping is estimated as follows:

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

$$P_{Pump} = E_{pump} \cdot Q_{out}$$

where:

- E_{mix} and E_{pump} indicate the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow (kWh/m3) respectively
- V denotes the tank volume (m3)

Parameters

Name	Description	Value	Units
V_Max	Maximum volume of the tank	2,000	m3
V_Min	Minimum volume of the tank	10	m3
V0	Initial volume of the tank	1,000	m3
V_02	Level at which pump#02 is triggered	1,500	m3
f_vol	Margin over V_Min to start the pump	0.1	-

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d

Name	Description	Units
Q_Out	Effluent flow rate	m3/d
Q_Over	Overflow flow rate	m3/d

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Overflow	out_3	Overflow (component vector)	---	g/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
P_Pump	out_2	Power consumption for pumping	---	kWh/d
V_Tank	out_2	Volume of the (liquid in the) tank	---	m3
Q01_Pump	*in_2*	*Desired effluent flow rate (pump #1)*	*100*	*m3*
Q02_Pump	*in_2*	*Desired effluent flow rate (pump #2)*	*100*	*m3*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kW/m3*
E_Pump_sp	*in_2*	*Pumping energy per unit volume*	*0.04*	*kWh/m3*

Tanks_Buffer.StormTankBw

Instances

All

Description

The model describes an ideally mixed buffer/storm tank with pumped-regulated outflow:
It can be used in a multi-tank configuration with a suitable master control, for sequential filling and emptying.

$$V < V_{min}: Q_{out} = 0$$
$$V \geq V_{min}\ and\ Q_{in} \leq 0: Q_{out} = Q_p^*$$

and possible overflow:

$$V < V_{max}: Q_{over} = 0$$
$$V \geq V_{max}: Q_{over} = max(0, Q_{in})$$

where:

- V_{min} and V_{max} denote the minimum and maximum volume of the tank (m3)
- Q_p and Q_p^* denote the maximum (or desired) and the actual pump flow rate (m3/d), respectively. The latter is calculated as:

$$Q_{bk} + Q_p < Q_{lim}: Q_p^* = Q_p$$
$$Q_{bk} + Q_p \geq Q_{lim}: Q_p^* = max(0, Q_{lim} - Q_{bk})$$

where:

- Q_{lim} and Q_{bk} denote the maximum and the background flow rate (m3/d), respectively.

The power (kWh/d) required for mixing is estimated as follows:

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

where:

- E_{mix} indicates the mixing energy per unit volume (kWh/m3/d)
- V denotes the tank volume (m3)

Parameters

Name	Description	Value	Units
V_Max	Maximum volume of the tank	2,000	m3
V_Min	Minimum volume of the tank	10	m3

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Over	Overflow flow rate	m3/d

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Overflow	out_3	Overflow (component vector)	---	g/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
V_Tank	out_2	Volume of the (liquid in the) tank	---	m3
IsFull	out_2	Tank is full (1) or not (0)	---	---
IsPumping	out_2	Pump is emptying the tank (1) or not (0)	---	---
QP	out_2	Actual pump flow rate	---	m3/d
Q_Pump	*in_2*	*Pump flow rate*	*100*	*m3*
Qbk	*in_2*	*Background flow rate*	*100*	*m3*
Qlim	*in_2*	*Maximum total flow rate*	*100*	*m3*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kW/m3*

Tanks_Buffer.StormTank

Instances

All

Description

The model describes a non-ideally mixed storm tank (solids deposition and resuspension takes place), with pumped-regulated outflow:

$$V < V_{min}: Q_{out} = 0$$
$$V \geq V_{min}\ and\ Q_{in} \leq 0: Q_{out} = Q_p$$

and possible overflow:

$$V < V_{max}: Q_{over} = 0$$
$$V \geq V_{max}: Q_{over} = Q_{in}$$

where:

- V_{min} and V_{max} denote the minimum and maximum volume of the tank (m3)
- Q_p is the pump flow rate (m3/d)

Solids removal is calculated empirically, based on the retention time (DT):

$$r_{TSS} = \frac{DT}{a+b \cdot DT}$$

$$DT = \frac{V}{Q_{over}}$$

The power (kWh/d) required for mixing and pumping is estimated as follows:

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

$$P_{Pump} = E_{pump} \cdot Q_{out}$$

where:

- E_{mix} and E_{pump} indicate the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow (kWh/m3) respectively
- V denotes the tank volume (m3)

Parameters

Name	Description	Value	Units
L	Length of the tank	10	m
H	Height of the tank	10	m
W	Width of the tank	10	m
V0	Initial volume of the tank	1,000	m3

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m3

Name	Description	Units
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Over	Overflow flow rate	m3/d
DT	Detention time	d
SOR	Surface Overflow Rate	m/d
vh	Horizontal velocity	m/d
r_TSS	Expected TSS removal efficiency	-

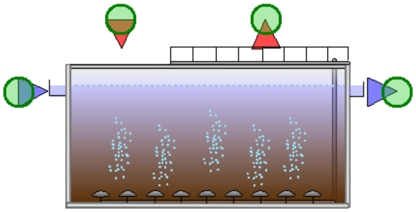
Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Overflow	out_3	Overflow (component vector)	---	g/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
P_Pump	out_2	Power consumption for pumping	---	kWh/d
V_Tank	out_2	Volume of the (liquid in the) tank	---	m3
Q01_Pump	*in_2*	*Desired effluent flow rate (pump #1)*	*100*	*m3*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kW/m3*
E_Pump_sp	*in_2*	*Pumping energy per unit volume*	*0.04*	*kWh/m3*

ACTIVATED SLUDGE TANKS

	Palette Group	**Biological Treatment**
	Category	Tanks_AS, TanksMulti_AS
	Icon Name	tank_activated_sludge

VolumeConstant

Instances

All

Description

The model describes an ideally mixed, activated sludge tank with constant volume:

$$Q_{out} = Q_{in}$$

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

The power (kWh/d) required for aeration and mixing is estimated as follows:

$$P_{aer} = \frac{1}{OTR} \cdot S_{O,sat} \cdot k_{La} \cdot V$$

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR and E_{mix} indicate the Oxygen Transfer Rate (g/kWh) and the mixing energy per unit volume (kWh/m3/d) respectively
- V denotes the tank volume (m3)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol	Volume of the tank	1000	m3
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Is it actively mixed when aerated?	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla	*in_2*	*Oxygen transfer coefficient*	*50*	*1/d*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

VolumePumped

Instances

All

Description

The model describes an ideally mixed, activated sludge tank with pumped-regulated outflow:

$$
\begin{aligned}
&(V < V_{min}):\\
&\qquad (Q_p > Q_{in}): Q_{out} = Q_{in}\\
&\qquad (Q_p \leq Q_{in}): Q_{out} = Q_p\\
&(V_{min} \leq V \leq V_{max}): Q_{out} = Q_p\\
&(V > V_{max}):\\
&\qquad (Q_p > Q_{in}): Q_{out} = Q_p\\
&\qquad (Q_p \leq Q_{in}): Q_{out} = Q_{in}
\end{aligned}
$$

where:

- V_{min} and V_{max} denote the minimum and maximum volume of the tank (m3)
- Q_p is the pump flow rate (m3/d)

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

The power (kWh/d) required for aeration, mixing and pumping is estimated as follows:

$$P_{aer} = \frac{1}{OTR} \cdot S_{O,sat} \cdot k_{La} \cdot V$$

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

$$P_{Pump} = E_{pump} \cdot Q_{out}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, E_{mix} and E_{pump} indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow (kWh/m3) respectively
- V denotes the tank volume (m3)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
V_Max	Maximum volume of the tank	2,000	m3
V_Min	Minimum volume of the tank	10	m3
Vol	Initial volume of the tank	1,000	m3
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Is it actively mixed when aerated?	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	kWh/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
P_Pump	out_2	Power consumption for pumping	---	kWh/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla	*in_2*	*Oxygen transfer coefficient*	*50*	*1/d*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

VolumeVariable

Instances

All

Description

The model describes an ideally mixed, activated sludge tank with variable outflow:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_c}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_c is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

The power (kWh/d) required for aeration and mixing is estimated as follows:

$$P_{aer} = \frac{1}{OTR} \cdot S_{O,sat} \cdot k_{La} \cdot V$$

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR and E_{mix} indicate the Oxygen Transfer Rate (g/kWh) and the mixing energy per unit volume (kWh/m3/d) respectively
- V denotes the tank volume (m3)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	200	m2
N	Number of weirs	100	---
Alpha	Empirical factor function of weir type or width	1	---
Beta	Empirical factor function of weir design	1	---
Vol	Volume of the tank (under the weir)	2,000	m3
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Is it actively mixed when aerated?	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	kWh/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla	*in_2*	*Oxygen transfer coefficient*	*50*	*1/d*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

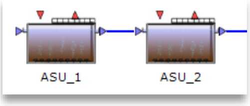
VolumeConstant02

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 2 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*

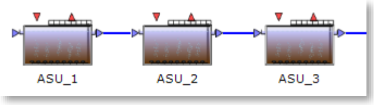
VolumeConstant03

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 3 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*

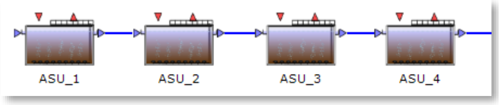
VolumeConstant04

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 4 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*

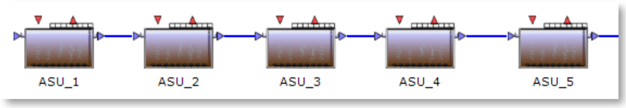
VolumeConstant05

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 5 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3
Vol05	Volume of compartment no.5	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*
kLa_05	*in_2*	*Oxygen transfer coeff. in compartment no.5*	*1*	*1/d*

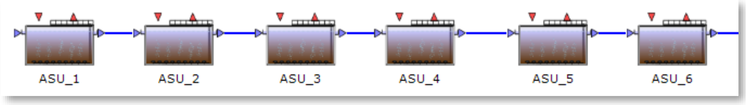
VolumeConstant06

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 6 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3
Vol05	Volume of compartment no.5	1000	m3
Vol06	Volume of compartment no.6	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*
kLa_05	*in_2*	*Oxygen transfer coeff. in compartment no.5*	*1*	*1/d*
kLa_06	*in_2*	*Oxygen transfer coeff. in compartment no.6*	*1*	*1/d*

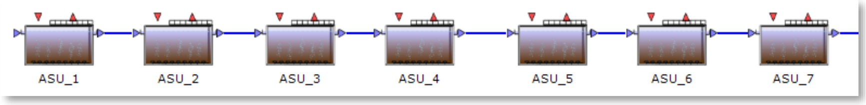
VolumeConstant07

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 7 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3
Vol05	Volume of compartment no.5	1000	m3
Vol06	Volume of compartment no.6	1000	m3
Vol07	Volume of compartment no.7	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*
kLa_05	*in_2*	*Oxygen transfer coeff. in compartment no.5*	*1*	*1/d*
kLa_06	*in_2*	*Oxygen transfer coeff. in compartment no.6*	*1*	*1/d*
kLa_07	*in_2*	*Oxygen transfer coeff. in compartment no.7*	*1*	*1/d*

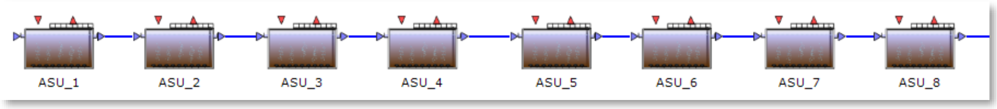
VolumeConstant08

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 8 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3
Vol05	Volume of compartment no.5	1000	m3
Vol06	Volume of compartment no.6	1000	m3
Vol07	Volume of compartment no.7	1000	m3
Vol08	Volume of compartment no.8	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*
kLa_05	*in_2*	*Oxygen transfer coeff. in compartment no.5*	*1*	*1/d*
kLa_06	*in_2*	*Oxygen transfer coeff. in compartment no.6*	*1*	*1/d*
kLa_07	*in_2*	*Oxygen transfer coeff. in compartment no.7*	*1*	*1/d*
kLa_08	*in_2*	*Oxygen transfer coeff. in compartment no.8*	*1*	*1/d*

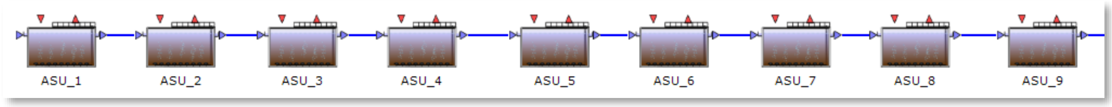
VolumeConstant09

Instances

All

Description

The model describes an ideally mixed, activated sludge tank consisting of 9 compartments with constant volume.



Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3
Vol05	Volume of compartment no.5	1000	m3
Vol06	Volume of compartment no.6	1000	m3
Vol07	Volume of compartment no.7	1000	m3
Vol08	Volume of compartment no.8	1000	m3
Vol09	Volume of compartment no.9	1000	m3

State Variables

None

Derived State Variables

None

Interface Variables

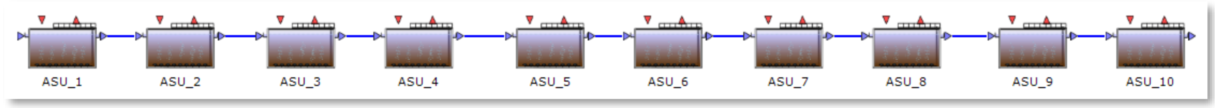
Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*
kLa_05	*in_2*	*Oxygen transfer coeff. in compartment no.5*	*1*	*1/d*
kLa_06	*in_2*	*Oxygen transfer coeff. in compartment no.6*	*1*	*1/d*
kLa_07	*in_2*	*Oxygen transfer coeff. in compartment no.7*	*1*	*1/d*
kLa_08	*in_2*	*Oxygen transfer coeff. in compartment no.8*	*1*	*1/d*
kLa_09	*in_2*	*Oxygen transfer coeff. in compartment no.9*	*1*	*1/d*

VolumeConstant10

Instances
All

Description
The model describes an ideally mixed, activated sludge tank consisting of 10 compartments with constant volume.



Parameters
Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol01	Volume of compartment no.1	1000	m3
Vol02	Volume of compartment no.2	1000	m3
Vol03	Volume of compartment no.3	1000	m3
Vol04	Volume of compartment no.4	1000	m3
Vol05	Volume of compartment no.5	1000	m3
Vol06	Volume of compartment no.6	1000	m3
Vol07	Volume of compartment no.7	1000	m3
Vol08	Volume of compartment no.8	1000	m3
Vol09	Volume of compartment no.9	1000	m3
Vol10	Volume of compartment no.10	1000	m3

State Variables
None

Derived State Variables
None

Interface Variables
Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15.0*	*°C*
kLa_01	*in_2*	*Oxygen transfer coeff. in compartment no.1*	*1*	*1/d*
kLa_02	*in_2*	*Oxygen transfer coeff. in compartment no.2*	*1*	*1/d*
kLa_03	*in_2*	*Oxygen transfer coeff. in compartment no.3*	*1*	*1/d*
kLa_04	*in_2*	*Oxygen transfer coeff. in compartment no.4*	*1*	*1/d*
kLa_05	*in_2*	*Oxygen transfer coeff. in compartment no.5*	*1*	*1/d*
kLa_06	*in_2*	*Oxygen transfer coeff. in compartment no.6*	*1*	*1/d*
kLa_07	*in_2*	*Oxygen transfer coeff. in compartment no.7*	*1*	*1/d*
kLa_08	*in_2*	*Oxygen transfer coeff. in compartment no.8*	*1*	*1/d*
kLa_09	*in_2*	*Oxygen transfer coeff. in compartment no.9*	*1*	*1/d*
kLa_10	*in_2*	*Oxygen transfer coeff. in compartment no.10*	*1*	*1/d*

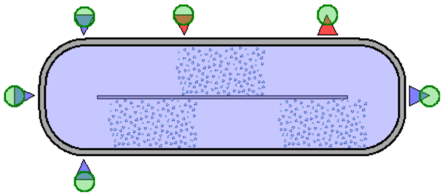
Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

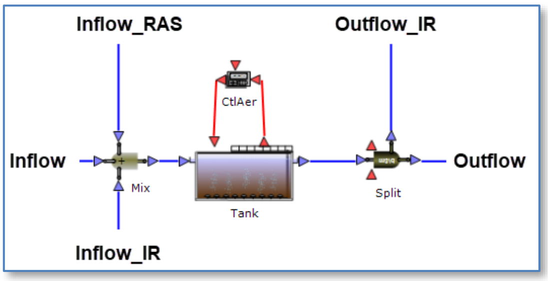
Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
P_Mix	out_2	Power consumption for mixing	---	W
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

OXIDATION DITCH

<table>
<tr><td rowspan="4"></td><td>Palette Group</td><td>Biological Treatment</td></tr>
<tr><td>Category</td><td>OxidationDitch</td></tr>
<tr><td>Icon Name</td><td>oxidation_ditch</td></tr>
<tr><td></td><td></td></tr>
</table>

Sector

This class is not associated to any icon, thus not exposed through the WEST GUI.
It is only used as a building block for the oxidation ditch classes.



Description

This class combines the following models into a coupled model (as shown in the figure):

- a 3-way combiner
- an ASU tank with constant volume
- a PI controller for DO control
- and a 2-way splitter

The 3-way combiner receives the main inflow and two additional flows, potentially assigned to an internal- and to a sludge recycle. Depending on the actual set up of the oxidation ditch that incorporates this unit, these two additional flows may be unassigned (see Oxidation_Ditch model).

The class does not implement any process, it merely coordinates the sub-models and exposes interface variables.

Parameters

None

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d

Derived State Variables

None

Sub-models

Name	Class Name	
Mix	Mixers.Mix03	
Tank	Tanks_AS.VolumeConstant	
CtlAer	Controllers.PI_Saturation	
Split	Splitters.SplitAbs02	

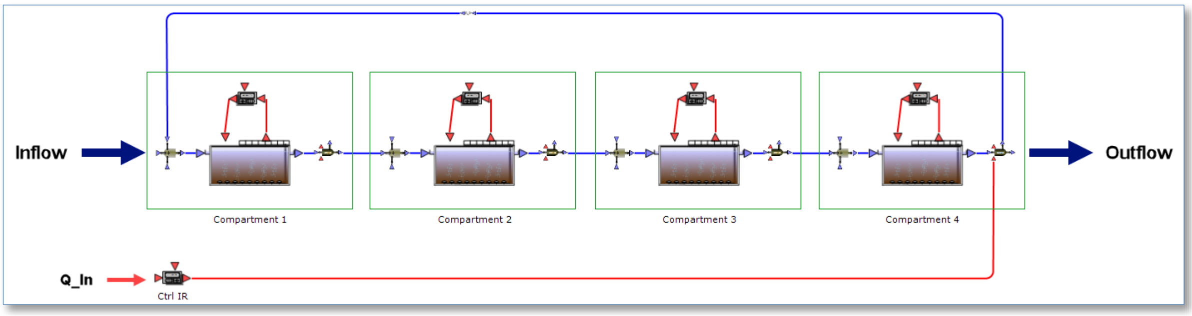
Interface Variables

Name	Terminal	Description	Value	Units
Inflow	---	Inflow	---	g/d
Outflow	---	Outflow	---	g/d
Inflow_IR	---	Inflow for internal recycle	---	g/d
Outflow_IR	---	Outflow for internal recycle	---	g/d
Inflow_RAS	---	Inflow for activated sludge recycle	---	g/d

Ditch04

Instances

All



Description

This class combines the following models into a coupled model (as shown in the figure):

- 4 sectors, each representing a section of the oxidation ditch that may or may not be aerated
- a ratio controller that regulates the internal recirculation from compartment 4 back to compartment 1
- and a loop-breaker

The temperature in the tank (same in all compartments) as well as the DO set-points and maximum kLa's for each compartment can be set via manipulated variables.
The internal (fictitious) recirculation rate is regulated via the manipulated variable R, and based on the influent flow rate – that is to be provided as an input signal, from an external flow sensor.

Remark: in the current version of the model, the RAS recirculation flow is not handled.
An external combiner, upstream to the first compartment, is to be used to receive the RAS flow.

Parameters

Name	Description	Value	Units
H	Depth of the tank	4	m
L	Length of the tank	50	m
W	Width of the tank	10	m
v_01 .. 04	Fraction of the total volume for compartment no.1 .. 4	0.25	---

State Variables

Name	Description	Units
Q_tot	Total flow through the ditch	m3/d
v_H	Horizontal velocity	m/s

Derived State Variables

None

Sub-models

Name	Class Name
Comp_01 .. 04	Sector
CtrlIR	Controllers.Ratio
LB	LoopBreakers.MainDiff

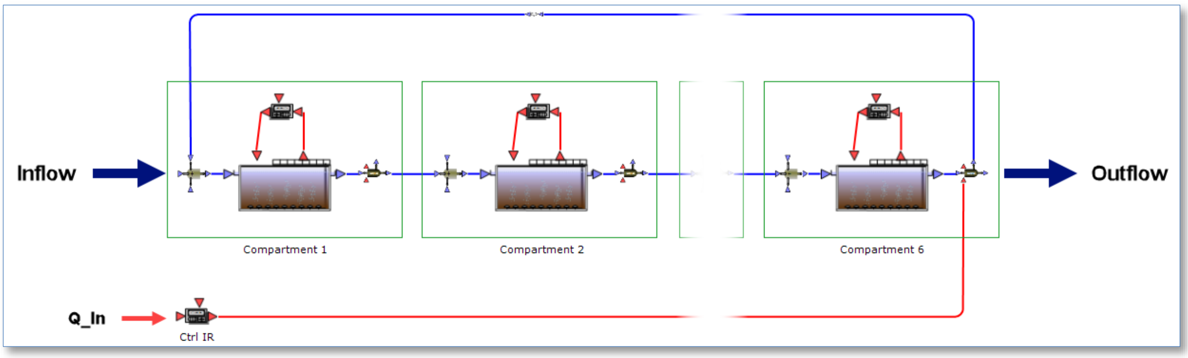
Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Inflow_IR	in_4	Inflow for internal recycle	---	g/d
Inflow_RAS	in_3	Inflow for activated sludge recycle	---	g/d
P_Aer	out_2	Power consumption for aeration	---	kWh/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
OUR_01 .. 04	out_2	Oxygen Uptake Rate, compartment no.1 .. 4	---	g/m3/d
TSS_01 .. 04	out_2	Total solids, compartment no.1 .. 4	---	g/m3
V_01 .. 04	out_2	Volume, compartment no.1 .. 4	---	m3
TSS_tot	out_2	Total TSS concentration in the tank	---	g/m3
V_tot	out_2	Total volume of the tank	---	m3
Q_In	in_2	Influent flow rate	20,000	m3/d
DOsp_01 .. 04	*in_2*	*DO set-point for compartment no.1 .. 4*	*2*	*g/m3*
KP_01 .. 04	*in_2*	*Factor of proportionality*	*25*	---
kLa_Max_01 .. 04	*in_2*	*Maximum kLa for compartment no.1 .. 4*	*1000*	*1/d*
R	*in_2*	*Internal (virtual) recirculation rate*	*50*	---
Temp	*in_2*	*Temperature*	*15.0*	*°C*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

Ditch06

Instances

All



Description

This class combines the following models into a coupled model (as shown in the figure):

- 6 sectors, each representing a section of the oxidation ditch that may or may not be aerated
- a ratio controller that regulates the internal recirculation from compartment 6 back to compartment 1
- and a loop-breaker

The temperature in the tank (same in all compartments) as well as the DO set-points and maximum kLa's for each compartment can be set via manipulated variables.
The internal (fictitious) recirculation rate is regulated via the manipulated variable R, and based on the influent flow rate – that is to be provided as an input signal, from an external flow sensor.

Remark: in the current version of the model, the RAS recirculation flow is not handled.
An external combiner, upstream to the first compartment, is to be used to receive the RAS flow.

Parameters

Name	Description	Value	Units
H	Depth of the tank	4	m
L	Length of the tank	50	m
W	Width of the tank	10	m
v_01 .. 06	Fraction of the total volume for compartment no.1 .. 6	0.2	---

State Variables

Name	Description	Units
Q_tot	Total flow through the ditch	m3/d
v_H	Horizontal velocity	m/s

Derived State Variables

None

Sub-models

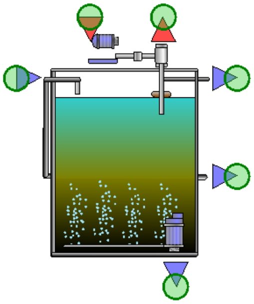
Name	Class Name
Comp_01 .. 06	Sector

Name	Class Name
CtrlIR	Controllers.Ratio
LB	LoopBreakers.MainDiff

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Inflow_IR	in_4	Inflow for internal recycle	---	g/d
Inflow_RAS	in_3	Inflow for activated sludge recycle	---	g/d
P_Aer	out_2	Power consumption for aeration	---	kWh/d
P_Mix	out_2	Power consumption for mixing	---	kWh/d
OUR_01 .. 06	out_2	Oxygen Uptake Rate, compartment no.1 .. 6	---	g/m3/d
TSS_01 .. 06	out_2	Total solids, compartment no.1 .. 6	---	g/m3
V_01 .. 06	out_2	Volume, compartment no.1 .. 6	---	m3
TSS_tot	out_2	Total TSS concentration in the tank	---	g/m3
V_tot	out_2	Total volume of the tank	---	m3
Q_In	in_2	Influent flow rate	20,000	m3/d
DOsp_01 .. 06	*in_2*	*DO set-point for compartment no.1 .. 6*	*2*	*g/m3*
KP_01 .. 06	*in_2*	*Factor of proportionality*	*25*	*---*
kLa_Max_01 .. 06	*in_2*	*Maximum kLa for compartment no.1 .. 6*	*1000*	*1/d*
R	*in_2*	*Internal (virtual) recirculation rate*	*50*	*---*
Temp	*in_2*	*Temperature*	*15.0*	*°C*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SEQUENCING BATCH REACTORS

	Palette Group	**Biological Treatment**
	Category	Tanks_SBR
	Icon Name	sbr

SBR_PS_R01

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The settling phase is described by a point-settler model.
A ‘launch’ phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d

Name	Description	Units
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	---
F_Th	*in_2*	*Thickening factor*	*2.0*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R02

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 2 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A ‘launch’ phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	*---*
F_Th	*in_2*	*Thickening factor*	*2.0*	*---*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R03

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 3 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A ‘launch’ phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	**Description**	**Units**
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	**Description**	**Units**
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	**Terminal**	**Description**	**Value**	**Units**
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
Kla_R03	*in_2*	*Oxygen transfer for reaction phase no.3*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T2R03	*in_2*	*Length of reaction phase no.3*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	---
F_Th	*in_2*	*Thickening factor*	*2.0*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R04

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 4 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A 'launch' phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
Kla_R03	*in_2*	*Oxygen transfer for reaction phase no.3*	*50*	*1/d*
Kla_R04	*in_2*	*Oxygen transfer for reaction phase no.4*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T2R03	*in_2*	*Length of reaction phase no.3*	*0.075*	*d*
T2R04	*in_2*	*Length of reaction phase no.4*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	*---*
F_Th	*in_2*	*Thickening factor*	*2.0*	*---*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R05

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 5 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A ‘launch’ phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
Kla_R03	*in_2*	*Oxygen transfer for reaction phase no.3*	*50*	*1/d*
Kla_R04	*in_2*	*Oxygen transfer for reaction phase no.4*	*50*	*1/d*
Kla_R05	*in_2*	*Oxygen transfer for reaction phase no.5*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T2R03	*in_2*	*Length of reaction phase no.3*	*0.075*	*d*
T2R04	*in_2*	*Length of reaction phase no.4*	*0.075*	*d*
T2R05	*in_2*	*Length of reaction phase no.5*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	*---*
F_Th	*in_2*	*Thickening factor*	*2.0*	*---*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R06

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 6 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A ‘launch’ phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
Kla_R03	*in_2*	*Oxygen transfer for reaction phase no.3*	*50*	*1/d*
Kla_R04	*in_2*	*Oxygen transfer for reaction phase no.4*	*50*	*1/d*
Kla_R05	*in_2*	*Oxygen transfer for reaction phase no.5*	*50*	*1/d*
Kla_R06	*in_2*	*Oxygen transfer for reaction phase no.6*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T2R03	*in_2*	*Length of reaction phase no.3*	*0.075*	*d*
T2R04	*in_2*	*Length of reaction phase no.4*	*0.075*	*d*
T2R05	*in_2*	*Length of reaction phase no.5*	*0.075*	*d*
T2R06	*in_2*	*Length of reaction phase no.6*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	---
F_Th	*in_2*	*Thickening factor*	*2.0*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R07

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 7 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A ‘launch’ phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
Kla_R03	*in_2*	*Oxygen transfer for reaction phase no.3*	*50*	*1/d*
Kla_R04	*in_2*	*Oxygen transfer for reaction phase no.4*	*50*	*1/d*
Kla_R05	*in_2*	*Oxygen transfer for reaction phase no.5*	*50*	*1/d*
Kla_R06	*in_2*	*Oxygen transfer for reaction phase no.6*	*50*	*1/d*
Kla_R07	*in_2*	*Oxygen transfer for reaction phase no.7*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T2R03	*in_2*	*Length of reaction phase no.3*	*0.075*	*d*
T2R04	*in_2*	*Length of reaction phase no.4*	*0.075*	*d*
T2R05	*in_2*	*Length of reaction phase no.5*	*0.075*	*d*
T2R06	*in_2*	*Length of reaction phase no.6*	*0.075*	*d*
T2R07	*in_2*	*Length of reaction phase no.7*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	*---*
F_Th	*in_2*	*Thickening factor*	*2.0*	*---*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SBR_PS_R08

Instances

All

Description

The model describes a Sequencing Batch Reactor (SBR), consisting of 5 phases:

	Filling	Reaction	Settling	Withdrawal	Idle
$Q_{bypass} =$	0	0	Q_{in}	Q_{in}	Q_{in}
$Q_{out} =$	$N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$	0	0	Q_{draw}	0
$Q_{under} =$	0	0	0	0	Q_{waster}

The reaction phase is split into 8 sub-phases which are independently aerated, thereby allowing for anoxic/aerated sequences.
The settling phase is described by a point-settler model.
A 'launch' phase allows for accounting for multiple units operated in sequence.

During the **filling phase**, the tank is assumed to be ideally mixed and receives the influent stream and gets progressively filled, until the volume reaches the threshold V_{max}.
When the tank is full, the influent flows over directly to an overflow, which is regulated by the weirs:

$$Q_{out} = N \cdot \alpha \cdot \left(\frac{V - V_{max}}{A}\right)^{\beta}$$

where:

- α and β are empirical factors (-), function of the type or width and of the design of the weirs respectively
- N is the number of weirs (-)
- V_{max} is the volume (m3) of the tank under the weirs
- V and A denote the volume (m3) and the surface area (m2) of the tank, respectively

During the **reaction phase**, the tank is assumed to be ideally mixed: the concentration of both the effluent- and the sludge stream therefore equals the concentration of the mixed liquor in the tank.

During the **settling phase**, no conversion process takes place and the point-settler model governs the solid/liquid separation process.

During the **withdrawal phase**, the clarified water is withdrawn from the tank and only contains the non-settleable fraction of particulate matter:

$$C_{out,X_i} = C_{X_i} \cdot f_{ns}$$

where:

- C_{out,X_i} and C_{X_i} denote the concentration (g/m3) of the generic i-*th* particulate component in the effluent and in the tank respectively
- f_{ns} is the fraction (-) of non-settleable suspended solids

During the **idle phase** the sludge gets wasted and contains the settleable fraction, which has thickened during the settle phase:

$$C_{under,X_i} = C_{X_i} \cdot (1 - f_{ns}) \cdot F_{th}$$

where:

- C_{under,X_i} denotes the concentration (g/m3) of the generic i-*th* particulate component in the underflow
- F_{th} represents a thickening factor (-) for the suspended solids

Before the first filling phase, a **launch period** is foreseen to accommodate for multiple SBR tanks run in parallel.
The launch period is considered as a reaction phase, i.e. no filling or settling, only biological reactions.

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

Energy consumption for aeration, mixing and pumping is estimated as follows:

$$P_{Aer} = \frac{S_{O,sat} \cdot k_{La} \cdot V}{24 \cdot OTR}$$

$$P_{Mix} = \frac{ME \cdot V}{24}$$

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR, ME and F indicate the Oxygen Transfer Rate (g/kWh), the mixing energy per unit volume (kWh/m3/d) and the pumping energy per unit flow rate (kWh/m3) respectively
- V and Q_{out} denote the tank volume (m3) and the effluent flow rate (m3/d)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
A	Surface area of the tank below the weirs	400.0	m2
V_Min	Minimum volume of the tank	1.0	m3
V_Max	Maximum volume of the tank	2000.0	m3
N	Number of weirs	100	---
alfa	Empirical factor function of weir type or width	1	---
beta	Empirical factor function of weir design	1	---
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Mixing is guaranteed while aerating? (0=yes, 1=no)	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Under	Sludge withdrawal flow rate	m3/d
Q_Over	By-pass flow rate	m3/d
T	Total duration of 1 cycle	d
T2	Total duration of the reaction phase	d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

Name	Description	Units
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

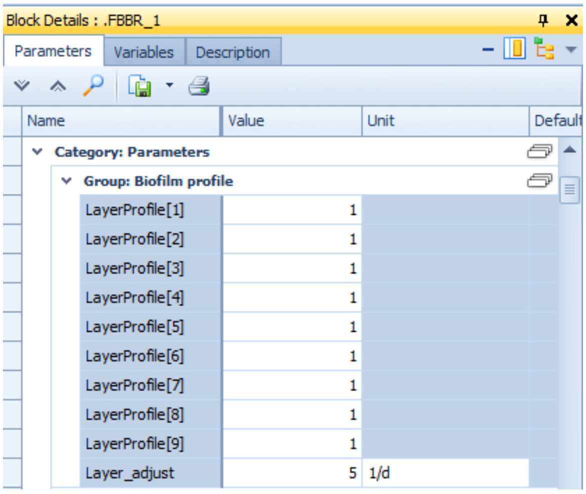
Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Outflow2	out_3	By-pass flow (component vector)	---	g/d
Outflow3	out_4	Waste flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
P_Pump	out_2	Power consumption for pumping	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
Kla_Launch	*in_2*	*Oxygen transfer for the launch phase*	*0*	*1/d*
Kla_Fill	*in_2*	*Oxygen transfer for the filling phase*	*0*	*1/d*
Kla_R01	*in_2*	*Oxygen transfer for reaction phase no.1*	*50*	*1/d*
Kla_R02	*in_2*	*Oxygen transfer for reaction phase no.2*	*50*	*1/d*
Kla_R03	*in_2*	*Oxygen transfer for reaction phase no.3*	*50*	*1/d*
Kla_R04	*in_2*	*Oxygen transfer for reaction phase no.4*	*50*	*1/d*
Kla_R05	*in_2*	*Oxygen transfer for reaction phase no.5*	*50*	*1/d*
Kla_R06	*in_2*	*Oxygen transfer for reaction phase no.6*	*50*	*1/d*
Kla_R07	*in_2*	*Oxygen transfer for reaction phase no.7*	*50*	*1/d*
Kla_R08	*in_2*	*Oxygen transfer for reaction phase no.8*	*50*	*1/d*
T_Launch	*in_2*	*Delay in the start-up*	*0.0*	*d*
T1	*in_2*	*Duration of the fill phase*	*0.125*	*d*
T2R01	*in_2*	*Length of reaction phase no.1*	*0.075*	*d*
T2R02	*in_2*	*Length of reaction phase no.2*	*0.075*	*d*
T2R03	*in_2*	*Length of reaction phase no.3*	*0.075*	*d*
T2R04	*in_2*	*Length of reaction phase no.4*	*0.075*	*d*
T2R05	*in_2*	*Length of reaction phase no.5*	*0.075*	*d*
T2R06	*in_2*	*Length of reaction phase no.6*	*0.075*	*d*
T2R07	*in_2*	*Length of reaction phase no.7*	*0.075*	*d*
T2R08	*in_2*	*Length of reaction phase no.8*	*0.075*	*d*
T3	*in_2*	*Duration of the settling phase*	*0.125*	*d*
T4	*in_2*	*Duration of the draw phase*	*0.125*	*d*
T5	*in_2*	*Duration of the idle phase*	*0.125*	*d*
Q_Draw	*in_2*	*Desired withdraw flow rate*	*24,000*	*m3/d*
Q_Waste	*in_2*	*Desired waste flow*	*240.0*	*m3/d*
f_ns	*in_2*	*Non-settleable fraction of the suspended solids*	*0.005*	*---*
F_Th	*in_2*	*Thickening factor*	*2.0*	*---*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*

E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

BIOFILM MODELS

The biofilm is represented as a number of layers (default 10), with the outer layer in contact with a “bulk” liquid compartment. Reactions take place in each layer and the bulk, and components diffuse between the different compartments. The layers generally grow with time, until the overall thickness of the biofilm reaches a maximum value, after which the biomass is detached into the bulk liquid.

The layers do not have any physical significance – they are a numerical device to represent the continuous variation of conditions through the biofilm. Since the number of layers is fixed, the layer thicknesses grow as the biofilm grows. The model has a mechanism to maintain the relative thicknesses of the layers as the biofilm grows. This is the **Biofilm Profile**, a set of parameters which represent the relative thickness of each layer. The default values of 1 mean that all layers will be maintained with equal thicknesses.

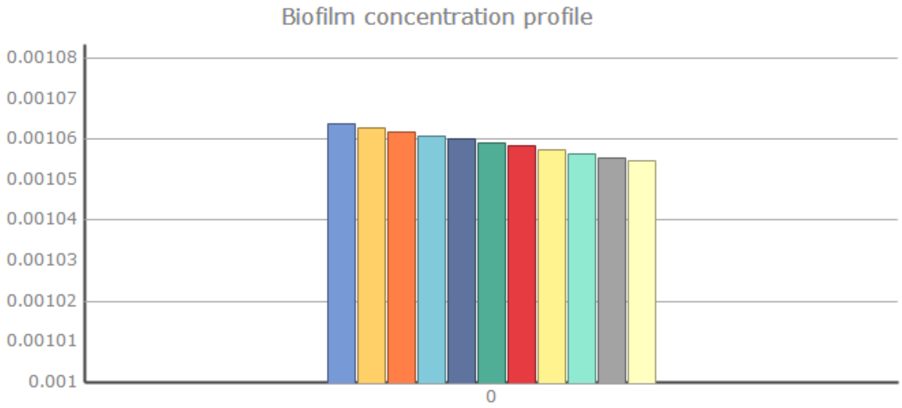


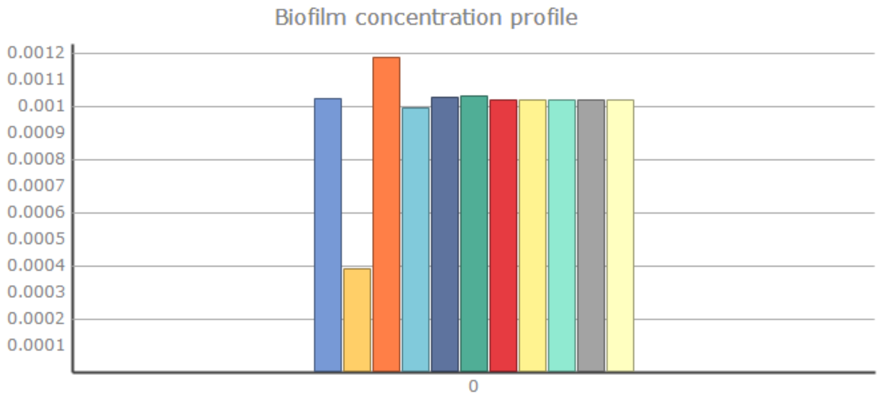
Category: Parameters

Group: Biofilm profile

Name	Value	Unit	Defaul
LayerProfile[1]	1		
LayerProfile[2]	1		
LayerProfile[3]	1		
LayerProfile[4]	1		
LayerProfile[5]	1		
LayerProfile[6]	1		
LayerProfile[7]	1		
LayerProfile[8]	1		
LayerProfile[9]	1		
Layer_adjust	5	1/d	

The **Layer_adjust** parameter controls how fast the layers adjust to maintain the profile.
The model of diffusion of components between layers is subject to numerical instability which causes concentration values to oscillate. These two graphs show snapshots of a stable solution and an unstable one.



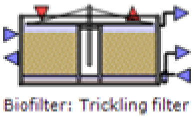


This instability causes the solution to run extremely slowly as the solver tries to track the oscillations. The problem can be partly mitigated by setting very tight tolerances on the solver accuracy. The problem is most acute at the start of a new model when the standard WEST procedure of initializing with default values causes steep initial concentration gradients between the bulk liquid and the biofilm layers.
To overcome this a “Biofilm Initialisation” mechanism is provided that adjusts the initial masses in the biofilm layers to match the bulk default values.
This is controlled by the parameter **Initialise_Biofilm_Masses**. If this is set > 0 the initialization runs, otherwise not. Since this only applies at the beginning of a new model, it is automatically set to zero once it has run. It should only be used when the bulk masses are initialized with default values, i.e. when starting up a model from new, or after resetting initial values to default.

The parameter **d_max** sets the maximum biofilm thickness (the sum of the layer thicknesses).
The layers grow until the limit is reached, after which particulate matter is detached into the bulk liquid. There are two options for the detachment model, controlled by the **Detach_option** parameter. If set to 0, detachment is from the outermost layer only (layer 1). If set to 1 detachment is proportionally from all layers. The potential problem with option 0 is that the inner layers gradually become completely filled with inert organic mass which crowds out the active biomass.

The biofilm models inherit variables and parameters from the underlying biochemical models (e.g., ASM1, AS2dMod, etc.). In addition, there are parameters and variables specific to the biofilm models.

Filter1D

	Palette Group	**Biological Treatment**
	Category	Tanks_Filters
	Icon Name	biofilter

Instances

All

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
d_ini	Initial biofilm thickness	0.0001	m
d_max	Maximum biofilm thickness	0.0005	m
eta	Porosity of the biofilm	1	---
rho	Density of the biofilm	40,000	g/m3
Initialise_Biofilm_Masses	1 - Initialise values; 0 - keep current values	1	---
Detach_option	0 - from outer layer only; 1 - from all layers	1	---
LayerProfile	Relative thickness of each biofilm layer	0	---
Layer_adjust	Layer adjustment rate constant	0.1	1/d
k_Dt	Rate constant for the detachment process	0.0001	---
A_c_sp	Specific surface area of the carriers	400	1/m
H	Depth of the reactor	4	m
L	Length of the reactor	10	m
W	Width of the reactor	5	m
f_void_vol	Void space of the media	0.5	---
deltao	Thickness of boundary layer between biofilm and bulk	1E-05	m
k_At	Coefficient for attachment of particulate	0.1	1/d

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C_Biofilm	Concentration of the state components in each layer (matrix)	g/m3
M_Biofilm	Mass of the state components in each layer (matrix)	g/m3
d	Thickness of the biofilm	m
d_layer	Thickness of each layer (vector)	m
V_bf	Volume of the biofilm	m3
V_layer	Volume of each layer (vector)	m3
C_Bulk	Concentration of the state components in the bulk (vector)	g/m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

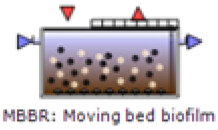
None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
DO	out_2	Dissolved oxygen concentration	---	g/m3
OUR_bf	out_2	Oxygen Uptake Rate in the biofilm	---	g/m3/d
OUR_bk	out_2	Oxygen Uptake Rate in the bulk	---	g/m3/d
OUR_tot	out_2	Total Oxygen Uptake Rate	---	g/m3/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*0*	*1/d*

MBBR

 	Palette Group	**Biological Treatment**
	Category	Tanks_Filters
	Icon Name	mbbr

Instances

All

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
d_ini	Initial biofilm thickness	0.0001	m
d_max	Maximum biofilm thickness	0.0005	m
eta	Porosity of the biofilm	1	---
rho	Density of the biofilm	40,000	g/m3
Initialise_Biofilm_Masses	1 - Initialise values; 0 - keep current values	1	---
Detach_option	0 - from outer layer only; 1 - from all layers	1	---
LayerProfile	Relative thickness of each biofilm layer	0	---
Layer_adjust	Layer adjustment rate constant	0.1	1/d
k_Dt	Rate constant for the detachment process	0.0001	---
A_c_sp	Specific surface area of the carriers	400	1/m
H	Depth of the reactor	4	m
L	Length of the reactor	10	m
W	Width of the reactor	5	m
f_c_vol	Fraction of the volume occupied by the carriers	0.05	---
deltao	Thickness of boundary layer between biofilm and bulk	1E-05	m
k_At	Coefficient for attachment of particulate	0.1	1/d

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C_Biofilm	Concentration of the state components in each layer (matrix)	g/m3
M_Biofilm	Mass of the state components in each layer (matrix)	g/m3
d	Thickness of the biofilm	m
d_layer	Thickness of each layer (vector)	m
V_bf	Volume of the biofilm	m3
V_layer	Volume of each layer (vector)	m3
C_Bulk	Concentration of the state components in the bulk (vector)	g/m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

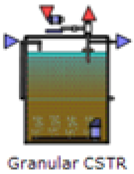
None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
DO	out_2	Dissolved oxygen concentration	---	g/m3
OUR_bf	out_2	Oxygen Uptake Rate in the biofilm	---	g/m3/d
OUR_bk	out_2	Oxygen Uptake Rate in the bulk	---	g/m3/d
OUR_tot	out_2	Total Oxygen Uptake Rate	---	g/m3/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*0*	*1/d*

GranuleCSTR

	Palette Group	**Biological Treatment**
	Category	Tanks_Filters
	Icon Name	cstr_gr

Instances

All

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
d_ini	Initial biofilm thickness	0.0001	m
d_max	Maximum biofilm thickness	0.0005	m
eta	Porosity of the biofilm	1	---
rho	Density of the biofilm	40,000	g/m3
Initialise_Biofilm_Masses	1 - Initialise values; 0 - keep current values	1	---
Detach_option	0 - from outer layer only; 1 - from all layers	1	---
LayerProfile	Relative thickness of each biofilm layer	0	---
Layer_adjust	Layer adjustment rate constant	0.1	1/d
k_Dt	Rate constant for the detachment process	0.0001	---
H	Depth of the reactor	4	m
L	Length of the reactor	10	m
W	Width of the reactor	5	m
carrier_dia	Diameter of the carrier	0.02	m
f_gr_max	Max filling degree of the granules in the reactor	0.5	---
deltao	Thickness of boundary layer between biofilm and bulk	1E-05	m
k_At	Coefficient for attachment of particulate	0.1	1/d

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C_Biofilm	Concentration of the state components in each layer (matrix)	g/m3
M_Biofilm	Mass of the state components in each layer (matrix)	g/m3
d	Thickness of the biofilm	m
d_layer	Thickness of each layer (vector)	m
V_bf	Volume of the biofilm	m3
V_layer	Volume of each layer (vector)	m3
C_Bulk	Concentration of the state components in the bulk (vector)	g/m3
f_gr_vol	Fraction of the volume occupied by the granules	---
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
V_gr_tot	Volume occupied by the granules in the reactor	m3
gr_dia	Diameter of the single granule	m

Derived State Variables

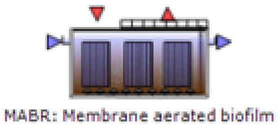
None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
DO	out_2	Dissolved oxygen concentration	---	g/m3
OUR_bf	out_2	Oxygen Uptake Rate in the biofilm	---	g/m3/d
OUR_bk	out_2	Oxygen Uptake Rate in the bulk	---	g/m3/d
OUR_tot	out_2	Total Oxygen Uptake Rate	---	g/m3/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*0*	*1/d*

MABR

	Palette Group	**Biological Treatment**
	Category	Tanks_Filters
	Icon Name	mabr

Instances

All

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
mode	Via kLa-membrane (0), ideal model (1)	0	---
d_ini	Initial biofilm thickness	0.0001	m
d_max	Maximum biofilm thickness	0.0005	m
eta	Porosity of the biofilm	1	---
rho	Density of the biofilm	40,000	g/m3
Initialise_Biofilm_Masses	1 - Initialise values; 0 - keep current values	1	---
Detach_option	0 - from outer layer only; 1 - from all layers	1	---
LayerProfile	Relative thickness of each biofilm layer	0	---
Layer_adjust	Layer adjustment rate constant	0.1	1/d
k_Dt	Rate constant for the detachment process	0.0001	---
A_sp_module	Specific surface area (per unit length) of one membrane aeration module	1,000	m
H	Depth of the reactor	4	m
L	Length of the reactor	10	m
L_module	Length of one membrane aeration module	1	m
N_module	Number of aeration modules in one reactor		
V_sp_module	Specific volume (per unit length) of one membrane aeration module	0.2	m2
W	Width of the reactor	5	m
carrier_dia	Diameter of the carrier	0.02	m
f_gr_max	Max filling degree of the granules in the reactor	0.5	---
deltao	Thickness of boundary layer between biofilm and bulk	1E-05	m
k_At	Coefficient for attachment of particulate	0.1	1/d

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
k_O2	Oxygen mass transfer coefficient from membrane to biofilm	m/d
C_Biofilm	Concentration of the state components in each layer (matrix)	g/m3
M_Biofilm	Mass of the state components in each layer (matrix)	g/m3
d	Thickness of the biofilm	m
d_layer	Thickness of each layer (vector)	m
V_bf	Volume of the biofilm	m3
V_layer	Volume of each layer (vector)	m3
C_Bulk	Concentration of the state components in the bulk (vector)	g/m3

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

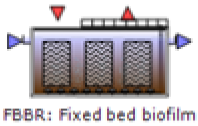
None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
DO	out_2	Dissolved oxygen concentration	---	g/m3
OUR_bf	out_2	Oxygen Uptake Rate in the biofilm	---	g/m3/d
OUR_bk	out_2	Oxygen Uptake Rate in the bulk	---	g/m3/d
OUR_tot	out_2	Total Oxygen Uptake Rate	---	g/m3/d
Kla_membrane	*in_2*	*Oxygen transfer coefficient for the membrane*	*1,000*	*1/d*
Q_air	*in_2*	*Air flow rate under standard conditions*	*100,000*	*m3/d*
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*0*	*1/d*

FBBR

	Palette Group	**Biological Treatment**
	Category	Tanks_Filters
	Icon Name	fbbr

Instances

All

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
d_ini	Initial biofilm thickness	0.0001	m
d_max	Maximum biofilm thickness	0.0005	m
eta	Porosity of the biofilm	1	---
rho	Density of the biofilm	40,000	g/m3
Initialise_Biofilm_Masses	1 - Initialise values; 0 - keep current values	1	---
Detach_option	0 - from outer layer only; 1 - from all layers	1	---
LayerProfile	Relative thickness of each biofilm layer	0	---
Layer_adjust	Layer adjustment rate constant	0.1	1/d
k_Dt	Rate constant for the detachment process	0.0001	---
A_sp_module	Specific surface area (per unit length) of one membrane aeration module	1,000	m
H	Depth of the reactor	4	m
L	Length of the reactor	10	m
L_module	Length of one membrane aeration module	1	m
N_module	Number of aeration modules in one reactor		
V_sp_module	Specific volume (per unit length) of one membrane aeration module	0.2	m2
W	Width of the reactor	5	m
carrier_dia	Diameter of the carrier	0.02	m
f_gr_max	Max filling degree of the granules in the reactor	0.5	---
deltao	Thickness of boundary layer between biofilm and bulk	1E-05	m
k_At	Coefficient for attachment of particulate	0.1	1/d

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C_Biofilm	Concentration of the state components in each layer (matrix)	g/m3
M_Biofilm	Mass of the state components in each layer (matrix)	g/m3
d	Thickness of the biofilm	m
d_layer	Thickness of each layer (vector)	m
V_bf	Volume of the biofilm	m3
V_layer	Volume of each layer (vector)	m3
C_Bulk	Concentration of the state components in the bulk (vector)	g/m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Derived State Variables

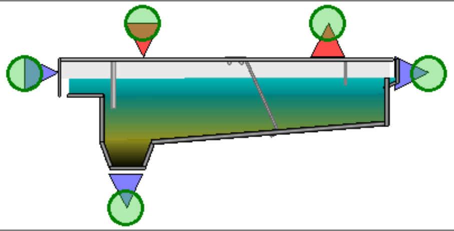
None

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
DO	out_2	Dissolved oxygen concentration	---	g/m3
OUR_bf	out_2	Oxygen Uptake Rate in the biofilm	---	g/m3/d
OUR_bk	out_2	Oxygen Uptake Rate in the bulk	---	g/m3/d
OUR_tot	out_2	Total Oxygen Uptake Rate	---	g/m3/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*0*	*1/d*

PRIMARY CLARIFIERS

	Palette Group	**Separation**
	Category	Settlers_PST
	Icon Name	clarifier_primary

Point

Instances

All

Description

The model is a large simplification of the actual process: the settling tank has no volume thus no retention time and acts as an ideal phase separator.

$$Q_{out} = Q_{in} - Q_{under}$$

$$(Q_{in} \leq Q_{under}): Q_{under} = Q_{in}$$
$$(Q_{in} > Q_{under}): Q_{under} = Q^{*}_{under}$$

where:

- Q_{in}, Q_{under} and Q_{in} denote the influent-, effluent- and underflow flow rates (m3/d) respectively
- Q^{*}_{under} is the desired underflow flow rate (m3/d)

The mass balance over the settling tank is as follows:

$$C_{out,S_i} = C_{in,S_i}$$

$$C_{out,X_i} = f_{ns} \cdot C_{in,X_i}$$

$$C_{under,S_i} = C_{in,S_i}$$

$$C_{under,X_i} = (1 - f_{ns}) \cdot C_{in,X_i}$$

where:

- C is the concentration of the *i*-th state component (g/m3) (suffixes S and X denotes soluble and particulate components)
- f_{ns} is fraction (-) of non-settleable solids

No conversion process occurs in the tank volume.

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
f_ns	*in_2*	*Fraction of non-settleable solids*	*0.6*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

OtterpohlFreund

Instances

All

Description

The removal of particulate matter is the key variable of the model of Otterpohl and Freund (1992) for primary clarifiers.

The assumption is made that the removal of solids is essentially dependent on the hydraulic residence time. The same empirical relationship, originally identified by Sierp (1967) for BOD removal, can be extended to COD removal:

$$Eff_{COD} = \alpha \cdot (\log HRT^2 + \beta)$$

where:

- α and β denote empirical factors
- HRT indicates the retention time in minutes

In a subsequent work, Otterpohl et al. (1994) improved the original formula, as follows:

$$Eff_{COD} = f_{corr} \cdot (2.88 \cdot f_X - 0.118) \cdot (1.45 + 6.15 \cdot \log HRT)$$

where:

- f_{corr} is a correction factor
- f_X is the particulate- to total COD ratio

This gives Eff_{COD} as a percent of the total COD in the influent that is removed by the primary clarifier. In this model all the COD removed is assumed to be particulate COD. It is assumed that there are no biological reactions.

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
Vol	Volume	1000	m3
f_corr	Correction factor removal efficiency	0.65	-
f_X	Particulate COD to total COD	0.85	-
t_m	Smoothing time constant	0.125	d

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
t_h	Hydraulic retention time	d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%
r_COD	Total COD removal efficiency	-
r_TSS	Total solids removal efficiency	-
r_X_COD	Particulate COD removal efficiency	-
V	Volume	m3

C	Concentration vector	g/m3

Derived State Variables

Name	Description	Units
M	Mass vector	g
Q_m	Mean influent flow rate	m3/d

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
f_PS	*in_2*	*Primary sludge- to influent flow rate ratio*	*0.007*	-
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
P_Pump	out_3	Pumping power	---	kWh/d
V_Tank	out_3	Volume of the tank	---	m3

Takacs_SVI

Instances

All

Description

The model of Takacs is based on the model of Vitasovic.

The settler is modelled with a number of layers (NR_OF_LAYERS) layers around which a solids balance is made.

Some assumptions are made:

- The incoming solids are distributed immediately homogenous over the feed layer.
- Only vertical flow is considered.

The settling velocity of the sludge blanket has been found to be a non-linear function of the solids concentration. In Vitasovic's model the settling flux is due to the gravity settling and also due to the bulk flux.

The **bulk flux** is upward above the feed layer and resulting from the overflow rate. Beneath the feed layer the bulk flux is downward and resulting from the underflow rate.

$$J_{up} = X_{L,i} \cdot v_{up}$$

$$v_{up} = \frac{Q_{out}}{A}$$

$$J_{dn} = X_{L,i} \cdot v_{dn}$$

$$v_{dn} = \frac{Q_{under}}{A}$$

The **gravitational flux** is always downwards.

$$J_g = X_{L,i} \cdot v_S$$

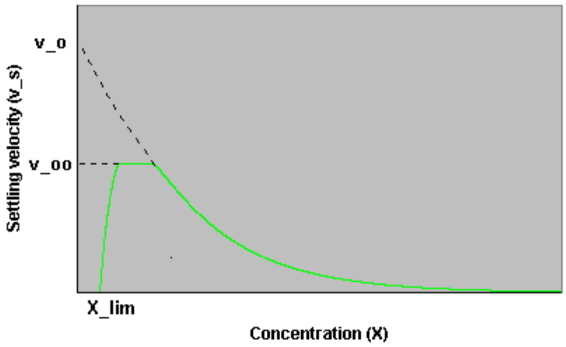
The calculation of the settling velocity v_S depends on the concentration of particulates.

$$(X < X_{Min}): v_S = 0$$
$$(X \geq X_{Min}): v_S = v_0 \cdot e^{-r_H \cdot X_j} - v_0 \cdot e^{-r_P \cdot X_j}$$

$$X_{Min} = f_{ns} \cdot \frac{X_{in}}{Q_{in}}$$

where:

- X_{in} is the solids concentration (g/m3) in the influent
- $X_j = X_{L,i} - X_{Min}$
- $r_H = (0.148 + 0.0021 \cdot SVI)/1000$



Above the minimum concentration the settling velocity follows the equation of Vesilind for the large particles with a correction for the smaller particles.

For the layers above the feed layer a threshold suspended solids concentration (X_T) is added. The threshold concentration is the maximum concentration that the layer below can handle. This is a limitation for the downward solids flux.

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
A	Surface area of the clarifier	1,500	m2
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m3
X_Lim	Minimal concentration in sludge blanket	900	g/m3
r_P	Low concentration settling parameter	0.0007	m3/g
v0	Maximum theoretical settling velocity	96	m/d
v00	Maximum practical settling velocity	45	m/d
n_Feed	Index of the feed layer	5	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m3
r_H	Hindered settling parameter	m3/g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m3

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Q_Under	*in_2*	*Desired underflow rate*	*50.0*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
SVI	*in_2*	*Sludge Volume Index*	*100*	*mL/g*
f_ns	*in_2*	*Non-settleable fraction of suspended solids*	*0.0024*	*---*
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m3
y_HS	out_3	Height of the sludge blanket	---	m

Lamellae_Takacs

Instances

All

Description

This is an extension of the “Takacs_SVI” model to mimic the improved solid separation due to the presence of lamellae packs inside the clarifier which increases the effective settling surface:

$$A = N \cdot A_{sp} \cdot cos\theta$$

where:

- N is the number of lamellae
- A_{sp} is the specific surface (m2) of the lamellae
- θ denotes the inclination of the pack in the clarifier

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
A	Surface area of the clarifier	1,500	m2
L_n	Number of lamellae	10	---
L_S	Specific area of the lamellae	100	m2
L_Theta	Inclination of the pack	45	deg
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m3
X_Lim	Minimal concentration in sludge blanket	900	g/m3
r_P	Low concentration settling parameter	0.0007	m3/g
v0	Maximum theoretical settling velocity	96	m/d
v00	Maximum practical settling velocity	45	m/d
n_Feed	Index of the feed layer	5	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m3
r_H	Hindered settling parameter	m3/g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m3

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Q_Under	*in_2*	*Desired underflow rate*	*50.0*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
SVI	*in_2*	*Sludge Volume Index*	*100*	*mL/g*
f_ns	*in_2*	*Non-settleable fraction of suspended solids*	*0.0024*	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m3
y_HS	out_3	Height of the sludge blanket	---	m

BSM2

Instances

All

Description

The model is a large simplification of the actual process: the settling tank has no volume (i.e. no retention time) and acts as an ideal phase separator.

$$Q_{out} = Q_{in} - Q_{under}$$

$$Q_{under} = R \cdot \frac{Q_{in}}{f_{th}}$$

$$f_{th} = 10^6 \cdot \frac{X_{under}}{X_{in}}$$

where:

- Q_{in}, Q_{under} and Q_{in} denote the influent-, effluent- and underflow flow rates (m3/d) respectively
- X_{in} is the solid flux (g/d) in the influent
- X_{under} is the fraction (-) of the incoming flux of solids that goes to the underflow
- R is the desired solid removal (-)
- f_{th} is the thickening factor (-)

The mass balance over the settling tank is as follows:

$$C_{out,S_i} = C_{in,S_i}$$

$$C_{out,X_i} = f_{th} \cdot C_{in,X_i}$$

$$C_{under,S_i} = C_{in,S_i}$$

$$C_{under,X_i} = (1 - f_{th}) \cdot C_{in,X_i}$$

where:

- C is the concentration of the *i*-th state component (g/m3) (suffixes S and X denotes soluble and particulate components)

No conversion process occurs in the tank volume.

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%
f_thick	Thickening factor	---

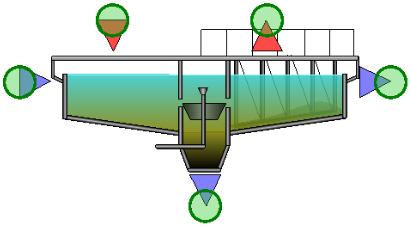
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
ds	*in_2*	*Desired solids content in the underflow*	*0.28*	---
P_Pump	out_3	Pumping power	---	kWh/d

SECONDARY CLARIFIERS

	Palette Group	**Separation**
	Category	Settlers_SST
	Icon Name	clarifier_secondary

Point

Instances

All

Description

The model is a large simplification of the actual process: the settling tank has no volume thus no retention time and acts as an ideal phase separator.

$$Q_{out} = Q_{in} - Q_{under}$$

$$(Q_{in} \leq Q_{under}): Q_{under} = Q_{in}$$
$$(Q_{in} > Q_{under}): Q_{under} = Q^{*}_{under}$$

where:

- Q_{in}, Q_{under} and Q_{in} denote the influent-, effluent- and underflow flow rates (m3/d) respectively
- Q^{*}_{under} is the desired underflow flow rate (m3/d)

The mass balance over the settling tank is as follows:

$$C_{out,S_i} = C_{in,S_i}$$

$$C_{out,X_i} = f_{ns} \cdot C_{in,X_i}$$

$$C_{under,S_i} = C_{in,S_i}$$

$$C_{under,X_i} = (1 - f_{ns}) \cdot C_{in,X_i}$$

where:

- C is the concentration of the *i*-th state component (g/m3) (suffixes S and X denotes soluble and particulate components)
- f_{ns} is fraction (-) of non-settleable solids

No conversion process occurs in the tank volume.

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
f_ns	*in_2*	*Fraction of non-settleable solids*	*0.005*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

Takacs_SVI

Instances

All

Description

The model of Takacs is based on the model of Vitasovic.

The settler is modelled with a number of layers (NR_OF_LAYERS) layers around which a solids balance is made.

Some assumptions are made:

- The incoming solids are distributed immediately homogenous over the feed layer.
- Only vertical flow is considered.

The settling velocity of the sludge blanket has been found to be a non-linear function of the solids concentration. In Vitasovic's model the settling flux is due to the gravity settling and also due to the bulk flux.

The **bulk flux** is upward above the feed layer and resulting from the overflow rate. Beneath the feed layer the bulk flux is downward and resulting from the underflow rate.

$$J_{up} = X_{L,i} \cdot v_{up}$$

$$v_{up} = \frac{Q_{out}}{A}$$

$$J_{dn} = X_{L,i} \cdot v_{dn}$$

$$v_{dn} = \frac{Q_{under}}{A}$$

The **gravitational flux** is always downwards.

$$J_g = X_{L,i} \cdot v_S$$

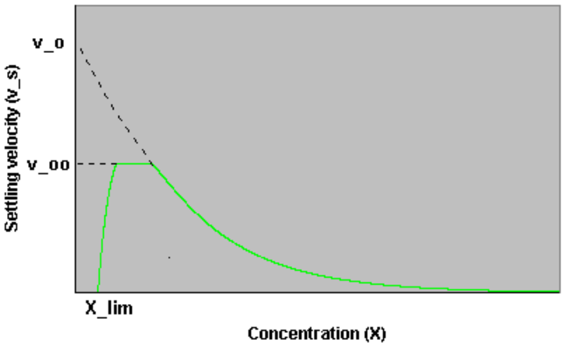
The calculation of the settling velocity v_S depends on the concentration of particulates.

$$(X < X_{Min}): v_S = 0$$
$$(X \geq X_{Min}): v_S = v_0 \cdot e^{-r_H \cdot X_j} - v_0 \cdot e^{-r_P \cdot X_j}$$

$$X_{Min} = f_{ns} \cdot X_{in}$$

where:

- X_{in} is the solids concentration (g/m3) in the influent
- $X_j = X_{L,i} - X_{Min}$
- $r_H = (0.148 + 0.0021 \cdot SVI)/1000$



Above the minimum concentration the settling velocity follows the equation of Vesilind for the large particles with a correction for the smaller particles.

For the layers above the feed layer a threshold suspended solids concentration (X_T) is added. The threshold concentration is the maximum concentration that the layer below can handle. This is a limitation for the downward solids flux.

Energy consumption for pumping (kWh/d) is estimated as follows:

$$P_{Pump} = E_{pump,s} \cdot Q_{out2}$$

where:

- $E_{pump,s}$ indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out2} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
A	Surface area of the clarifier	1,500	m2
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m3
X_Lim	Minimal concentration in sludge blanket	900	g/m3
r_P	Low concentration settling parameter	0.0007	m3/g
v0	Maximum theoretical settling velocity	96	m/d
v00	Maximum practical settling velocity	45	m/d
n_Feed	Index of the feed layer	5	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m3
r_H	Hindered settling parameter	m3/g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m3

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Q_Under	*in_2*	*Desired underflow rate*	*50.0*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
SVI	*in_2*	*Sludge Volume Index*	*100*	*mL/g*
f_ns	*in_2*	*Non-settleable fraction of suspended solids*	*0.00228*	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m3
y_HS	out_3	Height of the sludge blanket	---	m

BurgerDiehl30

Instances

All

Description

The model by Bürger et al. (2011) is based on a spatially one-dimensional partial differential equation (PDE).

Its numerical implementation can be seen as an extension of the layer approach as applied by Vitasovic (1986) and Takács et al. (1991).

The simulation model is robust and reliable for any inputs in contrast to the Takács model (see Bürger et al., 2012a). Further, the Bürger model extends the layer model with some extra features that allow for more flexibility.

A short description of the simulation model is given below. For implementation details and further explanations, see Bürger et al. (2012b).

Some assumptions are made:

- As the feed enters the tank, the solids are instantaneously and homogenously distributed over the "feed layer"
- Only vertical flow is considered (parallel to the axis of the tank)

Based on the conservation of mass, a secondary settling tank can be described by the following partial differential equation (PDE).

$$\frac{\partial C}{\partial t} = -\frac{\partial}{\partial z}F(C,z,t) + \frac{\partial}{\partial z}\left(\{\,d_{comp}(C) + d_{disp}(z,Q_f(t)\}\frac{\partial C}{\partial z}\right) + \frac{Q_f(t)C_f(t)}{A}\delta(z)$$

The first term on the right-hand side represents the solid flux through the settler, which is a combination of **bulk transport** (due to feed flow, underflow and overflow) and **gravity settling**.

The second term is an optional term which allows including the effects of sludge **compressibility** and/or **dispersion** into the model.

The third term is a singular source term for the feed mechanism.

The numerical solution of this equation needs that the equation be discretised over a number of layers (NR_OF_LAYERS_BURGER) around which a solids balance is made. The number of layers can be set by the user.

By increasing the number of layers, the model solution will converge to the physically correct solution. Note that this is not the case for the Takacs model.

The model makes use of two additional layers at the top and two at the bottom of the tank to describe the outlet concentrations and ensure that the mass conservation holds across the outlet boundaries. This is another important feature that is not present in the Takács model.

The solid fluxes are calculated as follows.

The **bulk flux** appears to be directed upwards above the feed layer (and driven by the overflow of the clarified water: $\mathbf{J_{up}}$), and downwards below the feed layer (and driven by the extraction of the sludge from the bottom of the settler: $\mathbf{J_{down}}$).

$$J_{up} = X_{Layer,i} \cdot v_{up} = X_{Layer,i} \cdot \frac{Q_{out}}{A}$$

$$J_{down} = X_{Layer,i} \cdot v_{down} = X_{Layer,i} \cdot \frac{Q_{under}}{A}$$

The **gravitational flux** is directed downwards and is computed by the mathematically sound Godunov scheme. The settling flux between two adjacent layers *i* and *i+1* (with concentrations C_i and C_{i+1}; layer 1 being the top layer) is implemented as follows:

$$(\mathrm{C_i} \le \mathrm{C_{i+1}}): J_G = \min_{\mathrm{C_i} \le \mathrm{C} \le \mathrm{C_{i+1}}} \{v_S(\mathrm{C}) \cdot \mathrm{C}\}$$

$$(C \ge C_{crit}): J_G = \max_{\mathrm{C_i} \ge \mathrm{C} \ge \mathrm{C_{i+1}}} \{v_S(\mathrm{C}) \cdot \mathrm{C}\}$$

The importance of using this scheme is twofold:

- It considers all intermediate concentrations in the flux calculation and not only the discrete concentration values of the two adjacent layers
- It does not use an empirical threshold concentration

This implementation of the model uses the hindered settling velocity by Vesilind (but any other equivalent function may be used):

$$v_S = v_0 \cdot e^{-r_V \cdot C}$$

Furthermore, the model accounts for sediment compressibility and inlet mixing phenomena through a **compression** (d_{comp}) and a **dispersion** function (d_{disp}).

Compression of the sediment occurs when the concentration in the sludge blanket exceeds a given critical concentration or gel point (C_{crit}), as illustrated by the following equation:

$$(0 \le C < C_{crit}): d_{comp} = 0$$

$$(C \ge C_{crit}): d_{comp} = \frac{Comp_{ON} \cdot Rho_s \cdot \alpha \,.\, v_S(C)}{g \cdot \left(Rho_s - Rho_f\right)}$$

The dispersion function enables to model a mixing region around the feed layer. The height of this region is dependent on the incoming flow rate.

$$\left(|z| < b_{mix} \cdot Q_{in}\right): d_{disp} = Disp_{ON} \cdot \frac{a_{mix}}{A} \cdot Q_{in} \cdot \cos^2\left(\frac{\pi \cdot z}{2 \cdot b_{mix} \cdot Q_{In}}\right)$$

$$\left(|z| \ge b_{mix} \cdot Q_{in}\right): d_{disp} = 0$$

Both the compression and the dispersion functions are optional. By setting the parameters $Comp_{ON}$ and $Disp_{ON}$ to either 0 or 1, these functions can be switched on or off to meet the user's needs.

In order to ensure a numerically stable solution, **it is essential that the user carefully set the time step** (Δt) **of the integrator**.
For a simulation over a time interval [0,T], with a given number of layers (which translates in a layer depth of Δz), Δt **must satisfy the following condition**:

$$\Delta t \le 1/\left[\begin{array}{c} \frac{1}{\Delta z}\left(\max\limits_{0<t<T} \frac{Q_{In(t)}}{A} + \max\limits_{0 \le C < C\_max} J_G'(C)\right) + \\ \frac{2}{(\Delta z)^2}\left(\max\limits_{0 \le C < C\_max} d_{comp}(C) + \max\limits_{0<t<T} d_{disp}(z, Q\_In(t))\right) \end{array}\right]$$

Energy consumption for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{out}}{24}$$

where:

- F indicates the pumping energy per unit flow rate (kWh/m3)
- Q_{out} is the effluent flow rate (m3/d)

Parameters

Name	Description	Value	Units
F_TSS_COD	TSS/COD ratio	0.75	---
A	Surface area of the clarifier	754	m2
H	Height of the clarifier	3	m
v0	Maximum theoretical settling velocity	474	m/d
r_V	Settling parameter	0.000576	m3/g
X_Lim	Minimum concentration in the sludge blanket	900	g/m3
Comp_ON	Switch compression on/off	0	---
Alpha	Effective solids stress parameter	0.8	m^2/s^2
Rhos	Solid density	1050000	g/m^3
Rhof	Fluid density	998000	g/m^3
C_crit	Gel point	6000	g/m^3
Disp_ON	Switch on/off dispersion	0	---
a_mix	Dispersion parameter	0.4	m
b_mix	Dispersion parameter	1E-05	d/m2

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
H_S	Height of the sludge blanket	m
z	Layers height (vector)	m

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m3

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Q_Under	*in_2*	*Desired underflow rate*	*50.0*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m3
TSS	out_3	Total Suspended Solids concentration	---	g/m3

y_HS	out_3	Height of the sludge blanket	---	m

References

Bürger, Diehl and Nopens (2011), Wat. Res. 45: 2247-2260

Bürger, Diehl, Farås and Nopens (2012a), Comput. Chem. Eng. 41: 93-105

Bürger, Diehl, Farås, Nopens, and Torfs (2012b). Preprint, CI2MA, Universidad de Concepción. Available under http://www.ci2ma.udec.cl/publicaciones/prepublicaciones/]

Takács, Patry and Nolasco (1991). A dynamic model of the clarification-thickening process, Wat. Res. 25: 1263-1271

Vitasovic (1986). An integrated control strategy for the activated sludge process. Ph.D. thesis, Rice University, Houston, TX, USA

Lamellae_Takacs

Instances

All

Description

This is an extension of the "Takacs_SVI" model to mimic the improved solid separation due to the presence of lamellae packs inside the clarifier which increases the effective settling surface:

$$A = N \cdot A_{sp} \cdot cos\theta$$

where:

- N is the number of lamellae
- A_{sp} is the specific surface (m2) of the lamellae
- θ denotes the inclination of the pack in the clarifier

Parameters

Name	Description	Value	Units
F_TSS_COD*	TSS/COD ratio	0.75	---
A	Surface area of the clarifier	1,500	m2
L_n	Number of lamellae	10	---
L_S	Specific area of the lamellae	100	m2
L_Theta	Inclination of the pack	45	deg
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m3
X_Lim	Minimal concentration in sludge blanket	900	g/m3
r_P	Low concentration settling parameter	0.0007	m3/g
v0	Maximum theoretical settling velocity	96	m/d
v00	Maximum practical settling velocity	45	m/d
n_Feed	Index of the feed layer	5	---

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d
X_In	Solids (TSS) concentration in the inflow	g/m3
X_Out	Solids (TSS) concentration in the outflow	g/m3
X_Under	Solids (TSS) concentration in the underflow	g/m3
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m3
r_H	Hindered settling parameter	m3/g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m3

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Q_Under	*in_2*	*Desired underflow rate*	*50.0*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
SVI	*in_2*	*Sludge Volume Index*	*100*	*mL/g*
f_ns	*in_2*	*Non-settleable fraction of suspended solids*	*0.0024*	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m3
y_HS	out_3	Height of the sludge blanket	---	m

Point_wVolumePre

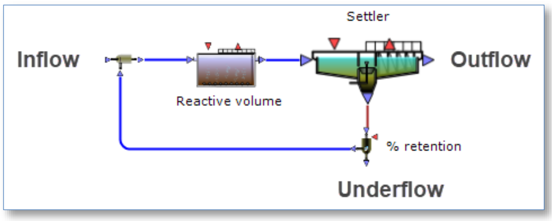
Instances

All

Description

The model offers a simplistic representation of a reactive point settler.

It combines a reactive volume, represented by a regular activated sludge tank with constant volume (Tanks_AS.VolumeConstant class) and a regular secondary point settler (Settlers_SST.Point class) for solids separation.
The reactive (fictitious) volume is placed upstream of the settling tank, as illustrated below:



The solids concentration in the reactive volume can be increased by tuning fictitious valve, thereby increasing the internal recirculation rate.

Parameters

Name	Description	Value	Units
Vol	Reactive volume	1,000	m3

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d

Derived State Variables

None

Sub-models

Name	Class Name
ReactiveVolume	Tanks_AS.VolumeConstant
Settler	Settlers_SST.Point
Combi	Mixers.Mix02
LB	Loopbreakers.MainDiff
Valve	Splitters.SplitRel02

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*1.0*	*1/d*

Name	Terminal	Description	Value	Units
f_ns	*in_2*	*Fraction of non-settleable solids*	*0.00228*	---
f_rec	*in_2*	*Fraction of internal recirculation*	*0.1*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

Point_wVolumePost

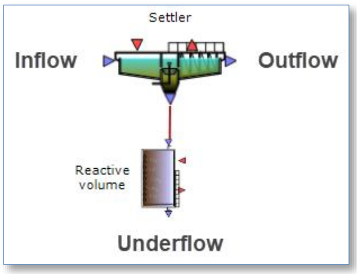
Instances

All

Description

The model offers a simplistic representation of a reactive point settler.

It combines a reactive volume, represented by a regular activated sludge tank with constant volume (Tanks_AS.VolumeConstant class) and a regular secondary point settler (Settlers_SST.Point class) for solids separation.
The reactive (fictitious) volume is placed downstream of the settling tank, as illustrated below:



Parameters

Name	Description	Value	Units
Vol	Reactive volume	1,000	m3

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d

Derived State Variables

None

Sub-models

Name	Class Name
ReactiveVolume	Tanks_AS.VolumeConstant
Settler	Settlers_SST.Point

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*1.0*	*1/d*
f_ns	*in_2*	*Fraction of non-settleable solids*	*0.00228*	---
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

TakacsSVI_wVolumePre

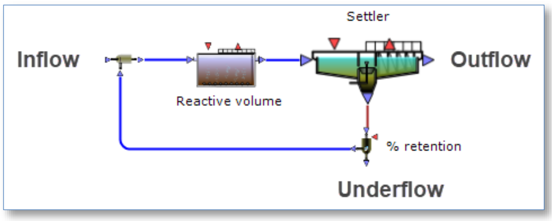
Instances

All

Description

The model offers a simplistic representation of a reactive point settler.

It combines a reactive volume, represented by a regular activated sludge tank with constant volume (Tanks_AS.VolumeConstant class) and a regular secondary 1D settler (Settlers_SST.Takacs_SVI class) for solids separation.
The reactive (fictitious) volume is placed upstream of the settling tank, as illustrated below:



The solids concentration in the reactive volume can be increased by tuning fictitious valve, thereby increasing the internal recirculation rate.

Parameters

Name	Description	Value	Units
Vol	Reactive volume	1,000	m3
A	Surface area of the clarifier	1,500	m2
H	Height of the clarifier	4	m

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d

Derived State Variables

None

Sub-models

Name	Class Name
ReactiveVolume	Tanks_AS.VolumeConstant
Settler	Settlers_SST.Takacs_SVI
Combi	Mixers.Mix02
LB	Loopbreakers.MainDiff
Valve	Splitters.SplitRel02

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d

Name	Terminal	Description	Value	Units
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*1.0*	*1/d*
f_ns	*in_2*	*Fraction of non-settleable solids*	*0.00228*	*---*
f_rec	*in_2*	*Fraction of internal recirculation*	*0.1*	*---*
SVI	*in_2*	*Sludge Volume Index*	*100*	*mL/g*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

TakacsSVI_wVolumePost

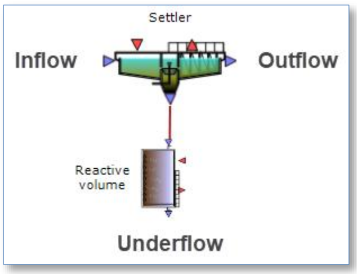
Instances

All

Description

The model offers a simplistic representation of a reactive point settler.

It combines a reactive volume, represented by a regular activated sludge tank with constant volume (Tanks_AS.VolumeConstant class) and a regular secondary 1D settler (Settlers_SST.Takacs_SVI class) for solids separation.
The reactive (fictitious) volume is placed downstream of the settling tank, as illustrated below:



Parameters

Name	Description	Value	Units
Vol	Reactive volume	1,000	m3
A	Surface area of the clarifier	1,500	m2
H	Height of the clarifier	4	m

State Variables

Name	Description	Units
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
Q_Out2	Effluent (under) flow rate	m3/d

Derived State Variables

None

Sub-models

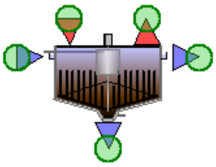
Name	Class Name
ReactiveVolume	Tanks_AS.VolumeConstant
Settler	Settlers_SST.Takacs_SVI

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
Underflow	out_2	Underflow (component vector)	---	g/d
Temp	*in_2*	*Temperature*	*15*	*°C*
kLa	*in_2*	*Oxygen transfer coefficient*	*1.0*	*1/d*
f_ns	*in_2*	*Fraction of non-settleable solids*	*0.00228*	---
SVI	*in_2*	*Sludge Volume Index*	*100*	*mL/g*

Name	Terminal	Description	Value	Units
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
Q_Under	*in_2*	*Desired sludge flow*	*50*	*m3/d*
P_Pump	out_3	Pumping power	---	kWh/d

THICKENERS

	Palette Group	**Separation**
	Category	Tanks_Dewater
	Icon Name	thickener

Tanks_Dewater.ThickenerDS

Instances

All

Description

The model is a large simplification of a sludge thickening/dewatering unit, based on the desired dry solids (DS) content and flow rate of the thickened sludge.

$$e_X = \frac{DS \cdot Q_{sl} \cdot \rho_{sl}}{X_{in}}$$

where:

- e_X is the resulting solids separation efficiency (-)
- Q_{sl} and ρ_{sl} denote the flow (m3/d) and the density (g/m3) of the thickened sludge, respectively
- X_{in} is the concentration (g/m3) of the raw sludge.

The power (kWh/d) required for pumping the thickened sludge is estimated as follows:

$$P_{Pump} = E_{pump} \cdot Q_{sl}$$

where:

- E_{pump} indicates pumping energy per unit flow (kWh/m3).

Parameters

Name	Description	Value	Units
mode_TSS	TSS calculated as X_TSS (0) or from conversion of X_COD (1)	0	-
i_TSS_BM	TSS to Biomass ratio	0.9	-
i_TSS_X_I	TSS to X_I ratio	0.75	-
i_TSS_X_S	TSS to X_S ratio	0.75	-
rho_sludge	specific gravity of the dewatered sludge	1.07e6	g/m3

State Variables

Name	Description	Units
Q_In	Raw sludge influent flow	m3/d
Q_Out	Flow rate of the clarified water	m3/d
Q_Out2	Flow rate of the thickened sludge	m3/d
Q_Sludge_Actual	Flow rate of the thickened sludge	m3/d
DrySolids	Dry solids content of the sludge	%

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Clarified water (component vector)	---	g/d
Outflow2	out_3	Thickened sludge (component vector)	---	g/d

Name	**Terminal**	**Description**	**Value**	**Units**
DS	*in_2*	*Dry Solids content*	*5*	*---*
Q_Sludge	*in_2*	*Desired flow rate of thickened sludge*	*10*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
P_Pump	out_2	Pumping power	---	kWh/d
e_X	out_2	Solids separation efficiency	---	-
X_In	out_2	Solids (TSS) concentration in the inflow	---	g/m3
X_Out	out_2	Solids (TSS) concentration in the clarified water	---	g/m3
X_Sludge	out_2	Solids (TSS) concentration in the thickened sludge	---	g/m3

Tanks_Dewater.ThickenerEfficiency

Instances

All

Description

The model is a large simplification of a sludge thickening/dewatering unit, based on the desired solids separation efficiency (e_X) and on the flow rate of thickened sludge.

$$DS = \frac{X_{in} \cdot (1 - e_X)}{Q_{sl} \cdot \rho_{sl}}$$

where:

- DS is the resulting dry solids content (-) of the thickened sludge
- Q_{sl} and ρ_{sl} denote the flow (m3/d) and the density (g/m3) of the thickened sludge, respectively
- X_{in} is the concentration (g/m3) of the raw sludge.

The power (kWh/d) required for pumping the thickened sludge is estimated as follows:

$$P_{Pump} = E_{pump} \cdot Q_{sl}$$

where:

- E_{pump} indicates pumping energy per unit flow (kWh/m3).

Parameters

Name	Description	Value	Units
mode_TSS	TSS calculated as X_TSS (0) or from conversion of X_COD (1)	0	-
i_TSS_BM	TSS to Biomass ratio	0.9	-
i_TSS_X_I	TSS to X_I ratio	0.75	-
i_TSS_X_S	TSS to X_S ratio	0.75	-
rho_sludge	specific gravity of the dewatered sludge	1.07e6	g/m3

State Variables

Name	Description	Units
Q_In	Raw sludge influent flow	m3/d
Q_Out	Flow rate of the clarified water	m3/d
Q_Out2	Flow rate of the thickened sludge	m3/d
Q_Sludge_Actual	Flow rate of the thickened sludge	m3/d
DrySolids	Dry solids content of the sludge	%

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Clarified water (component vector)	---	g/d
Outflow2	out_3	Thickened sludge (component vector)	---	g/d

Name	Terminal	Description	Value	Units
e_X	*in_2*	*Desired solids separation efficiency*	*0.96*	-
Q_Sludge	*in_2*	*Desired flow rate of thickened sludge*	*10*	*m3/d*
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
P_Pump	out_2	Pumping power	---	kWh/d
DS	out_2	Dry Solids content of the thickened sludge	---	-
X_In	out_2	Solids (TSS) concentration in the inflow	---	g/m3
X_Out	out_2	Solids (TSS) concentration in the clarified water	---	g/m3
X_Sludge	out_2	Solids (TSS) concentration in the thickened sludge	---	g/m3

Tanks_Dewater.ThickenerEfficiency2

Instances

All

Description

The model is a large simplification of a sludge thickening/dewatering unit, based on the desired solids separation efficiency (e_X) and on the ratio between the flow thickened and the raw sludge flow rate (q_{sl}).

$$DS = \frac{X_{in} \cdot (1 - e_X)}{(Q_{in} \cdot q_{sl}) \cdot \rho_{sl}}$$

where:

- DS is the resulting dry solids content (-) of the thickened sludge
- Q_{sl} and ρ_{sl} denote the flow (m3/d) and the density (g/m3) of the thickened sludge, respectively
- X_{in} is the concentration (g/m3) of the raw sludge.

The power (kWh/d) required for pumping the thickened sludge is estimated as follows:

$$P_{Pump} = E_{pump} \cdot Q_{sl}$$

where:

- E_{pump} indicates pumping energy per unit flow (kWh/m3).

Parameters

Name	Description	Value	Units
mode_TSS	TSS calculated as X_TSS (0) or from conversion of X_COD (1)	0	-
i_TSS_BM	TSS to Biomass ratio	0.9	-
i_TSS_X_I	TSS to X_I ratio	0.75	-
i_TSS_X_S	TSS to X_S ratio	0.75	-
rho_sludge	specific gravity of the dewatered sludge	1.07e6	g/m3

State Variables

Name	Description	Units
Q_In	Raw sludge influent flow	m3/d
Q_Out	Flow rate of the clarified water	m3/d
Q_Out2	Flow rate of the thickened sludge	m3/d
Q_Sludge_Actual	Flow rate of the thickened sludge	m3/d
DrySolids	Dry solids content of the sludge	%

Derived State Variables

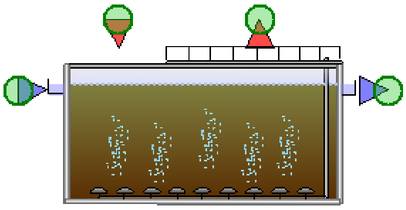
None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent flow (component vector)	---	g/d
Outflow	out_1	Clarified water (component vector)	---	g/d

Name	Terminal	Description	Value	Units
Outflow2	out_3	Thickened sludge (component vector)	---	g/d
e_X	*in_2*	*Desired solids separation efficiency*	*0.96*	-
q_under	*in_2*	*Thickened to raw sludge flow ratio*	*0.5*	-
E_Pump_sp	*in_2*	*Energy per unit flow rate*	*0.04*	*kWh/m3*
P_Pump	out_2	Pumping power	---	kWh/d
DS	out_2	Dry Solids content of the thickened sludge	---	-
X_In	out_2	Solids (TSS) concentration in the inflow	---	g/m3
X_Out	out_2	Solids (TSS) concentration in the clarified water	---	g/m3
X_Sludge	out_2	Solids (TSS) concentration in the thickened sludge	---	g/m3

AEROBIC DIGESTERS

	Palette Group	**Sludge Treatment**
	Category	Tank_AerDig
	Icon Name	aerobic_digester

Tanks_AerDig.VolumeConstant

Instances

All

Description

This model describes an aerobic digestion unit, i.e., a tank in which sludge is digested aerobically. The tank volume is constant, that is:

$$Q_{out} = Q_{in}$$

The specific Instance defines the Conversion Model that is in place and therefore the processes taking place inside the tank.

The Oxidation Reduction Potential (ORP) is empirically calculated as:

$$ORP_{DO\leq 0.2} = -2434.04 + 336.61 \cdot pH + 98.60 \cdot log \frac{NO_3}{14}$$

$$ORP_{DO>0.2} = -153.43 + 20.32 \cdot pH - 59.88 \cdot log \frac{NH_4}{NO_3}$$

The power (kWh/d) required for aeration and mixing is estimated as follows:

$$P_{aer} = \frac{1}{OTR} \cdot S_{O,sat} \cdot k_{La} \cdot V$$

$$P_{mix} = 24 \cdot E_{mix} \cdot V$$

where:

- $S_{O,sat}$ is the oxygen concentration at saturation (g/m3)
- k_{La} is the oxygen transfer coefficient (1/d)
- OTR and E_{mix} indicate the Oxygen Transfer Rate (g/kWh) and the mixing energy per unit volume (kWh/m3/d) respectively
- V denotes the tank volume (m3)

Parameters

Stoichiometric and kinetic parameters derived from the underlying, instance-specific, conversion model.

Name	Description	Value	Units
Vol	Volume of the tank	1000	m3
Kla_Min	Lowest kLa that ensures adequate mixing	20.0	1/d
Is_MixIfAer	Is it actively mixed when aerated?	0	---

State Variables

Kinetic algebraic variables derived from the underlying, instance-specific, conversion model.

Name	Description	Units
C	Concentration of the state components (vector)	g/m3
V	Volume of the tank	m3
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d

Name	**Description**	**Units**
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

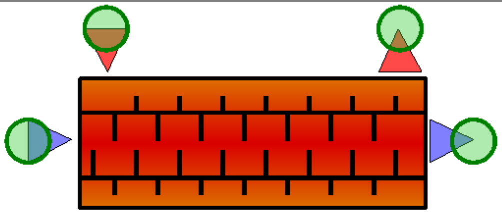
Name	**Description**	**Units**
M	Mass of the state components (vector)	---

Interface Variables

Sensor variables derived from the underlying, instance-specific, conversion model.

Name	**Terminal**	**Description**	**Value**	**Units**
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Effluent flow (component vector)	---	g/d
P_Aer	out_2	Power consumption for aeration	---	W
P_Mix	out_2	Power consumption for mixing	---	W
Temp	*in_2*	*Temperature*	*15.0*	*°C*
T_air	*in_2*	*Air temperature*	*15.0*	*°C*
pH	*in_2*	*pH*	*7.0*	-
Kla	*in_2*	*Oxygen transfer coefficient*	*50*	*1/d*
E_OTR	*in_2*	*Oxygen Transfer Rate per unit energy*	*1800.0*	*g/kWh*
E_Mix_sp	*in_2*	*Mixing energy per unit volume*	*0.005*	*kWh/m3/d*

SLUDGE DRYING

	Palette Group	**Sludge Treatment**
	Category	ASM1, ASM2dISS, ASM2dMod
	Icon Name	sludge_dryer

SludgeDrying_Ideal

Instances

ASM1, ASM2dISS, ASM2dMod

Description

Ideal model for sludge drying, based on the power input and on a simple 1st order drying kinetics.

The power input is calculated based on the heat exchange capacity of the system:

$$P = h \cdot A \cdot \left(T_{heat} + T_{sludge}\right)$$

The drying rate is calculated as follows:

$$r_{dw} = e^{-k \cdot RT}$$

where the 1st order rate is: $k = n \cdot {}^{P}/_{A}$

Parameters

Name	Description	Value	Units
A	Surface of the drying bed	100	m2
VR	Volume of the reactor	1	m3
h	Heat exchange capacity	100	W/m2/degC
n	Empirical correlation k-p	0.001	---
rho_in	Density of the influent sludge	1,070,000	g/m3
F_TSS_COD*	TSS to COD conversion	0.75	---

* only ASM1

State Variables

Name	Description	Units
DS_In	Dry Solid content of the influent sludge	---
DS_Out	Dry Solid content of the dried sludge	---
M_In	Moisture content of the influent sludge	---
M_Out	Moisture content of the dried sludge	---
P	Power provided by the heating stream	W
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
k	1st order drying rate	1/d
r_dw	Rate of dewatering	---

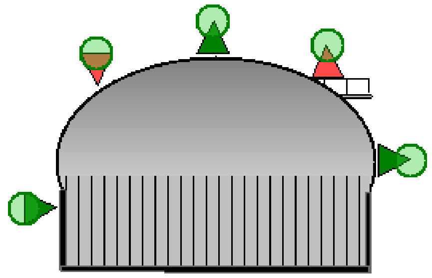
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	out_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
T_heat	*in_2*		*80.0*	°C
T_sludge	*in_2*		*30.0*	°C

BIOGAS ACCUMULATION

	Palette Group	**Sludge Treatment**
	Category	Biogas
	Icon	biogasholder

GasHolder

Instances

All

Description

This is a simple model to describe the accumulation of biogas inside a variable volume-, variable pressure-gas holder.
Gas outflow occurs at a given flow rate (Q_Util), if sufficient gas has accumulated inside the chamber (the threshold is set to 10% of the maximum volume).
Gas overflow occurs as the volume of gas accumulated approaches the maximum volume, at a given flow rate (Q_Flare).

The molar mass, volume and pressure of each component are calculated as follows:

$$\frac{dM_i}{dt} = \frac{Inflow_i - Outflow_i - Overflow_i}{M_{COD,i}}$$

$$V_i = M_i \cdot R_{Gas} \cdot \frac{T}{P_{Gas}}$$

$$P_i = \frac{Inflow_i}{Q} \cdot R_{Gas} \cdot \frac{T}{M_{COD,i}}$$

where:

- *Inflow*, *Outflow* and *Overflow* denote the mass flows [g COD/d]
- $M_{COD,i}$ denotes the COD molar equivalent of the i-th species
- R_{Gas} is the gas constant, 8.314 [J/mol/K]
- T is the temperature [K]
- P_{Gas} is the total pressure of the gas [Pa]
- Q is the gas flow rate [m3/d]

Parameters

Name	Description	Value	Units
P_Max	Max pressure inside the gas tank	2	bar
P_atm	Atmospheric pressure	1.013	bar
V_Max	Max volume of the tank	1,000	m3

State Variables

Name	Description	Units
P_Gas	Total pressure in the gas tank	bar
Q_Out	Effluent flow	m3/d
Q_Over	Overflow	m3/d
V_Gas	Total volume in the gas tank	m3
P	Pressure (component vector)	bar
P_H2O	Vapour pressure in the gas tank	bar
V	Volume (component vector)	m3

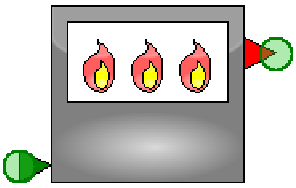
Derived State Variables

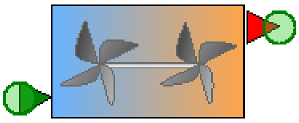
Name	Description	Units
M	Molar mass (component vector)	mol

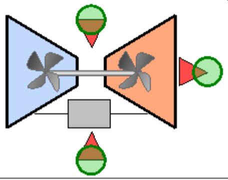
Interface Variables

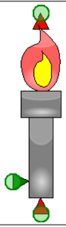
Name	Terminal	Description	Value	Units
Inflow	in_1	Influent gas flow (component vector)	0	---
Outflow	out_1	Effluent gas flow (component vector)	---	---
Overflow	out_3	Overflow (component vector)	---	---
Q_Flare	*in_2*	*Overflow*	*9600*	*m3/d*
Q_Util	*in_2*	*Effluent flow*	*3240*	*m3/d*
Temp	*in_2*	*Temperature*	*20*	*degC*

BIOGAS UTILISATION

	Palette Group	**Energy**
	Category	Biogas
	Icon	boiler

	Palette Group	**Energy**
	Category	Biogas
	Icon	engine

	Palette Group	**Energy**
	Category	Energy
	Icon Name	gas_turbine

	Palette Group	**Energy**
	Category	Biogas
	Icon	flare

GasBoiler

Instances

All

Description

This is a simple model to describe a gas boiler for thermal power generation.

$$P_{GasTh} = \eta_{th} * Q_{CH4} * \frac{16.0}{64.0} * F_{CH4}$$

where:

- P_{GasTh} is the generated thermal power [kWh/d]
- η_{th} is the efficiency of the motor
- Q_{CH4} is the influent gas flow of methane [g COD/d]
- 16 is the molar weight of methane [g CH4/mol]
- 64 is the COD molar equivalent of methane [g COD/mol]
- F_{CH4} is the conversion factor of methane to energy [kWh/g]

Parameters

Name	Description	Value	Units
F_CH4_Energy	Methane to energy (ideal) conversion factor	0.015	kWh/g
eta_th	Efficiency of the motor for thermal energy production	0.5	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent gas flow (component vector)	---	g/d
P_GasTh	out_1	Generated thermal power from biogas	---	kWh/d

GasEngine

Instances

All

Description

This is a simple model for a biogas engine that generates electrical power:

$$P_{GasEl} = \eta_{el} \cdot Q_{CH4} \cdot \frac{16.0}{64.0} \cdot F_{CH4}$$

where:

- P_{GasEl} is the generated electrical power [kWh/d]
- η_{el} is the efficiency of the motor
- Q_{CH4} is the influent gas flow of methane to the model [g COD/d]
- 16 is the molar weight of methane [g CH4/mol]
- 64 is the COD molar equivalent of methane [g COD/mol]
- F_{CH4} is the conversion factor of methane to energy [kWh/g]

Parameters

Name	Description	Value	Units
F_CH4_Energy	Methane to energy conversion factor (kWh/g)	0.015	---
eta_el	Efficiency of the motor for electricity production	0.4	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent gas flow (component vector)	---	g/d
P_GasEl	out_1	Generated electrical power from biogas	---	kWh/d

GasTurbine_Simple

Instances

All

Description

A simple model for a gas turbine which converts biogas to electrical and thermal power:

$$P = f_{gas} \cdot Q_{Biogas} \cdot \frac{P_{CH4}}{P_{Biogas}} \cdot F_{CH4}$$

where:

- P is the potential amount of power generated [kWh/d]
- f_{gas} is the fraction of gas distributed to the turbine
- Q_{Biogas} and P_{Biogas} denote the biogas flow rate [m3/d] and total headspace pressure [bar] respectively; while P_{CH4} is the partial pressure of methane [bar]
- F_{CH4} is the conversion factor of methane to energy [kWh/m3]

The resulting electrical [kWh/d] and thermal power [kWh/d] generated by the turbine are:

$$P_{El} = \eta_{el} \cdot P$$

$$P_{Th} = \eta_{th} \cdot P$$

Parameters

Name	Description	Value	Units
eta_el	Efficiency of the motor for electricity production	0.4	---
eta_th	Efficiency of the motor for thermal energy production	0.5	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
P_Biogas	in_1	Total headspace pressure	---	bar
P_CH4	in_1	Partial pressure of methane	---	bar
Q_Biogas	in_1	Biogas flow rate	---	m3/d
P_GasEl	out_1	Generated electrical power from biogas	---	kWh/d
P_GasTh	out_1	Generated thermal power from biogas	---	kWh/d
F_CH4_Energy	*in_2*	*Methane to energy conversion factor*	*10.842*	*kWh/m3*
f_gas	*in_2*	*Fraction of gas distributed to the turbine*	*0.8*	---

Flare

Instances

All

Description

This is a simple model for a biogas flare.
It calculates the residual gas composition after the biogas has been flared:

$$O_{ch4} = I_{ch4} \cdot (1 - e_{ch4})$$

$$O_{co2} = I_{co2} + I_{ch4} \cdot e_{ch4}$$

where:

- I and O denote the influent and effluent flux of the component [g/d]

Hydrogen gas and H2S are assumed not to be affected by flaring.

Parameters

Name	Description	Value	Units
e_CH4	Combustion efficiency of methane	1	---

State Variables

None

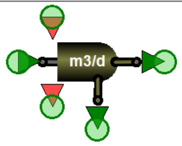
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Influent gas flow (component vector)	---	g/d
Outflow	out_1	Effluent gas flow (component vector)	---	g/d
M_CO2	out_1	Gas flow of CO2	---	kg/d

SplitAbs02

 m3/d	Palette Group	**Sludge treatment**
	Category	Biogas
	Icon Name	split_flow_02_gas

Instances

All

Description

It splits the incoming gas flow into two flows:

$$Q_{out,2} = Q_{in} - Q_{out,1}$$

where:

- Q_{in}, $Q_{out,1}$ and $Q_{out,2}$ denote the influent-, effluent no.1 and effluent no.2 flow rates [m3/d]

Parameters

None

State Variables

None

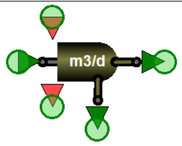
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Out_01	out_1	Outflow no.1	---	g/d
Out_02	out_2	Outflow no.2	---	g/d
Q_Out_01	*in_2*	*Desired flow rate no.1*	*10*	*m3/d*

SplitAbs02_bypass

	Palette Group	**Sludge treatment**
	Category	Biogas
	Icon Name	split_flow_02_gas

Instances

All

Description

It splits the incoming gas flow into two flows:

$$Q_{out,2} = Q_{in} - Q_{out,1}$$

$$Q_{out,1} = if\ (Q_{in} < Q_{out,2,max})\ then\ Q^{*}_{out,1}\ else\ Q_{in} - Q_{out,2,max}$$

where:

- Q_{in}, $Q_{out,1}$ and $Q_{out,2}$ denote the influent-, effluent no.1 and effluent no.2 flow rates [m3/d]
- $Q^{*}_{out,1}$ and $Q_{out,2,max}$ denote the desired output flow no.1 and the maximum outflow no.2 flow rates [m3/d]

Parameters

None

State Variables

None

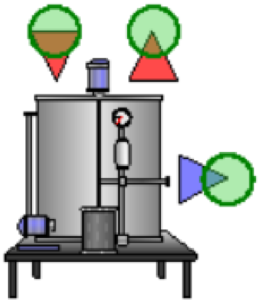
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Out_01	out_1	Outflow no.1	---	g/d
Out_02	out_2	Outflow no.2	---	g/d
Q_Out_01	*in_2*	*Desired flow rate no.1*	*10*	*m3/d*
Q_Out_02_Max	*in_2*	*Maximum flow rate no.2*	*10*	*m3/d*

CHEMICAL DOSING

	Palette Group	**Dosing**
	Category	ASM1, ASM2dMod, ASM2dISS
	Icon name	dosing_carbon, dosing_Pchem

Dose_Acetate

Instances

All

Description

The model describes the addition of an external carbon source, in the form of acetate:

$$M_S = Q_{dose} \cdot C_{dose} \cdot \frac{COD_{eq}}{MW}$$

$$M_{ALK} = \frac{M_S}{Alk_{eq}}$$

where:

- M_S and M_{ALK} denote the flux (g/d) of acetate (S_S in ASM1, S_A in ASM2dMod, or S_VFA in ASM2dISS) and of alkalinity, respectively
- Q_{dose} and C_{dose} indicate the flow rate- (m3/d) and the concentration (g/m3) of the solution
- COD_{eq} and MW indicate the COD equivalent- (64 g/g) and molecular weight (60 g/mol) of acetate
- Alk_{eq} is the alkalinity equivalent released by acetate uptake (64)

The power required for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{dose}}{24} \cdot 10^3$$

where:

- F is the pumping power per unit flow (kWh/m3)

Parameters

Name	Description	Value	Units
F_En_Q	Conversion factor: energy needed/pump flow rate	0.04	kWh/m3

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow vector	---	g/d
Flow_M	out_2	Amount of solution dosed	---	g/d
Flow_Q	out_2	Flow rate of solution dosed	---	m3/d
Energy_Pump	out_2	Energy for pumping	---	kWh
Power_Pump	out_2	Power consumption for pumping	---	W
C_Dose	*in_1*	*Concentration of the solution*	*10,000*	*g/m3*
Q_Dose	*in_1*	*Flow rate of the solution*	*10.0*	*m3/d*

Dose_Ethanol

Instances

All

Description

The model describes the addition of an external carbon source, in the form of ethanol:

$$M_S = Q_{dose} \cdot C_{dose} \cdot \frac{COD_{eq}}{MW}$$

In ASM2dMod and ASM2dISS, the soluble substrate contains a small amount of nitrogen (S_NH) and phosphorous (S_PO):

$$M_{PO} = i_{P,SF} \cdot M_{SF}$$
$$M_{NH} = i_{N,SF} \cdot M_{SF}$$

where:

- M_S is the flux (g/d) of fermentable soluble COD (S_S in ASM1, S_F in ASM2dMod and ASM2dISS)
- Q_{dose} and C_{dose} indicate the flow rate- (m3/d) and the concentration (g/m3) of the solution
- COD_{eq} and MW indicate the COD equivalent- (96 g/g) and molecular weight (46 g/mol) of ethanol

The power required for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{dose}}{24} \cdot 10^3$$

where:

- F is the pumping power per unit flow (kWh/m3)

Parameters

Name	Description	Value	Units
F_En_Q	Conversion factor: energy needed/pump flow rate	0.04	kWh/m3
i_N_S_F	Nitrogen content of soluble substrate S_F	0.03	---
i_P_S_F	Phosphorous content of soluble substrate S_F	0.01	---

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow vector	---	g/d
Flow_M	out_2	Amount of solution dosed	---	g/d
Flow_Q	out_2	Flow rate of solution dosed	---	m3/d
Energy_Pump	out_2	Energy for pumping	---	kWh

Name	Terminal	Description	Value	Units
Power_Pump	out_2	Power consumption for pumping	---	W
C_Dose	*in_1*	*Concentration of the solution*	*10,000*	*g/m3*
Q_Dose	*in_1*	*Flow rate of the solution*	*10.0*	*m3/d*

Dose_Methanol

Instances

All

Description

The model describes the addition of an external carbon source, in the form of methanol:

$$M_S = Q_{dose} \cdot C_{dose} \cdot \frac{COD_{eq}}{MW}$$

In ASM2dMod and ASM2dISS, the soluble substrate contains a small amount of nitrogen (S_NH) and phosphorous (S_PO):

$$M_{PO} = i_{P,SF} \cdot M_{SF}$$
$$M_{NH} = i_{N,SF} \cdot M_{SF}$$

where:

- M_S is the flux (g/d) of fermentable soluble COD (S_S in ASM1, S_F in ASM2dMod and ASM2dISS)
- Q_{dose} and C_{dose} indicate the flow rate- (m3/d) and the concentration (g/m3) of the solution
- COD_{eq} and MW indicate the COD equivalent- (48 g/g) and molecular weight (32 g/mol) of methanol

The power required for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{dose}}{24} \cdot 10^3$$

where:

- F is the pumping power per unit flow (kWh/m3)

Parameters

Name	Description	Value	Units
F_En_Q	Conversion factor: energy needed/pump flow rate	0.04	kWh/m3
i_N_S_F	Nitrogen content of soluble substrate S_F	0.03	---
i_P_S_F	Phosphorous content of soluble substrate S_F	0.01	---

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow vector	---	g/d
Flow_M	out_2	Amount of solution dosed	---	g/d
Flow_Q	out_2	Flow rate of solution dosed	---	m3/d
Energy_Pump	out_2	Energy for pumping	---	kWh

Name	Terminal	Description	Value	Units
Power_Pump	out_2	Power consumption for pumping	---	W
C_Dose	*in_1*	*Concentration of the solution*	*10,000*	*g/m3*
Q_Dose	*in_1*	*Flow rate of the solution*	*10.0*	*m3/d*

Dose_Alum

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of alum:

$$M_{MEOH} = Q_{dose} \cdot C_{dose} \cdot P_{eq} \cdot \frac{MW}{MW_{eq}}$$

where:

- M_{MEOH} is the flux (g/d) of metal hydroxide
- Q_{dose} and C_{dose} indicate the flow rate- (m3/d) and the concentration (g/m3) of the solution
- P_{eq} is the alum to phosphorous molar ratio (1 mol/mol)
- MW and MW_{eq} indicate the molecular weight of alum (342 g/mol) and that of iron hydroxide (FeOH, 106.85 g/mol)

The power required for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{dose}}{24} \cdot 10^3$$

where:

- F is the pumping power per unit flow (kWh/m3)

Parameters

Name	Description	Value	Units
F_En_Q	Conversion factor: energy needed/pump flow rate	0.04	kWh/m3

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow vector	---	g/d
Flow_M	out_2	Amount of solution dosed	---	g/d
Flow_Q	out_2	Flow rate of solution dosed	---	m3/d
Energy_Pump	out_2	Energy for pumping	---	kWh
Power_Pump	out_2	Power consumption for pumping	---	W
C_Dose	*in_1*	*Concentration of the solution*	*10,000*	*g/m3*
Q_Dose	*in_1*	*Flow rate of the solution*	*10.0*	*m3/d*

Dose_FeOH

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of iron hydroxide:

$$M_{MEOH} = Q_{dose} \cdot C_{dose} \cdot P_{eq} \cdot \frac{MW}{MW_{eq}}$$

where:

- M_{MEOH} is the flux (g/d) of metal hydroxide
- Q_{dose} and C_{dose} indicate the flow rate- (m3/d) and the concentration (g/m3) of the solution
- P_{eq} is the alum to phosphorous molar ratio (1 mol/mol)
- MW and MW_{eq} indicate the molecular weight of iron hydroxide (106.85 g/mol) and that of iron hydroxide (FeOH, 106.85 g/mol)

The power required for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{dose}}{24} \cdot 10^3$$

where:

- F is the pumping power per unit flow (kWh/m3)

Parameters

Name	Description	Value	Units
F_En_Q	Conversion factor: energy needed/pump flow rate	0.04	kWh/m3

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow vector	---	g/d
Flow_M	out_2	Amount of solution dosed	---	g/d
Flow_Q	out_2	Flow rate of solution dosed	---	m3/d
Energy_Pump	out_2	Energy for pumping	---	kWh
Power_Pump	out_2	Power consumption for pumping	---	W
C_Dose	*in_1*	*Concentration of the solution*	*10,000*	*g/m3*
Q_Dose	*in_1*	*Flow rate of the solution*	*10.0*	*m3/d*

Dose_FeCl3

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of iron chloride:

$$M_{MEOH} = Q_{dose} \cdot (S \cdot \rho) \cdot P_{eq} \cdot \frac{MW_{eq}}{MW}$$

where:

- M_{MEOH} is the flux (g/d) of metal hydroxide
- Q_{dose} is the flow rate (m3/d) of the solution
- S and ρ are the strength (%) and the density (g/m3) of the solution
- P_{eq} is the alum to phosphorous molar ratio (1.5 mol/mol)
- MW_{eq} and MW indicate the molecular weight of iron hydroxide (106.85 g/mol) and that of iron chloride (162.2 g/mol)

The power required for pumping is estimated as follows:

$$P_{Pump} = \frac{F \cdot Q_{dose}}{24} \cdot 10^3$$

where:

- F is the pumping power per unit flow (kWh/m3)

Parameters

Name	Description	Value	Units
F_En_Q	Conversion factor: energy needed/pump flow rate	0.04	kWh/m3
P_eq	Molar equivalence to phosphorous	0	---
Rho	Specific weight of the solution	1,500	kg/m3
Strength	Strength of the solution (%w/w)	12	%

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m3/d

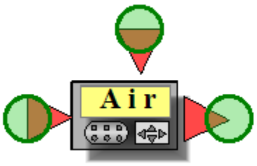
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow vector	---	g/d
Flow_M	out_2	Amount of solution dosed	---	g/d
Flow_Q	out_2	Flow rate of solution dosed	---	m3/d
Energy_Pump	out_2	Energy for pumping	---	kWh
Power_Pump	out_2	Power consumption for pumping	---	W
Q_Dose	*in_1*	*Flow rate of the solution*	*10.0*	*m3/d*

AERATION

	Palette Group	**Aeration**
	Category	Aerators
	Icon name	aerator

Ideal

Instances

All

Description

This is a simplistic aeration model. The model computes kLa based on the mass flow of oxygen, the oxygen gradient with respect to saturation at the working temperature and the volume of the tank.

The mass flow of oxygen:

$$m = Q_{air} \cdot \left(\frac{O2_{air}}{M_{vol_{air}}} \cdot M_{O2} \right)$$

where:

- Q_{air} is the flow rate of air [m3/d]
- $O2_{air}$ is the fraction of oxygen in air (0.2085)
- $M_{vol_{air}}$ is the molar volume of air [m3 air/mol air]
- M_{O2} is the molar weight of oxygen (32 g/mol)

The oxygen transfer coefficient, kLa:

$$k_L a = \frac{m}{(C_S - C_0) \cdot V}$$

where:

- C_S and C_0 denote the oxygen saturation and dissolved oxygen concentration in the aerated tank [g O2/m3)
- V is the volume of the aerated tank [m3]

Parameters

Name	Description	Value	Units
Vol_tank	Volume of the aeration tank	1000	m3
AE	Aeration efficiency	0.8	kgO2/kWh

State Variables

Name	Description	Units
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m3
Energy_Aer	Energy consumption for aeration, integral	kWh

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
O2_tank	in_1	DO concentration in the aeration tank	---	g/m3
Kla	out_1	Computed Oxygen Transfer Coefficient	---	1/d
T_air	*in_2*	*Air temperature*	*15*	*°C*
T_water	*in_2*	*Water temperature*	*15*	*°C*
Q_air	*in_2*	*Air flow rate under Standard Conditions*	*35,000*	*m3/d*

IdealMulti

Instances

All

Description

This is an aeration model. The model separates the air flow into the tanks, the model can handle up to 10 tanks.

The model computes kLa for each tank based on the mass flow of oxygen into the tank, the oxygen saturation and the volume of the tank.

The mass flow of oxygen into tank i:

$$\dot{m}_i = Q_{air,i} \cdot \left(\frac{O2_{air}}{M_{vol_{air}}} \cdot M_{O2} \right)$$

where:

- $Q_{air,i}$ is the flow rate of air into tank i [m3/d]
- $O2_{air}$ and M_{O2} denote the fraction of oxygen in air (0.2085) and the molar weight of oxygen (32 g/mol) respectively
- $M_{vol_{air}}$ is the molar volume of air [m3 air/mol air]

The oxygen transfer coefficient of tank i, kLa_i:

$$kLa_i = \frac{\dot{m}_i}{C_S \cdot V_i}$$

where:

- C_S is the oxygen saturation [g O2/m3]
- V_i is the volume of tank i [m3]

Parameters

Name	Description	Value	Units
V_01 … V_10	Volume of tank no. 1 to 10	1000	m3
AE	Aeration efficiency	0.8	kgO2/kWh

State Variables

Name	Description	Units
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m3
Energy_Aer	Energy consumption for aeration, integral	kWh

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
DO_01 … DO_10	in_1	DO concentration in tank no. 1 to 10	---	g/m3
Kla_01 … Kla_10	out_1	Computed kLa for tank no. 1 to 10	---	1/d
T_air	*in_2*	*Air temperature*	*15*	*°C*
T_water	*in_2*	*Water temperature*	*15*	*°C*
Q_air_01 … Q_air_10	*in_2*	*Air flow rate to tank no. 1 to 10*	*35,000*	*m3/d*

IdealMulti2

Instances

All

Description

This is an aeration model. The model separates the air flow into the tanks based on fractions of the total air flow. The model can handle up to 10 tanks.
The model computes kLa for each tank based on the mass flow of oxygen into the tank, the oxygen saturation and the volume of the tank.

The mass flow of oxygen into tank i:

$$\dot{m}_i = (Q_{air} \cdot f_{air,i}) \cdot \left(\frac{O2_{air}}{M_{vol_{air}}} \cdot M_{O2} \right)$$

where:

- Q_{air} is the total flow rate of air [m3/d]
- $f_{air,i}$ is the fraction of the total air flow into tank i
- $O2_{air}$ and M_{O2} denote the fraction of oxygen in air (0.2085) and the molar weight of oxygen (32 g/mol) respectively
- $M_{vol_{air}}$ is the molar volume of air [m3 air/mol air]

The oxygen transfer coefficient of tank i, kLa_i:

$$kLa_i = \frac{\dot{m}_i}{C_s \cdot V_i}$$

where:

- C_S is the oxygen saturation [g O2/m3]
- V_i is the volume of tank i [m3]

Parameters

Name	Description	Value	Units
V_01 … V_10	Volume of tank no. 1 to 10	1000	m3
AE	Aeration efficiency	0.8	kgO2/kWh

State Variables

Name	Description	Units
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m^3
Energy_Aer	Energy consumption for aeration, integral	kWh

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
DO_01 … DO_10	in_1	DO concentration in tank no. 1 to 10	---	g/m3
Kla_01 … Kla_10	out_1	Computed kLa for tank no. 1 to 10	---	1/d
T_air	*in_2*	*Air temperature*	*15*	°C
T_water	*in_2*	*Water temperature*	*15*	°C

Name	**Terminal**	**Description**	**Value**	**Units**
Q_air	*in_2*	*Total air flow rate*	*35,000*	*m3/d*
f_air_01 … f_air_10	*in_2*	*Fraction of total air flow to tank no. 1 to 10*	*0,1*	*---*

Surface

Instances

All

Description

This is a simple aeration model which computes the value of KLa as a function of the aeration efficiency, the power input and the oxygen gradient with respect to saturation at the working temperature:

$$k_L a = \frac{AE \cdot P}{(C_S - C_0) \cdot V}$$

where:

- AE is the aeration efficiency (kg O2/kWh)
- P is the power input (W)
- C_S and C_0 denote the oxygen saturation and dissolved oxygen concentration in the aerated tank (g O2/m3)
- V is the volume of the aerated tank (m3)

Parameters

Name	Description	Value	Units
Vol_tank	Volume of the aeration tank	1000	m3
AE	Aeration efficiency	0.8	kgO2/kWh

State Variables

Name	Description	Units
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m^3
Energy_Aer	Energy consumption for aeration, integral	kWh

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
O2_tank	in_1	DO concentration in the aeration tank	---	g/m3
Kla	out_1	Computed Oxygen Transfer Coefficient	---	1/d
T_air	*in_2*	*Air temperature*	*15*	*°C*
T_water	*in_2*	*Water temperature*	*15*	*°C*
P	*in_2*	*Power input*	*500,000*	*W*

FineBubble1

Instances

All

Description

Fine bubble aeration model characterised by an alpha factor as function of the sludge age.

The oxygen transfer coefficient (1/d) is calculated as:

$$kLa = \frac{OTR}{(\beta \cdot O2_{rsat} - O2_{tank}) \cdot V_{tank}}$$

where:

- OTR is the Oxygen Transfer Rate (g/d) under field conditions
- β is the correction factor (-) for oxygen saturation in non-clean water
- $O2_{rsat}$ and $O2_{tank}$ denote the average concentration at saturation and the actual concentration (g/m3) of dissolved oxygen respectively
- V_{tank} is the volume of the aerated tank (m3)

The oxygen transfer rate depends on the α-F factor which in turns depends on α (the empirical factor), which is calculated as follows:

$$\alpha SOTE = A \cdot \log \chi - B$$

$$\chi = \frac{SRT}{Q_n}$$

$$Q_n = \frac{Q_{Air}}{A_{sp} \cdot N_d \cdot h}$$

where:

- A and B are calibration parameters
- SRT denotes the sludge age (d)
- Q_n and Q_{Air} are the normalised air flow (m3/s) and the air flow rate (m3/d) respectively
- A_{sp} and N_d are the active area (m3) and the total number (-) of the diffusers
- h is the depth (m) of the fine bubble aerator

The power requirement for adiabatic compression:

$$P_{blower} = \frac{\rho_{air} \cdot Q_{air} \cdot R \cdot T_{in}}{M_{air} \cdot \varepsilon} \cdot \frac{\lambda}{\lambda - 1} \cdot \left[\left(\frac{p_{st,atm} + p_{out}}{p_{st,atm}} \right)^{\left(\frac{\lambda-1}{\lambda}\right)} - 1 \right]$$

where:

- ρ_{air}, Q_{air} and M_{air} denote the density (g/m3), flow rate (m3/d) and molar mass (g/mol) of air
- R is the universal gas constant
- T_{in} is the absolute inlet temperature (K)
- ε indicates the blower efficiency
- $p_{st,atm}$ and p_{out} indicate the absolute inlet- and absolute outlet pressures

- λ is an empirical constant for air

Parameters

Name	Description	Value	Units
Beta	Correct for oxygen saturation in non-clean water	0.98	---
MRi	Mole ratio of oxygen that enters air and off gas	0.2635	---
A	Empirical factor	5.7	---
B	Empirical factor	6.8	---
f	Fraction of tank depth (from surface) at which pressure corresponds to the average saturation concentration	0.44	---
mode	Alpha as input (0) or calculated from empirical regression (1)	0	---
H	Altitude	0	m
Rho_air	Air density	1,230	g/m3
Rho_sludge	Sludge density	1,000,000	g/m3
Vol_tank	Volume of the aeration tank	1,000	m3
A_sp	Specific area of the diffusers	2	m2
Nd	Number of diffusers	500	---
h	Depth of the (fine bubble) aerator	6	m
O2_sat20	Oxygen saturation at Standard Conditions and no salts	10.5	g/m3
SOTE	Standard Oxygen Transfer Efficiency per unit depth	6	%
Epsilon	Efficiency of the motor	0.58	---
Lambda	Empirical constant for air	1.395	---
T_in	Inlet temperature	20	°C
fCO2	CO2 production per unit of energy	0.718	kg/kWh

State Variables

Name	Description	Units
AlphaSOTE	Oxygen transfer efficiency for new aerators	---
OTE	Oxygen Transfer Efficiency (under field conditions)	---
OTR	Oxygen Transfer Rate (under field conditions)	g/d
OTRsp	Specific Oxygen Transfer Rate	g/m3/d
Q_O2	Oxygen mass load in air flow	kg/h
Qn	Normalised air flow	---
Qsp	Specific air flow (through each diffuser)	m3/d
SOTR	Standard Oxygen Transfer Rate	g/d
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m3
P_vapour	Vapour pressure	Pa
Alpha	Empirical factor	---
AlphaF	Alpha-F factor (account for fouling of diffusers)	---
O2_rsat_ave	Average oxygen saturation for fine bubble aeration	g/m3
M_CO2	CO2 production	g/d

Derived State Variables

Name	Description	Units
E_CO2	CO2 emission	g

Interface Variables

Name	Terminal	Description	Value	Units
O2_tank	in_1	DO concentration in the aeration tank	---	g/m^3
T_air	*in_2*	*Air temperature*	*15*	*C*
T_water	*in_2*	*Water temperature*	*15*	*C*
P_Out	*in_2*	*Pressure at delivery*	*80,000*	*Pa*

Name	Terminal	Description	Value	Units
AlphaF_new	*in_2*	*Alpha-F for new diffusers (= alpha if f_Foul=1)*	*0.6*	---
f_Foul	*in_2*	*Relative pressure increase (1=clean membrane) due to fouling*	*1*	---
Q_air	*in_2*	*Air flow rate under Standard Conditions*	*10,000*	*m3/d*
SRT	*in_2*	*Sludge age*	*10*	*d*
Kla	out_1	Computed Oxygen Transfer Coefficient	---	1/d
P_Aer	out_1	Power consumption	---	kWh/d
P_Blowers	out_1	Power consumption	---	W

FineBubble2

Instances
All

Description
Fine bubble aeration model characterised by an alpha factor as function of the solids concentration.

The oxygen transfer coefficient (1/d) is calculated as:

$$kLa = \frac{OTR}{(\beta \cdot O2_{rsat} - O2_{tank}) \cdot V_{tank}}$$

where:

- OTR is the Oxygen Transfer Rate (g/d) under field conditions
- β is the correction factor (-) for oxygen saturation in non-clean water
- $O2_{rsat}$ and $O2_{tank}$ denote the average concentration at saturation and the actual concentration (g/m3) of dissolved oxygen respectively
- V_{tank} is the volume of the aerated tank (m3)

The oxygen transfer rate depends on the α-F factor which in turns depends on α (the empirical factor), which is calculated as follows:

Krampe and Krauth (2003): $\alpha_0 = e^{-0.08788 \cdot MLSS}$

Baquero-Rodriguez et al. (2018): $\alpha_1 = \frac{0{,}507}{0{,}507-0{,}104} \cdot (e^{-0.104 \cdot MLSS} - e^{-0.507 \cdot MLSS})$

where:

- $MLSS$ is the solids concentration in the tank (kg/m3)

The power requirement for adiabatic compression:

$$P_{blower} = \frac{\rho_{air} \cdot Q_{air} \cdot R \cdot T_{in}}{M_{air} \cdot \varepsilon} \cdot \frac{\lambda}{\lambda - 1} \cdot \left[\left(\frac{p_{st,atm} + p_{out}}{p_{st,atm}} \right)^{\left(\frac{\lambda-1}{\lambda}\right)} - 1 \right]$$

where:

- ρ_{air}, Q_{air} and M_{air} denote the density (g/m3), flow rate (m3/d) and molar mass (g/mol) of air
- R is the universal gas constant
- T_{in} is the absolute inlet temperature (K)
- ε indicates the blower efficiency
- $p_{st,atm}$ and p_{out} indicate the absolute inlet- and absolute outlet pressures
- λ is an empirical constant for air

Parameters

Name	Description	Value	Units
Beta	Correct for oxygen saturation in non-clean water	0.98	---
MRi	Mole ratio of oxygen that enters air and off gas	0.2635	---

Name	Description	Value	Units
f	Fraction of tank depth (from surface) at which pressure corresponds to the average saturation concentration	0.44	---
mode	Krampe and Krauth (0) or Baquero-Rodriguez (1)	0	---
H	Altitude	0	m
Rho_air	Air density	1,230	g/m3
Rho_sludge	Sludge density	1,000,000	g/m3
Vol_tank	Volume of the aeration tank	1,000	m3
A_sp	Specific area of the diffusers	2	m2
Nd	Number of diffusers	500	---
h	Depth of the (fine bubble) aerator	6	m
O2_sat20	Oxygen saturation at Standard Conditions and no salts	10.5	g/m3
SOTE	Standard Oxygen Transfer Efficiency per unit depth	6	%
Epsilon	Efficiency of the motor	0.58	---
Lambda	Empirical constant for air	1.395	---
T_in	Inlet temperature	20	°C
fCO2	CO2 production per unit of energy	0.718	kg/kWh

State Variables

Name	Description	Units
AlphaSOTE	Oxygen transfer efficiency for new aerators	---
OTE	Oxygen Transfer Efficiency (under field conditions)	---
OTR	Oxygen Transfer Rate (under field conditions)	g/d
OTRsp	Specific Oxygen Transfer Rate	g/m3/d
Qsp	Specific air flow (through each diffuser)	m3/d
SOTR	Standard Oxygen Transfer Rate	g/d
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m3
P_vapour	Vapour pressure	Pa
Alpha	Empirical factor	---
AlphaF	Alpha-F factor (account for fouling of diffusers)	---
O2_rsat_ave	Average oxygen saturation for fine bubble aeration	g/m3
M_CO2	CO2 production	g/d

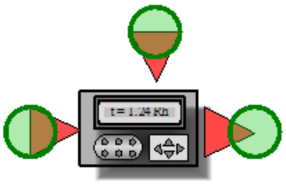
Derived State Variables

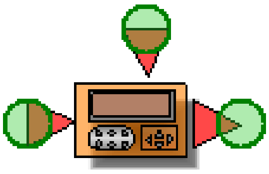
Name	Description	Units
E_CO2	CO2 emission	g

Interface Variables

Name	Terminal	Description	Value	Units
O2_tank	in_1	DO concentration in the aeration tank	---	g/m^3
T_air	*in_2*	*Air temperature*	*15*	*C*
T_water	*in_2*	*Water temperature*	*15*	*C*
P_Out	*in_2*	*Pressure at delivery*	*80,000*	*Pa*
f_Foul	*in_2*	*Relative pressure increase (1=clean membrane) due to fouling*	*1*	---
Q_air	*in_2*	*Air flow rate under Standard Conditions*	*10,000*	*m3/d*
MLSS	*in_2*	*MLSS concentration in the tank*	*4,000*	*g/m3*
Kla	out_1	Computed Oxygen Transfer Coefficient	---	1/d
P_Aer	out_1	Power consumption	---	kWh/d
P_Blowers	out_1	Power consumption	---	W

CONTROLLERS

	Palette Group	**Controllers & Timers**
	Category	Controllers

	Palette Group	**Controllers & Timers**
	Category	ControllersOp
	Icon	controller_op

Remark: all control models, unless stated otherwise, incorporate an algebraic loop-breaker.

Controllers.P_Saturation

Instances

All

Icon Name

“controller_p”

Description

The control action is proportional to the “error”, i.e. the difference between the set-point and the measured value (incoming signal):

$$e = y_S - y_M$$

$$u = u_0 + K_P \cdot e$$

where:

- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
y1_S	*in_2*	*Set-point value for controlled variable*	*2*	---
K1_P	*in_2*	*Factor of proportionality*	*25*	---
u1_0	*in_2*	*No error action*	*50*	---
u1_Min	*in_2*	*Minimum control action*	*0*	---
u1_Max	*in_2*	*Maximum control action*	*1000.0*	---

Controllers.PI_Saturation

Instances

All

Icon Name

“controller_pi”

Description

The control action is proportional to the “error”, i.e. the difference between the set-point and the measured value (incoming signal) and to its integral:

$$e = y_S - y_M$$

$$u = u_0 + K_P \cdot e + \frac{K_P}{T_I} \cdot \int e$$

where:

- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller
- T_I is the integral time frame (d)

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
y1_S	*in_2*	*Set-point value for controlled variable*	*2*	---
K1_P	*in_2*	*Factor of proportionality*	*25*	---
T1_I	*in_2*	*Integral time*	*0.1*	*d*
u1_0	*in_2*	*No error action*	*50*	---
u1_Min	*in_2*	*Minimum control action*	*0*	---
u1_Max	*in_2*	*Maximum control action*	*1000.0*	---

Controllers.PI05_Saturation

Instances

All

Icon Name

“controller_pi”

Description

This is the combination of five (5) independent proportional-integral controllers, with output signal limited between a lower and an upper bound.

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1-5_M	in_1	Sensor measured output 1 to 5	---	---
u1-5	out_1	Controlled variables 1 to 5	---	---
y1-5_S	*in_2*	*Set-point values for the controlled variables*	*2*	---
K1-5_P	*in_2*	*Factors of proportionality*	*25*	---
u1-5_0	*in_2*	*No error actions*	*50*	---
u1-5_Min	*in_2*	*Minimum control actions*	*0*	---
u1-5_Max	*in_2*	*Maximum control actions*	*1000.0*	---

Controllers.PID_Saturation

Instances

All

Icon Name

“controller_pid”

Description

The control action is proportional to the “error”, i.e. the difference between the set-point and the measured value (incoming signal), to its integral and first derivative:

$$e = y_S - y_M$$

$$u = u_0 + K_P \cdot e + \frac{K_P}{T_I} \cdot \int e + K_P \cdot T_D \cdot \frac{de}{dt}$$

where:

- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller
- T_I and T_D denote the integral and the derivative time frames (d)

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
y1_S	*in_2*	*Set-point value for controlled variable*	*2*	---
K1_P	*in_2*	*Factor of proportionality*	*25*	---
T1_I	*in_2*	*Integral time*	*0.1*	*d*
T1_D	*in_2*	*Derivative time*	*0.1*	*d*
u1_0	*in_2*	*No error action*	*50*	---
u1_Min	*in_2*	*Minimum control action*	*0*	---
u1_Max	*in_2*	*Maximum control action*	*1000.0*	---

Controllers.PID_SaturationAW

Instances

All

Icon Name

“controller_pid”

Description

The control action is proportional to the “error”, i.e. the difference between the set-point and the measured value (incoming signal), to its integral and first derivative:

$$e = y_S - y_M$$

$$u = u_0 + K_P \cdot e + \frac{K_P}{T_I} \cdot \int e + K_P \cdot T_D \cdot \frac{de}{dt} + u_{aw}$$

$$u_{aw} = \int \frac{u^* - u}{T_t}$$

where:

- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller
- T_I and T_D denote the integral and the derivative time frames (d)

The control action (u^*) is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
y1_S	*in_2*	*Set-point value for controlled variable*	*2*	---
K1_P	*in_2*	*Factor of proportionality*	*25*	---
T1_I	*in_2*	*Integral time*	*0.1*	*d*
T1_D	*in_2*	*Derivative time*	*0.1*	*d*
T_t	*in_2*	*Antiwindup time constant*	*0.0002*	*d*
u1_0	*in_2*	*No error action*	*50*	---
u1_Min	*in_2*	*Minimum control action*	*0*	---
u1_Max	*in_2*	*Maximum control action*	*1000.0*	---

Controllers.OnOff

Instances

All

Icon Name

“controller_on_off”

Description

The control action has two states (i.e. ‘on’ and ‘off’) corresponding to measured value (incoming signal) below and above a given set-point, respectively:

$$(Y_M < Y_S): u = u_{Min}$$
$$(Y_M \geq Y_S): u = u_{Max}$$

where:

- Y_S denotes the set-point of the incoming signal
- u_{Min} and u_{Max} indicate the corresponding states (-), i.e. output signals

Remark: the same model is available without intrinsic loop-breaker (classname: “OnOff_noLB”).

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
y1_S	*in_2*	*Set-point value for controlled variable*	*0*	---
u1_Min	*in_2*	*Minimum control action*	*0*	---
u1_Max	*in_2*	*Maximum control action*	*0*	---

Controllers.OnOff_Band

Instances

All

Icon Name

“controller_on_off”

Description

The control action has two states (i.e. ‘on’ and ‘off’) corresponding to the two thresholds for the measured value (incoming signal):

$$(Y_M < Y_{Min}): u = u_{Min}$$
$$(Y_{Min} \leq Y_M < Y_{Max}): u = u_{t-\Delta t}$$
$$(Y_M \geq Y_{Max}): u = u_{Max}$$

where:

- Y_{Min} and Y_{Max} denote the lower- and upper threshold (-) of the incoming signal
- u_{Min} and u_{Max} indicate the corresponding states (-), i.e. output signals
- $u_{t-\Delta t}$ is output signal at the previous time step

Within the band (Y_{Min}-Y_{Max}), the control action does not change.

Remark: the same model is available without intrinsic loop-breaker (classname: “OnOff_Band_noLB”).

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
y1_Min	*in_2*	*Lower limit for controlled variable*	*0*	---
y1_Max	*in_2*	*Upper limit for controlled variable*	*0*	---
u1_Min	*in_2*	*Minimum control action*	*0*	---
u1_Max	*in_2*	*Maximum control action*	*0*	---

Controllers.Ratio

Instances

All

Icon Name

“controller_ratio”

Description

The control action is proportional to the incoming signal (measured value):

$$u = k \cdot y_M$$

where:

- k is the proportionality factor (-)

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
R1	*in_2*	*Ratio between output and measured value*	*1*	---

Ratio2

Instances

All

Icon Name

“controller_ratio”

Description

The control action is proportional to the incoming signal (measured value):

$$u = k \cdot y_M$$

where:

- k is the proportionality factor (-)

Instead of the conventional algebraic loop-breaker, this model incorporates an implicit loop-breaker.

Parameters

Name	Description	Value	Units
Tau	Time constant	5E-04	d

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1_M	in_1	Sensor measured output no.1	---	---
u1	out_1	Controlled variable no.1	---	---
R1	*in_2*	*Ratio between output and measured value*	*1*	---

ControllersOp.OnOff11

Instances

All

Icon Name

“controller_op”

Description

This is an on/off controller with band, identical to the Controllers.OnOff, i.e., 1 incoming measurement and 1 outgoing control action, but with the option to be turned off to a fall-back mode.

When on, the control action is proportional to the incoming signal (measured value):

$$u = k \cdot y_M$$

where:

- k is the proportionality factor (-)

Instead of the conventional algebraic loop-breaker, this model incorporates an implicit loop-breaker.

Parameters

None

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
in_01	in_1	Input signal no.1	---	---
out_01	out_1	Output signal no.1	---	---
in01_Max	*in_2*	*Upper limit for the measured value no.1*	*0*	---
in01_Min	*in_2*	*Lower limit for the measured value no.1*	*0*	---
out01_Max	*in_2*	*Output when measured value > in01_Max*	*0*	---
out01_Min	*in_2*	*Output when measured value < in01_Min*	*0*	---
mode	*in_2*	*On (1), off (0)*	*1*	---
out_01_fb	*in_2*	*Fall-back for output no.1*	*0*	---

ControllersOp.PI11

Instances
All

Icon Name
“controller_op”

Description
This is a proportional-integral (PI) controller, identical to the Controllers.PI_Saturation, i.e., 1 incoming measurement and 1 outgoing control action, but with the option to be turned off to a fall-back mode, as well as the option to change the sign of the difference between the set-point and the measured value:

$$e = s_e \cdot (y_S - y_M)$$

$$u = u_0 + K_P \cdot e + \frac{K_P}{T_I} \cdot \int e$$

where:

- s_e is the sign (+1/-1) of the error
- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller
- T_I is the integral time frame (d)

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

Name	Description	Value	Units
sign_e	Sign for error: 1 (sp-m), -1 (m-sp)	+1	---

State Variables
None

Derived State Variables
None

Interface Variables

Name	Terminal	Description	Value	Units
in_01	in_1	Input signal no.1	---	---
out_01	out_1	Output signal no.1	---	---
y01_S	*in_2*	*Setpoint value for controlled variable no.1*	*2*	---
K01_P	*in_2*	*Factor of proportionality*	*25*	---
T01_I	*in_2*	*Integral time*	*0.1*	*d*
u01_0	*in_2*	*No error action*	*50*	---
u01_Min	*in_2*	*Output when measured value < in01_Min*	*0*	---
u01_Max	*in_2*	*Output when measured value > in01_Max*	*0.0*	---
mode	*in_2*	*On (1), off (0)*	*1*	---
out_01_fb	*in_2*	*Fall-back for output no.1*	*0*	---

ControllersOp.PID11

Instances

All

Icon Name

"controller_op"

Description

This is a proportional-integral-derivative (PID) controller, identical to the Controllers.PID_Saturation, i.e., 1 incoming measurement and 1 outgoing control action, but with the option to be turned off to a fall-back mode, as well as the option to change the sign of the difference between the set-point and the measured value:

$$e = s_e \cdot (y_S - y_M)$$

$$u = u_0 + K_P \cdot e + \frac{K_P}{T_I} \cdot \int e + K_P \cdot T_D \cdot \frac{de}{dt}$$

where:

- s_e is the sign (+1/-1) of the error
- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller
- T_I and T_D denote the integral and the derivative time frames (d)

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

Name	Description	Value	Units
sign_e	Sign for error: 1 (sp-m), -1 (m-sp)	+1	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
in_01	in_1	Input signal no.1	---	---
out_01	out_1	Output signal no.1	---	---
y01_S	*in_2*	*Setpoint value for controlled variable no.1*	*2*	---
K01_P	*in_2*	*Factor of proportionality*	*25*	---
T01_I	*in_2*	*Integral time*	*0.1*	*d*
T1_D	*in_2*	*Derivative time*	*0.1*	*d*
u01_0	*in_2*	*No error action*	*50*	---
u01_Min	*in_2*	*Output when measured value < in01_Min*	*0*	---
u01_Max	*in_2*	*Output when measured value > in01_Max*	*0.0*	---
mode	*in_2*	*On (1), off (0)*	*1*	---
out_01_fb	*in_2*	*Fall-back for output no.1*	*0*	---

ControllersOp.PID11_aw

Instances

All

Icon Name

“controller_op”

Description

This is a proportional-integral-derivative (PID) controller with anti-windup, identical to the Controllers.PID_SaturationAW, i.e., 1 incoming measurement and 1 outgoing control action, but with the option to be turned off to a fall-back mode, as well as the option to change the sign of the difference between the set-point and the measured value:

$$e = s_e \cdot (y_S - y_M)$$

$$u = u_0 + K_P \cdot e + \frac{K_P}{T_I} \cdot \int e + K_P \cdot T_D \cdot \frac{de}{dt} + u_{aw}$$

$$u_{aw} = \int \frac{u^* - u}{T_t}$$

where:

- s_e is the sign (+1/-1) of the error
- u_0 is the baseline control action (-)
- K_P is the proportionality factor (-), or gain of the controller
- T_I and T_D denote the integral and the derivative time frames (d)

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters

Name	Description	Value	Units
sign_e	Sign for error: 1 (sp-m), -1 (m-sp)	+1	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
in_01	in_1	Input signal no.1	---	---
out_01	out_1	Output signal no.1	---	---
y01_S	*in_2*	*Setpoint value for controlled variable no.1*	*2*	---
K01_P	*in_2*	*Factor of proportionality*	*25*	---
T01_I	*in_2*	*Integral time*	*0.1*	*d*
T1_D	*in_2*	*Derivative time*	*0.1*	*d*
T_t	*in_2*	*Antiwindup time constant*	*0.0002*	*d*
u01_0	*in_2*	*No error action*	*50*	---
u01_Min	*in_2*	*Output when measured value < in01_Min*	*0*	---

Name	Terminal	Description	Value	Units
u01_Max	*in_2*	*Output when measured value > in01_Max*	*0.0*	---
mode	*in_2*	*On (1), off (0)*	*1*	---
out_01_fb	*in_2*	*Fall-back for output no.1*	*0*	---

ControllersOp.PID_SRT

Instances

All

Icon Name

"controller_op"

Description

This is a model for the regulation of the sludge wastage, in an activated sludge process, based on the sludge age.
It combines an SRT calculator and a PID controller.

Submodels

Name	Model
calc	Calculators.AS_SRT
pid	ControllersOp.PID11_aw

Parameters

None

State Variables

Name	Description	Units
SRTavg	Average SRT	d
SRTi	Instantaneous SRT	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
TSS_01 ... 30	in_1	TSS in tanks no.1 to 30		g/m3
V_01 ... 30	in_1	Volume of tanks no. 1 to 30		m3
Q_Waste1, 2	in_1	Flow rate of waste sludge no.1 and 2		m3/d
TSS_Waste1, 2	in_1	TSS in waste sludge no.1 and 2		g/m3
Q_Out	in_1	Effluent flow rate	---	m3/d
TSS_Out	in_1	Sludge concentration in the effluent	---	g/m3
Q_WAS	out_1	Regulated WAS flow rate		m3/d
T_Window	*in_2*	*Moving window*	*1*	*d*
K01_P	*in_2*	*Factor of proportionality*	*0.1*	*---*
Q_WAS_0	*in_2*	*No error action WAS flow rate*	*50*	*m3/d*
Q_WAS_Max	*in_2*	*Max WAS flow rate*	*100*	*m3/d*
Q_WAS_Min	*in_2*	*Min WAS flow rate*	*1*	*m3/d*
Q_WAS_fb	*in_2*	*Fall-back for WAS flow rate*	*0*	*m3/d*
SRT_sp	*in_2*	*SRT set point*	*12*	*d*
T01_D	*in_2*	*Derivative time*	*30*	*min*
T01_I	*in_2*	*Integral time*	*60*	*min*
T01_t	*in_2*	*Tracking time (anti-windup)*	*30*	*min*
mode	*in_2*	*On (1), off (0)*	*1*	*---*

ControllersOp.Ratio

Instances
All

Icon Name
“controller_op”

Description
This is a ratio controller, identical to the Controllers.Ratio, i.e., 1 incoming measurement and 1 outgoing control action, but with the option to be turned off to a fall-back mode:

$$u = k \cdot y_M$$

where:

- k is the proportionality factor (-)

The control action is limited between a lower (u_{Min}) and an upper bound (u_{Max}) for the outgoing signal.

Parameters
None

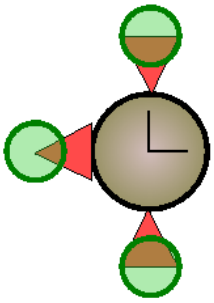
State Variables
None

Derived State Variables
None

Interface Variables

Name	Terminal	Description	Value	Units
in_01	in_1	Input signal no.1	---	---
out_01	out_1	Output signal no.1	---	---
R01	*in_2*	*Ratio between measured value and output*	*1*	---
u01_Min	*in_2*	*Output when measured value < in01_Min*	*0*	---
u01_Max	*in_2*	*Output when measured value > in01_Max*	*0.0*	---
mode	*in_2*	*On (1), off (0)*	*1*	---
out_01_fb	*in_2*	*Fall-back for output no.1*	*0*	---

TIMERS

	Palette Group	**Controllers & Timers**
	Category	Timers
	Icon Name	timer

Timer21

Instances

All

Description

The model has two periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*

Timer22

Instances

All

Description

The model has two periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*10.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*

Timer31

Instances

All

Description

The model has three periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2 + T_3$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
u13	*in_2*	*Signal in period no.3*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*

Timer32

Instances

All

Description

The model has three periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2 + T_3$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*50.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
u31	*in_2*	*Signal no.3 in period no.1*	*50.0*	---
u32	*in_2*	*Signal no.3 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*

Timer41

Instances

All

Description

The model has four periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
u13	*in_2*	*Signal in period no.3*	*50.0*	---
u14	*in_2*	*Signal in period no.4*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*

Timer42

Instances

All

Description

The model has four periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*50.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
u31	*in_2*	*Signal no.3 in period no.1*	*50.0*	---
u32	*in_2*	*Signal no.3 in period no.2*	*50.0*	---
u41	*in_2*	*Signal no.4 in period no.1*	*50.0*	---
u42	*in_2*	*Signal no.4 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*

Timer51

Instances
All

Description
The model has five periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters
None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables
None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
u13	*in_2*	*Signal in period no.3*	*50.0*	---
u14	*in_2*	*Signal in period no.4*	*50.0*	---
u15	*in_2*	*Signal in period no.5*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*

Timer52

Instances

All

Description

The model has five periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*50.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
u31	*in_2*	*Signal no.3 in period no.1*	*50.0*	---
u32	*in_2*	*Signal no.3 in period no.2*	*50.0*	---
u41	*in_2*	*Signal no.4 in period no.1*	*50.0*	---
u42	*in_2*	*Signal no.4 in period no.2*	*50.0*	---
u51	*in_2*	*Signal no.5 in period no.1*	*50.0*	---
u52	*in_2*	*Signal no.5 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*

Timer61

Instances

All

Description

The model has six periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
u13	*in_2*	*Signal in period no.3*	*50.0*	---
u14	*in_2*	*Signal in period no.4*	*50.0*	---
u15	*in_2*	*Signal in period no.5*	*50.0*	---
u16	*in_2*	*Signal in period no.6*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*
T6	*in_2*	*Period no.6*	*0.125*	*d*

Timer62

Instances

All

Description

The model has six periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*50.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
u31	*in_2*	*Signal no.3 in period no.1*	*50.0*	---
u32	*in_2*	*Signal no.3 in period no.2*	*50.0*	---
u41	*in_2*	*Signal no.4 in period no.1*	*50.0*	---
u42	*in_2*	*Signal no.4 in period no.2*	*50.0*	---
u51	*in_2*	*Signal no.5 in period no.1*	*50.0*	---
u52	*in_2*	*Signal no.5 in period no.2*	*50.0*	---
u61	*in_2*	*Signal no.6 in period no.1*	*50.0*	---
u62	*in_2*	*Signal no.6 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*
T6	*in_2*	*Period no.6*	*0.125*	*d*

Timer71

Instances

All

Description

The model has seven periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
u13	*in_2*	*Signal in period no.3*	*50.0*	---
u14	*in_2*	*Signal in period no.4*	*50.0*	---
u15	*in_2*	*Signal in period no.5*	*50.0*	---
u16	*in_2*	*Signal in period no.6*	*50.0*	---
u17	*in_2*	*Signal in period no.7*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*
T6	*in_2*	*Period no.6*	*0.125*	*d*
T7	*in_2*	*Period no.7*	*0.125*	*d*

Timer72

Instances

All

Description

The model has seven periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*50.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
u31	*in_2*	*Signal no.3 in period no.1*	*50.0*	---
u32	*in_2*	*Signal no.3 in period no.2*	*50.0*	---
u41	*in_2*	*Signal no.4 in period no.1*	*50.0*	---
u42	*in_2*	*Signal no.4 in period no.2*	*50.0*	---
u51	*in_2*	*Signal no.5 in period no.1*	*50.0*	---
u52	*in_2*	*Signal no.5 in period no.2*	*50.0*	---
u61	*in_2*	*Signal no.6 in period no.1*	*50.0*	---
u62	*in_2*	*Signal no.6 in period no.2*	*50.0*	---
u71	*in_2*	*Signal no.7 in period no.1*	*50.0*	---
u72	*in_2*	*Signal no.7 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*
T6	*in_2*	*Period no.6*	*0.125*	*d*
T7	*in_2*	*Period no.7*	*0.125*	*d*

Timer81

Instances

All

Description

The model has eight periods and one regulated output that can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
u11	*in_2*	*Signal in period no.1*	*10.0*	---
u12	*in_2*	*Signal in period no.2*	*50.0*	---
u13	*in_2*	*Signal in period no.3*	*50.0*	---
u14	*in_2*	*Signal in period no.4*	*50.0*	---
u15	*in_2*	*Signal in period no.5*	*50.0*	---
u16	*in_2*	*Signal in period no.6*	*50.0*	---
u17	*in_2*	*Signal in period no.7*	*50.0*	---
u18	*in_2*	*Signal in period no.8*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*
T6	*in_2*	*Period no.6*	*0.125*	*d*
T7	*in_2*	*Period no.7*	*0.125*	*d*
T8	*in_2*	*Period no.8*	*0.125*	*d*

Timer82

Instances

All

Description

The model has eight periods and two regulated output. Each output signal can take a different value in each period.

$$T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8$$

Remark: the maximum integrator time step may need to be smaller than the period (T).

Parameters

None

State Variables

Name	Description	Units
T	Total cycle	d

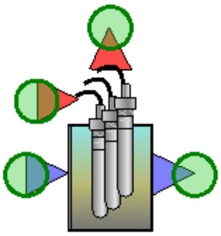
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y1	out_1	Output signal no.1	---	---
y2	out_1	Output signal no.2	---	---
u11	*in_2*	*Signal no.1 in period no.1*	*10.0*	---
u12	*in_2*	*Signal no.1 in period no.2*	*50.0*	---
u21	*in_2*	*Signal no.2 in period no.1*	*50.0*	---
u22	*in_2*	*Signal no.2 in period no.2*	*50.0*	---
u31	*in_2*	*Signal no.3 in period no.1*	*50.0*	---
u32	*in_2*	*Signal no.3 in period no.2*	*50.0*	---
u41	*in_2*	*Signal no.4 in period no.1*	*50.0*	---
u42	*in_2*	*Signal no.4 in period no.2*	*50.0*	---
u51	*in_2*	*Signal no.5 in period no.1*	*50.0*	---
u52	*in_2*	*Signal no.5 in period no.2*	*50.0*	---
u61	*in_2*	*Signal no.6 in period no.1*	*50.0*	---
u62	*in_2*	*Signal no.6 in period no.2*	*50.0*	---
u71	*in_2*	*Signal no.7 in period no.1*	*50.0*	---
u72	*in_2*	*Signal no.7 in period no.2*	*50.0*	---
u81	*in_2*	*Signal no.8 in period no.1*	*50.0*	---
u82	*in_2*	*Signal no.8 in period no.2*	*50.0*	---
T1	*in_2*	*Period no.1*	*0.125*	*d*
T2	*in_2*	*Period no.2*	*0.125*	*d*
T3	*in_2*	*Period no.3*	*0.125*	*d*
T4	*in_2*	*Period no.4*	*0.125*	*d*
T5	*in_2*	*Period no.5*	*0.125*	*d*
T6	*in_2*	*Period no.6*	*0.125*	*d*
T7	*in_2*	*Period no.7*	*0.125*	*d*
T8	*in_2*	*Period no.8*	*0.125*	*d*

SENSORS

	Palette Group	**Sensors**
	Category	ASM1, ASM2dISS, ASM2dMod, PWM_SA

ASM1.Multiprobe

Instances

ASM1

Description

This is an in-line sensor that measures the following quantities:

Quantity	Units	Expression
Q	m3/d	Q_{In}
DO	g/m3	S_O
COD	g/m3	$S_S + S_I + X_S + X_I + X_{BA} + X_{BH} + X_P$
BOD	g/m3	$S_S + X_S + (1 - f_P) \cdot (X_{BA} + X_{BH})$
NH	g/m3	S_{NH}
NO	g/m3	S_{NO}
TKN	g/m3	$S_{NH} + S_{ND} + i_{NSI} \cdot S_I + i_{XB} \cdot (X_{BA} + X_{BH}) + i_{XP} \cdot (X_P + X_I)$
TN	g/m3	$S_{NO} + TKN$
TSS	g/m3	$F_{TSS,COD} \cdot TSS$
VSS	g/m3	$(X_S + X_I + X_{BA} + X_{BH} + X_P)/i_{COD,VSS}$

Parameters

Name	Description	Value	Units
F_BOD_COD	Conversion factor BOD/COD	0.65	---
F_TSS_COD	TSS to particulate COD ratio	0.75	---
i_COD_VSS	VSS to COD conversion	1.42	---
f_P	Fraction of biomass converted to inert matter	0.20	---
i_N_S_I	Mass of nitrogen per mass of inert soluble COD	0	g N/g COD
i_X_B	Mass of nitrogen per mass of COD in biomass	0.086	g N/g COD
i_X_P	Mass of nitrogen per mass of COD in products formed	0.06	g N/g COD

State Variables

Name	Description	Units
Q_In	Flow rate	m3/d
Q_Out	Flow rate	m3/d
C	Concentration vector	g/m3

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Q	out_2	Flow rate	---	m3/d
DO	out_2	Dissolved oxygen	---	g/m3
BOD	out_2	BOD	---	g/m3
COD	out_2	COD	---	g/m3
NH	out_2	Ammonia	---	g/m3
NO	out_2	Nitrate + nitrite	---	g/m3

Name	Terminal	Description	Value	Units
TKN	out_2	TKN	---	g/m3
TN	out_2	Total nitrogen	---	g/m3
TSS	out_2	Total suspended solids	---	g/m3
VSS	out_2	Volatile suspended solids	---	g/m3
L_DO	out_2	Oxygen load	---	g/d
L_BOD	out_2	BOD load	---	g/d
L_COD	out_2	COD load	---	g/d
L_NH	out_2	Ammonia load	---	g/d
L_NO	out_2	Nitrate + nitrite load	---	g/d
L_TKN	out_2	TKN load	---	g/d
L_TN	out_2	Total nitrogen load	---	g/d
L_TSS	out_2	TSS load	---	g/d
P_Pump	out_2	Pumping power	---	kWh/d
IsPumped	*in_2*	*Flow is pumped (1) or not (0)*	*0*	---
E_Pump_sp	*in_2*	*Pumping energy per unit flow*	*0.04*	*kWh/m3*

ASM1.MultiSampler_kVol

Instances

ASM1

Description

This is an extension of the ASM1.Multiprobe in-line sensor with a kVolume sampler model.
In addition to the parameters and variables exposed by the multiprobe sensor, this model exposes the following quantities.

Parameters

Name	Description	Value	Units
t_start	Start time for sampling	0	d
t_stop	Stop time for sampling	1	d
C_Lim_BOD	Detection limit for BOD	0.1	g/m3
C_Lim_COD	Detection limit for COD	0.1	g/m3
C_Lim_DO	Detection limit for DO	0.1	g/m3
C_Lim_NH	Detection limit for NH	0.1	g/m3
C_Lim_NO	Detection limit for NO	0.1	g/m3
C_Lim_TKN	Detection limit for TKN	0.1	g/m3
C_Lim_TN	Detection limit for TN	0.1	g/m3
C_Lim_TSS	Detection limit for TSS	0.1	g/m3
C_Lim_TSSc	Detection limit for TSSc	0.1	g/m3
C_Lim_VSS	Detection limit for VSS	0.1	g/m3
Q_Min	Minimum flow above which sampling starts	1,000	m3/d
f_Vol	Volume of water between each sample	100	m3
dt	Sampling frequency	1	d

State Variables

Name	Description	Units
N_Comp	Accumulated nr of composite samples over sampling period	---
Cm_BOD	Measured BOD concentration	g/m3
Cm_COD	Measured COD concentration	g/m3
Cm_DO	Measured DO concentration	g/m3
Cm_NH	Measured NH concentration	g/m3
Cm_NO	Measured NO concentration	g/m3
Cm_TKN	Measured TKN concentration	g/m3
Cm_TN	Measured TN concentration	g/m3
Cm_TSS	Measured TSS concentration	g/m3
Cm_TSSc	Measured TSSc concentration	g/m3
Cm_VSS	Measured VSS concentration	g/m3

Derived State Variables

None

Interface Variables

None

ASM2dISS.Multiprobe

Instances

ASM2dISS

Description

This is an in-line sensor that measures the following quantities:

Quantity	Units	Expression
Q	m3/d	Q_{In}
DO	g/m3	S_O
COD	g/m3	$S_{VFA} + S_F + S_U + XC_B + X_U + \sum X_{BM,i} + X_{PAO,Stor}$
BOD	g/m3	$F_{BOD5,BOD20} \cdot \left(S_{VFA} + S_F + F_{BOD,COD,X} \cdot \left(XC_B + \sum X_{BM,i} + X_{PAO,Stor}\right)\right)$
NH	g/m3	S_{NHx}
NO	g/m3	$NO_2 + NO_3$
NO2	g/m3	S_{NO2}
NO3	g/m3	S_{NO3}
OrgN	g/m3	$i_{NSU} \cdot S_U + i_{NSF} \cdot S_F + i_{NXU} \cdot X_U + i_{NXCB} \cdot XC_B + i_{NXBM} \cdot \sum X_{BM,i}$
TKN	g/m3	$Org_N + S_{NHx}$
TN	g/m3	$Org_N + S_{NHx} + S_{NO3} + S_{NO2} + S_{NO} + S_{N2O}$
OrgP	g/m3	$i_{PSU} \cdot S_U + i_{PSF} \cdot S_F + i_{PXU} \cdot X_U + i_{PXCB} \cdot XC_B + i_{PXBM} \cdot \sum X_{BM,i}$
PO	g/m3	S_{PO}
TP	g/m3	$Org_P + S_{PO} + X_{PAO,PP} + 0.205 \cdot X_{MEP}$
SO4	g/m3	S_{SO}
TSS	g/m3	$VSS + ISS$
VSS	g/m3	$\sum X_{BM,i}/i_{COD,VSS,BM_i} + (XC_B + X_U + X_{PAO,Stor})/i_{COD,VSS}$
ISS	g/m3	$X_{MEOH} + X_{MEP} + i_{ISS,PP} \cdot X_{PAO,PP} + X_{U,Ig} + X_{Ash}$
X_Ash	g/m3	$i_{ISS,BM} \cdot (X_{OHO} + X_{AOB} + X_{NOB} + X_{ANA} + X_{PAO})$

Parameters

Name	Description	Value	Units
F_BOD_COD	Conversion factor BOD/COD	0.65	---
F_BOD_COD_X	Conversion factor X_BOD/COD	0.65	---
F_BOD5_BOD20	Conversion BOD5/BOD20	0.66	---
i_COD_VSS	VSS to COD conversion	1.42	---
i_COD_VSS_ANA	VSS to COD conversion for Anammox biomass	1.42	---
i_COD_VSS_AOB	VSS to COD conversion for AOBs	1.42	---
i_COD_VSS_NOB	VSS to COD conversion for NOBs	1.42	---
i_COD_VSS_OHO	VSS to COD conversion for OHOs	1.42	---
i_COD_VSS_PAO	VSS to COD conversion for PAOs	1.42	---
i_ISS_BM	Ash content of biomass	0.08	g SS/g COD
i_ISS_PP	Polyphosphate conversion to ISS	3.065	g/g
i_N_S_F	Nitrogen content of S_F	0.03	g N/g COD
i_N_S_U	Nitrogen content of S_U	0.01	g N/g COD

i_N_XC_B	Nitrogen content of XC_B	0.04	g N/g COD
i_N_X_BM	Nitrogen content of X_BM	0.07	g N/g COD
i_N_X_U	Nitrogen content of X_U	0.03	g N/g COD
i_P_S_F	Phosphorous content of S_F	0.01	g P/g COD
i_P_S_U	Phosphorous content of S_U	0	g P/g COD
i_P_XC_B	Phosphorous content of XC_B	0.01	g P/g COD
i_P_X_BM	Phosphorous content of X_BM	0.02	g P/g COD
i_P_X_U	Phosphorous content of X_U	0.01	g P/g COD

State Variables

Name	Description	Units
Q_In	Flow rate	m3/d
Q_Out	Flow rate	m3/d
C	Concentration vector	g/m3
Org_N	Organic nitrogen	g/m3
Org_P	Organic phosphorous	g/m3
X_Ash	Ash content of biomass	g/m3
X_ISS	Inorganic suspended solids	g/m3
X_VSS	Volatile suspended solids	g/m3

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Q	out_2	Flow rate	---	m3/d
DO	out_2	Dissolved oxygen	---	g/m3
BOD	out_2	BOD	---	g/m3
COD	out_2	COD	---	g/m3
NH	out_2	Ammonia	---	g/m3
NO	out_2	Nitrate + nitrite	---	g/m3
NO2	out_2	Nitrite	---	g/m3
NO3	out_2	Nitrate	---	g/m3
TKN	out_2	TKN	---	g/m3
TN	out_2	Total nitrogen	---	g/m3
PO	out_2	Orto-phosphate	---	g/m3
TP	out_2	Total phosphorous	---	g/m3
SO4	out_2	Sulphate	---	g/m3
TSS	out_2	Total suspended solids	---	g/m3
TSSc	out_2	Calculated total suspended solids	---	g/m3
VSS	out_2	Volatile suspended solids	---	g/m3
ISS	out_2	Inorganic suspended solids	---	g/m3
L_DO	out_2	Oxygen load	---	g/d
L_BOD	out_2	BOD load	---	g/d
L_COD	out_2	COD load	---	g/d
L_NH	out_2	Ammonia load	---	g/d
L_NO	out_2	Nitrate + nitrite load	---	g/d
L_TKN	out_2	TKN load	---	g/d
L_TN	out_2	Total nitrogen load	---	g/d
L_PO	out_2	Phosphate load	---	g/d
L_TP	out_2	Total phosphorous load	---	g/d
L_TSS	out_2	TSS load	---	g/d
L_ISS	out_2	ISS load	---	g/d

Name	Terminal	Description	Value	Units
P_Pump	out_2	Pumping power	---	kWh/d
IsPumped	*in_2*	*Flow is pumped (1) or not (0)*	*0*	*---*
E_Pump_sp	*in_2*	*Pumping energy per unit flow*	*0.04*	*kWh/m3*

ASM2dISS.MultiSampler_kVol

Instances

ASM2dISS

Description

This is an extension of the ASM2dISS.Multiprobe in-line sensor with a kVolume sampler model. In addition to the parameters and variables exposed by the multiprobe sensor, this model exposes the following quantities.

Parameters

Name	Description	Value	Units
t_start	Start time for sampling	0	d
t_stop	Stop time for sampling	1	d
C_Lim_BOD	Detection limit for BOD	0.1	g/m3
C_Lim_COD	Detection limit for COD	0.1	g/m3
C_Lim_DO	Detection limit for DO	0.1	g/m3
C_Lim_NH	Detection limit for NH	0.1	g/m3
C_Lim_NO2	Detection limit for NO2	0.1	g/m3
C_Lim_NO3	Detection limit for NO3	0.1	g/m3
C_Lim_PO	Detection limit for PO	0.1	g/m3
C_Lim_TKN	Detection limit for TKN	0.1	g/m3
C_Lim_TN	Detection limit for TN	0.1	g/m3
C_Lim_TP	Detection limit for TP	0.1	g/m3
C_Lim_TSS	Detection limit for TSS	0.1	g/m3
C_Lim_TSSc	Detection limit for TSSc	0.1	g/m3
C_Lim_VSS	Detection limit for VSS	0.1	g/m3
Q_Min	Minimum flow above which sampling starts	1,000	m3/d
f_Vol	Volume of water between each sample	100	m3
dt	Sampling frequency	1	d

State Variables

Name	Description	Units
N_Comp	Accumulated nr of composite samples over sampling period	---
Cm_BOD	Measured BOD concentration	g/m3
Cm_COD	Measured COD concentration	g/m3
Cm_DO	Measured DO concentration	g/m3
Cm_NH	Measured NH concentration	g/m3
Cm_NO2	Measured NO2 concentration	g/m3
Cm_NO3	Measured NO3 concentration	g/m3
Cm_PO	Measured PO concentration	g/m3
Cm_TKN	Measured TKN concentration	g/m3
Cm_TN	Measured TN concentration	g/m3
Cm_TP	Measured TP concentration	g/m3
Cm_TSS	Measured TSS concentration	g/m3
Cm_TSSc	Measured TSSc concentration	g/m3
Cm_VSS	Measured VSS concentration	g/m3

Derived State Variables

None

Interface Variables

None

ASM2dMod.Multiprobe

Instances

ASM2dMod

Description

This is an in-line sensor that measures the following quantities:

Quantity	Units	Expression
Q	m3/d	Q_{In}
DO	g/m3	S_O
COD	g/m3	$S_A + S_F + S_I + X_S + X_I + X_H + X_{AUT} + X_{PAO} + X_{PHA}$
BOD	g/m3	$F_{BOD,COD} \cdot \left(S_A + S_F + X_S + X_{PHA} + \left(1 - f_{X,I}\right) \cdot (X_H + X_{AUT} + X_{PAO})\right)$
NH	g/m3	S_{NH}
NO	g/m3	S_{NO}
OrgN	g/m3	$i_{NSI} \cdot S_I + i_{NSF} \cdot S_F + i_{NXI} \cdot X_I + i_{NXS} \cdot X_S + i_{NBM} \cdot \sum X_{BM,i}$
TKN	g/m3	$Org_N + S_{NH}$
TN	g/m3	$Org_N + S_{NH} + S_{NO}$
OrgP	g/m3	$i_{PSI} \cdot S_I + i_{PSF} \cdot S_F + i_{PXI} \cdot X_I + i_{PXS} \cdot X_S + i_{PBM} \cdot \sum X_{BM,i}$
PO	g/m3	S_{PO}
TP	g/m3	$Org_P + S_{PO} + X_{PAO,PP} + 0.205 \cdot X_{MEP}$
TSS	g/m3	X_{TSS}
TSSc	g/m3	$i_{TSS,XS} \cdot X_S + i_{TSS,XI} \cdot X_I + i_{TSS,BM} \cdot \sum X_{BM,i} + 3.25 \cdot X_{PP} + 0.6 \cdot X_{PHA} + X_{MEOH} + X_{MEP}$
VSS	g/m3	$(X_S + X_I + X_H + X_{AUT} + X_{PAO})/i_{COD,VSS}$

Parameters

Name	Description	Value	Units
F_BOD_COD	Conversion factor BOD/COD	0.65	---
i_COD_VSS	VSS to COD conversion	1.42	---
i_TSS_BM	TSS to biomass ratio for X_H, X_PAO, X_AUT	1.42	---
i_TSS_X_I	TSS to X_I ratio	0.9	---
i_TSS_X_S	TSS to X_S ratio	0.75	---
f_X_I	Fraction of inert COD generated in biomass lysis	0.1	---
i_N_S_F	Nitrogen content of S_F	0.03	g N/g COD
i_N_S_I	Nitrogen content of S_I	0.01	g N/g COD
i_N_X_S	Nitrogen content of X_S	0.04	g N/g COD
i_N_BM	Nitrogen content of biomass	0.07	g N/g COD
i_N_X_I	Nitrogen content of X_I	0.03	g N/g COD
i_P_S_F	Phosphorous content of S_F	0.01	g P/g COD
i_P_S_I	Phosphorous content of S_I	0	g P/g COD
i_P_X_S	Phosphorous content of X_S	0.01	g P/g COD
i_P_BM	Phosphorous content of biomass	0.02	g P/g COD
i_P_X_I	Phosphorous content of X_I	0.01	g P/g COD

State Variables

Name	Description	Units
Q_In	Flow rate	m3/d
Q_Out	Flow rate	m3/d
C	Concentration vector	g/m3

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Q	out_2	Flow rate	---	m3/d
DO	out_2	Dissolved oxygen	---	g/m3
BOD	out_2	BOD	---	g/m3
COD	out_2	COD	---	g/m3
NH	out_2	Ammonia	---	g/m3
NO	out_2	Nitrate + nitrite	---	g/m3
TKN	out_2	TKN	---	g/m3
TN	out_2	Total nitrogen	---	g/m3
PO	out_2	Orto-phosphate	---	g/m3
TP	out_2	Total phosphorous	---	g/m3
TSS	out_2	Total suspended solids	---	g/m3
TSSc	out_2	Calculated total suspended solids	---	g/m3
VSS	out_2	Volatile suspended solids	---	g/m3
L_DO	out_2	Oxygen load	---	g/d
L_BOD	out_2	BOD load	---	g/d
L_COD	out_2	COD load	---	g/d
L_NH	out_2	Ammonia load	---	g/d
L_NO	out_2	Nitrate + nitrite load	---	g/d
L_TKN	out_2	TKN load	---	g/d
L_TN	out_2	Total nitrogen load	---	g/d
L_PO	out_2	Phosphate load	---	g/d
L_TP	out_2	Total phosphorous load	---	g/d
L_TSS	out_2	TSS load	---	g/d
P_Pump	out_2	Pumping power	---	kWh/d
IsPumped	*in_2*	*Flow is pumped (1) or not (0)*	*0*	---
E_Pump_sp	*in_2*	*Pumping energy per unit flow*	*0.04*	*kWh/m3*

ASM2dMod.MultiSampler_kVol

Instances

ASM2dMod

Description

This is an extension of the ASM2dMod.Multiprobe in-line sensor with a kVolume sampler model. In addition to the parameters and variables exposed by the multiprobe sensor, this model exposes the following quantities.

Parameters

Name	Description	Value	Units
t_start	Start time for sampling	0	d
t_stop	Stop time for sampling	1	d
C_Lim_BOD	Detection limit for BOD	0.1	g/m3
C_Lim_COD	Detection limit for COD	0.1	g/m3
C_Lim_DO	Detection limit for DO	0.1	g/m3
C_Lim_NH	Detection limit for NH	0.1	g/m3
C_Lim_NO	Detection limit for NO	0.1	g/m3
C_Lim_PO	Detection limit for PO	0.1	g/m3
C_Lim_TKN	Detection limit for TKN	0.1	g/m3
C_Lim_TN	Detection limit for TN	0.1	g/m3
C_Lim_TP	Detection limit for TP	0.1	g/m3
C_Lim_TSS	Detection limit for TSS	0.1	g/m3
C_Lim_TSSc	Detection limit for TSSc	0.1	g/m3
C_Lim_VSS	Detection limit for VSS	0.1	g/m3
Q_Min	Minimum flow above which sampling starts	1,000	m3/d
f_Vol	Volume of water between each sample	100	m3
dt	Sampling frequency	1	d

State Variables

Name	Description	Units
N_Comp	Accumulated nr of composite samples over sampling period	---
Cm_BOD	Measured BOD concentration	g/m3
Cm_COD	Measured COD concentration	g/m3
Cm_DO	Measured DO concentration	g/m3
Cm_NH	Measured NH concentration	g/m3
Cm_NO	Measured NO concentration	g/m3
Cm_PO	Measured PO concentration	g/m3
Cm_TKN	Measured TKN concentration	g/m3
Cm_TN	Measured TN concentration	g/m3
Cm_TP	Measured TP concentration	g/m3
Cm_TSS	Measured TSS concentration	g/m3
Cm_TSSc	Measured TSSc concentration	g/m3
Cm_VSS	Measured VSS concentration	g/m3

Derived State Variables

None

Interface Variables

None

PWM_SA.Multiprobe

Instances

PWM_SA

Description

This is an in-line sensor that measures the following quantities:

Quantity	Expression
Q	Q_{In}
DO	S_O
COD_us	S_U
COD_bs	$S_{VFA} + S_F + S_{Glu} + S_{Pr} + S_{H2}$
COD_up	$X_{U,Inf} + X_{U,Org}$
COD_bp	$X_{AC} + X_{AD} + X_{AM} + X_{ANO} + X_{B,Inf} + X_{B,Org} + X_{HM} + X_{OHO} + X_{PAO} + X_{PAO,Stor}$
CODs	$S_{VFA} + S_F + S_{Glu} + S_{Pr} + S_{CH4} + S_{HS} + S_{H2} + S_U$
CODp	$X_{AC} + X_{AD} + X_{AM} + X_{ANO} + X_{B,Inf} + X_{B,Org} + X_{HM} + X_{OHO} + X_{PAO} + X_{PAO,Stor} + X_{U,Inf} + X_{U,Org}$
CODt	$COD_s + COD_p$
VFA	$COD_{S,VFA} + COD_{S,Pr}$
VFA_c	$S_{VFA}/COD_{VFA} + S_{Pr}/COD_{Pr}$
FSA	$0.7765 \cdot S_{NH}$
NO3_N	$0.2259 \cdot S_{NO3}$
TKN*	$FSA + MW_N \cdot \big(i_{N,SU} \cdot S_U + i_{N,SF} \cdot S_F + i_{N,XUInf} \cdot X_{U,Inf} + i_{N,XBOrg} \cdot X_{B,Org} + i_{N,XOHO} \cdot (X_{OHO} + X_{PAO} + X_{AD} + X_{AC} + X_{AM} + X_{XM} + X_{ANO}) + i_{N,XUOrg} \cdot X_{U,Org} + i_{N,XBInf} \cdot X_{BInf} + i_{N,XStr,NH4} \cdot X_{Str,NH4}\big)$
TKN_filt*	$FSA + MW_N \cdot \big(i_{N,SU} \cdot S_U + i_{N,SF} \cdot S_F\big)$
OrthoP	$0.3261 \cdot S_{PO4}$
Soluble_P	$\alpha_{P,i} \cdot \sum S_i$
Particulate_P	$\alpha_{P,i} \cdot \sum X_i$
P_t**	$TP_o + TP_u + MW_P \cdot \big(i_{P,SPO4} \cdot S_{PO4} + i_{P,XStr,NH4} \cdot X_{Str,NH4} + i_{P,XStr,K} \cdot X_{Str,K} + i_{P,XACP} \cdot X_{ACP} + i_{P,XPAO,PP} \cdot X_{PAO,PP}\big)$
TSS	$X_{AC} + X_{ACP} + X_{AD} + X_{AM} + X_{ANO} + X_{B,Inf} + X_{B,Org} + X_{Cal} + X_{HM} + X_{ISS} + X_{Mag} + X_{Newb} + X_{OHO} + X_{PAO} + X_{PAO,PP} + X_{PAO,Stor} + X_{Str,K} + X_{Str,NH4} + X_{U,Inf} + X_{U,Org}$
TSS_c	$X_{AC} + X_{ACP} + X_{AD} + X_{AM} + X_{ANO} + X_{B,Inf} + X_{B,Org} + X_{Cal} + X_{HM} + X_{ISS} + X_{Mag} + X_{Newb} + X_{OHO} + X_{PAO} + X_{PAO,PP} + X_{PAO,Stor} + X_{Str,K} + X_{Str,NH4} + X_{U,Inf} + X_{U,Org}$
VSS	$X_{U,Inf} + X_{B,Inf} + X_{B,Org} + X_{PAO,Stor} + X_{OHO} + X_{PAO} + X_{ANO} + X_{AD} + X_{AC} + X_{AM} + X_{HM} + X_{U,Org}$
VSS_c	$X_{U,Inf} + X_{B,Inf} + X_{B,Org} + X_{PAO,Stor} + X_{OHO} + X_{PAO} + X_{ANO} + X_{AD} + X_{AC} + X_{AM} + X_{HM} + X_{U,Org}$

Quantity	Expression
ISS_c	$TSS_c - VSS_c$

* i denotes i_N / MW_i
** i denotes i_P / MW_i

Parameters

Name	Description	Value	Units
i_Ca_PP_mol_perP	Molar fraction of Ca/P in polyphosphate	0.053	---
i_K_PP_mol_perP	Molar fraction of K/P in polyphosphate	0.312	---
i_Mg_PP_mol_perP	Molar fraction of Mg/P in polyphosphate	0.297	---
i_H_Org_mol_perC	H/C : organisms	1.463	---
i_H_SF_mol_perC	H/C : fermentable soluble	2.01	---
i_H_SU_mol_perC	H/C : unbiodegradable soluble	1.646	---
i_H_XBInf_mol_perC	H/C : PS biodegradable particulate	2.19	---
i_H_XBOrg_mol_perC	H/C : biodegradable particulate	1.463	---
i_H_XUInf_mol_perC	H/C : unbiodegradable particulate	1.482	---
i_H_XUOrg_mol_perC	H/C : endogenous residue	1.482	---
i_N_Org_mol_perC	N/C : organisms	0.229	---
i_N_SF_mol_perC	N/C : fermentable soluble	0.119	---
i_N_SU_mol_perC	N/C : unbiodegradable soluble	0.062	---
i_N_XBInf_mol_perC	N/C : PS biodegradable particulate	0.0643	---
i_N_XBOrg_mol_perC	N/C : biodegradable particulate	0.229	---
i_N_XUInf_mol_perC	N/C : unbiodegradable particulate	0.113	---
i_N_XUOrg_mol_perC	N/C : endogenous residue	0.113	---
i_O_Org_mol_perC	O/C : organisms	0.335	---
i_O_SF_mol_perC	O/C : fermentable soluble	0.592	---
i_O_SU_mol_perC	O/C : unbiodegradable soluble	0.593	---
i_O_XBInf_mol_perC	O/C : PS biodegradable particulate	0.653	---
i_O_XBOrg_mol_perC	O/C : biodegradable particulate	0.355	---
i_O_XUInf_mol_perC	O/C : unbiodegradable particulate	0.472	---
i_O_XUOrg_mol_perC	O/C : endogenous residue	0.472	---
i_P_Org_mol_perC	P/C : organisms	0.031	---
i_P_SF_mol_perC	P/C : fermentable soluble	0.012	---
i_P_SU_mol_perC	P/C : unbiodegradable soluble	0.02	---
i_P_XBInf_mol_perC	P/C : PS biodegradable particulate	0.0097	---
i_P_XBOrg_mol_perC	P/C : biodegradable particulate	0.031	---
i_P_XUInf_mol_perC	P/C : unbiodegradable particulate	0.022	---
i_P_XUOrg_mol_perC	P/C : endogenous residue	0.022	---
kdis_cal	Dissolution product of calcite	0.5	---
kdis_cap	Dissolution product of calcium phosphate	150	---
kdis_mag	Dissolution product of magnesite	50	---
kdis_mgkp	Dissolution product of K-struvite	100	---
kdis_newb	Dissolution product of newberyite	0.05	---
kdis_str	Dissolution product of struvite	0.0001	---
Y_PP_Stor_PAO	PP requirement (S_PO4 release) per PHA stored	0.4	---
Y_Stor_PP_PAO	PHA requirement for PP storage	0.2	---
Y_f_PP_VFA	Ratio of P released from PP per VFA in PHA storage	0.5	---
F_TSS_COD	Fraction TSS/COD in point-settler clarifier	0.75	---

State Variables

Name	Description	Units
Q_In	Flow rate	m3/d
Q_Out	Flow rate	m3/d

Name	Description	Units
C	Concentration vector	g/m3
Temp_Actual	Temperature	°C
COD	COD concentration vector	g/m3
PCH4_eq	Equilibrium CH4 partial pressure	Pa
PCO2_eq	Equilibrium CO2 partial pressure	Pa
PH2O_eq	Equilibrium H2O partial pressure	Pa
PH2S_eq	Equilibrium H2S partial pressure	Pa
PH2_eq	Equilibrium H2 partial pressure	Pa
PN2_eq	Equilibrium N2 partial pressure	Pa
PNH3_eq	Equilibrium NH3 partial pressure	Pa
PO2_eq	Equilibrium O2 partial pressure	Pa
S_O_Saturation	Oxygen saturation concentration	g/m3
CO3_M	CO3 molality	g/m3
Ca_M	Ca molality	g/m3
D_Struv	Ash content of biomass	g/m3
D_cal		
D_cap		
D_mag		
D_mgkp		
D_newb		
Driver_Str	Driving force factor for struvite	---
Driver_cal	Driving force factor for Cal	---
Driver_cap	Driving force factor for CaP	---
Driver_mag	Driving force factor for Mag	---
Driver_mgkp	Driving force factor for MgKP	---
Driver_newb	Driving force factor for Newb	---
K_M	K molality	---
K_cal	Rate constant for calcite dissolution	---
K_cap	Rate constant for calcium phosphate dissolution	---
K_mag	Rate constant for magnesite dissolution	---
K_mgkp	Rate constant for MgKPO4 dissolution	---
K_newb	Rate constant for newberyite dissolution	---
K_stru	Rate constant for struvite dissolution	---
KspCorr	KSp temperature correction	---
Mg_M	Mg molality	---
NH4_M	NH4 molality	---
PO4_M	PO4 molality	---
Ppt_Str	Precipitated struvite	mol/kg
Ppt_cal	Precipitated calcite	mol/kg
Ppt_cap	Precipitated calcium phosphate	mol/kg
Ppt_mag	Precipitated magnesite	mol/kg
Ppt_mgkp	Precipitated K-struvite	mol/kg
Ppt_newb	Precipitated newberyite	mol/kg
saturation_cal	Saturation ratio for calcite	---
saturation_cap	Saturation ratio for calcium phosphate	---
saturation_mag	Saturation ratio for magnesite	---
saturation_mgkp	Saturation ratio for MgKPO4	---
saturation_newb	Saturation ratio for newberyite	---
saturation_stru	Saturation ratio for struvite	---
ActH2CO3	Activity of H2CO3 (dissolved CO2)	---
H_M	Total H molality	---
IonicStrength	Calculated Ionic Strength	mol/kg
IterationCount	Number of iterations since start of simulation	---
SpeciationDone	Dummy variable to signal that speciation has been done	---
pH	Calculated pH	---

Derived State Variables

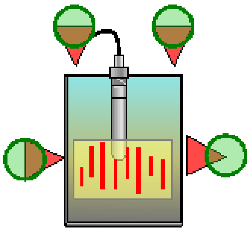
None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Q	out_2	Flow rate	---	m3/d
DO	out_2	Dissolved oxygen	---	g/m3
COD_p	out_2	Particulate COD	---	g/m3
COD_s	out_2	Soluble COD	---	g/m3
COD_t	out_2	Total COD	---	g/m3
COD_bp	out_2	Biodegradable particulate COD	---	g/m3
COD_bs	out_2	Biodegradable soluble COD	---	g/m3
COD_up	out_2	Unbiodegradable particulate COD	---	g/m3
COD_us	out_2	Unbiodegradable soluble COD	---	g/m3
COD_bpf	out_2	Flux of biodegradable particulate COD	---	g/d
COD_bsf	out_2	Flux of biodegradable soluble COD	---	g/d
COD_f	out_2	Flux of total COD	---	g/d
COD_pf	out_2	Flux of particulate COD	---	g/d
COD_sf	out_2	Flux of soluble COD	---	g/d
COD_upf	out_2	Flux of unbiodegradable particulate COD	---	g/d
COD_usf	out_2	Flux of unbiodegradable soluble COD	---	g/d
VFA	out_2	VFA COD concentration	---	g/m3
VFA_c	out_2	VFAs concentration	---	g/m3
FSA_f	out_2	Mass flux of FSA	---	g/d
NO3_N	out_2	Nitrate as N	---	g/m3
NO3_Nf	out_2	Mass flux of NO3-N	---	g/d
NOrg_sf	out_2	Mass flux of soluble organic N	---	g/d
TKN	out_2	Total Kjeldahl Nitrogen	---	g/d
TKN_f	out_2	Mass flux of TKN	---	g/d
TKN_filt	out_2	Soluble of TKN	---	g/m3
TKN_pf	out_2	Mass flux of particulate TKN	---	g/d
OrthoP	out_2	Soluble PO4	---	g/m3
OrthoP_f	out_2	Mass flux of soluble PO4	---	g/d
Part_Pf	out_2	Mass flux of particulate P	---	g/d
TP	out_2	Total phosphorous	---	g/m3
P_t	out_2	Total phosphorous	---	g/m3
Soluble_P	out_2	Concentration of soluble phosphorus	---	g/m3
Particulate_P	out_2	Concentration of particulate phosphorus	---	g/m3
TSS	out_2	Total suspended solids	---	g/m3
TSS_c	out_2	Total suspended solids	---	g/m3
TSS_f	out_2	Mass flux of TSS	---	g/d
VSS	out_2	Volatile suspended solids	---	g/m3
VSS_c	out_2	Volatile suspended solids	---	g/m3
VSS_f	out_2	Mass flux of VSS	---	g/d
ISS	out_2	Inorganic suspended solids	---	g/m3
ISS_c	out_2	Inorganic suspended solids	---	g/m3
ISS_f	out_2	Mass flux of ISS	---	g/d
Alk_NH3	out_2	NH3 alkalinity (CaCO3)	---	mg/L
Alk_OH	out_2	NH3 alkalinity (CaCO3)	---	mg/L
Alk_PO4	out_2	NH3 alkalinity (CaCO3)	---	mg/L
Alk_VFA	out_2	NH3 alkalinity (CaCO3)	---	mg/L
Alkalinity	out_2	Total alkalinity (CaCO3)	---	mg/L
CO3Alkalinity	out_2	Carbonate alkalinity (CaCO3)	---	mg/L
y_pH	out_2	pH	---	---

Name	Terminal	Description	Value	Units
AnionCharge	out_2	Combined charge of anions	---	---
CationCharge	out_2	Combined charge of cations	---	---
CarbonateAlkalinity	out_2	Carbonate alkalinity as CaCO3	---	g/m3
TotalAlkalinity	out_2	Total alkalinity as CaCO3	---	g/m3
EC25	out_2	Electrical conductivity at 25°C	---	ms/m
Temp	*in_2*	*Stream temperature*	*20*	*°C*

SIGNAL TREATMENT

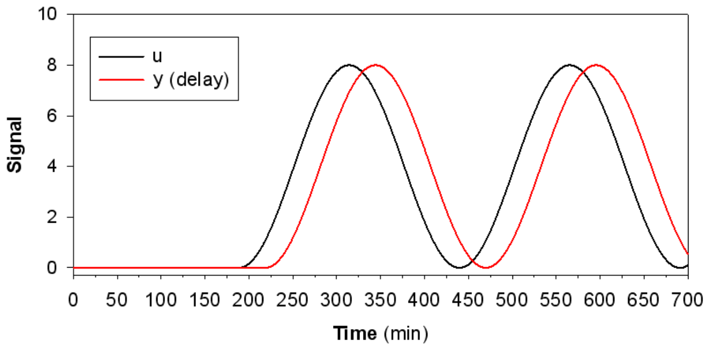
	Palette Group	**Sensors**
	Category	Data
	Icon Name	signal_treatment

Data.Delay

Instances
All

Description
The model introduces a delay between the input and the output signals, described by the following equation and illustrated in the figure below.

$$y(t) = u \cdot (t - t_{delay})$$



Parameters

Name	Description	Value	Units
dt	Sampling interval	5	min

State Variables
None

Derived State Variables
None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Input signal	---	---
y_Out	out_1	Output signal	---	---

Data.Noise

Instances

All

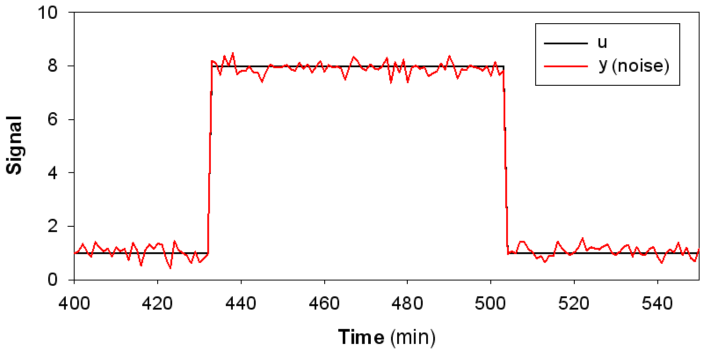
Description

The model adds a random noise to the input signal.
The noise is generated by randomly sampling from a normal distribution N(0,1).
The model is described by the following equation and illustrated in the figure below.

$$y(t) = u(t) + noise(t) \cdot NoiseLevel \cdot y_{max}$$

where:

- $noise(t)$ is the random noise
- $NoiseLevel \cdot y_{max}$ denotes the standard deviation (defined as a percentage of the maximum measuring range)



Parameters

Name	Description	Value	Units
dt	Noise sampling time	1	min
std	Percentage of the measuring range to define the standard deviation	2.5	%
y_Max	Upper bound for the measured signal	10	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Input signal	---	---
y_Out	out_1	Output signal	---	---

Data.NoiseFromFile

Instances

All

Description

The model adds a random noise to the input signal.
The noise is obtained from an input file

$$y(t) = u(t) + noise(t) \cdot NoiseLevel \cdot y_{max}$$

where:

- $noise(t)$ is the random noise
- $NoiseLevel \cdot y_{max}$ denotes the standard deviation (defined as a percentage of the maximum measuring range)

Parameters

None

State Variables

Name	Description	Units
std	Percentage of the measuring range to define the standard deviation	%
y_Max	Upper bound for the measured signal	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Input signal	---	---
y_Out	out_1	Output signal	---	---
y_Noise	*in_2*	*Noise from file*	*0*	---

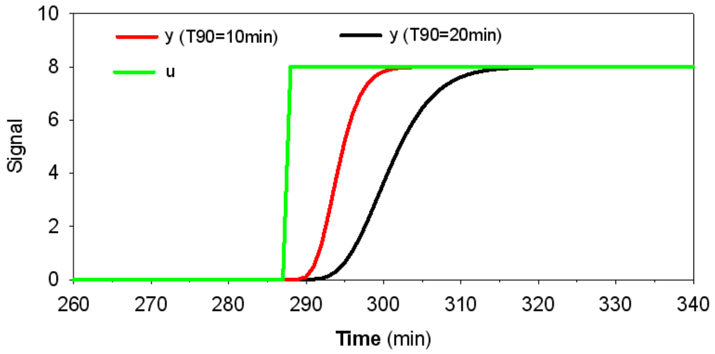
Data.ResponseTime

Instances

All

Description

The model describes the dynamic behaviour of a signal that is subjected to input dynamics (cf. figure).



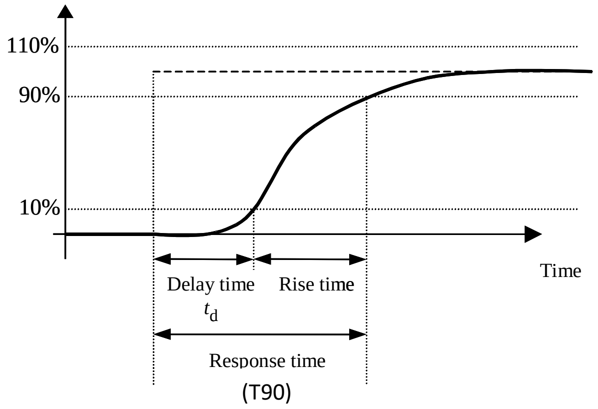
The dynamic behaviour of the response time is modelled through a series of Laplace transfer functions (i.e. creating an n-*th* order linear system composed of n first order differential equations) as in the following equation:

$$G_S(s) = \frac{y(s)}{u(s)} = \left(\frac{1}{1 + Tau \cdot s}\right)^n$$

where:

- Tau denotes the time constant
- n ranges from 1 to 8 and denotes the order of the response time (i.e. the number of transfer functions in series).

For convenience, the parameter Tau is expressed as a function of T90, which is defined as the overall time to reach (and not to leave) a 90-110% band of the final value of the step response (as shown in figure; adapted from Rieger *et al.*, 2003).



The T90 / Tau relationship was numerically calculated (more information in Alex *et al.*, 2009) and the results are show in the following table.

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Tau90/Tau	2.3247	3.89	5.3336	6.6902	8.0031	9.2680	10.5357	11.7724

Remark: the T90 value is to be greater than the minimum step size of the solver.

Parameters

Name	Description	Value	Units
T90	Response-time for 90% of incoming signal	10	min
n	Order for the response time (2-8)	2	---

State Variables

Name	Description	Units
Tau	Time constant	d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Input signal	---	---
y_Out	out_1	Output signal	---	---

Data.SampleHold

Instances

All

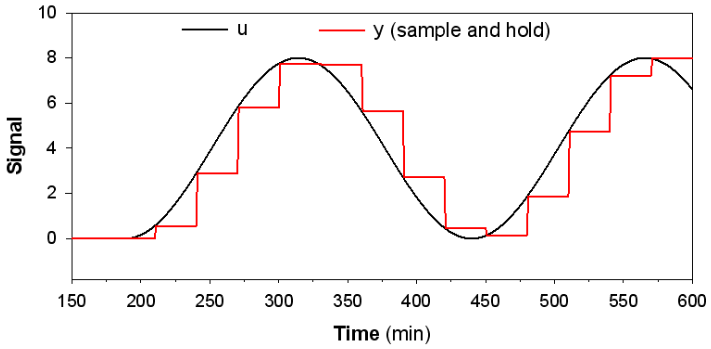
Description

The model mimics the discontinuous signal produced by a zero-order hold sensor. In such a device, a signal is maintained for a certain period of time, until the next signal is actually recorded.
The model is described by the following equation and illustrated in the figure below.

$$y(t) = u\left(t_{sample}\right)$$

where:

$$t_{sample} = floor\left(\frac{t}{T_{interval}}\right)$$



Parameters

Name	Description	Value	Units
dt	Sampling interval	5	min

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Input signal	---	---
y_Out	out_1	Output signal	---	---

Data.Saturation

Instances

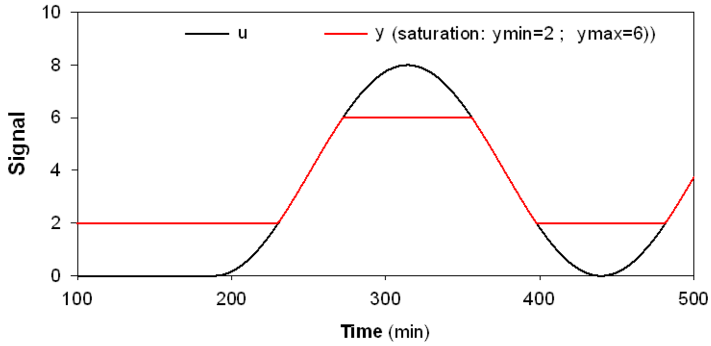
All

Description

The model limits the range of the output signal, between a minimum and a maximum value.

The model is described by the following equation and illustrated in the figure below.

$$(t) = \begin{cases} y_{max}, & u(t) > y_{max} \\ u(t), & y_{min} \leq u(t) \leq y_{max} \\ y_{min}, & u(t) < y_{min} \end{cases}$$



Parameters

Name	Description	Value	Units
y_Min	Minimum level for the signal	0	---
y_Max	Maximum level for the signal	10	---

State Variables

None

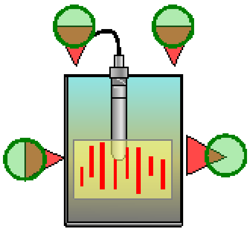
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Input signal	---	---
y_Out	out_1	Output signal	---	---

SAMPLERS

	Palette Group	**Sensors**
	Category	Samplers
	Icon Name	sampler

Grab

Instances

All

Description

The model computes a set of quantities that are relevant when conducting a sampling campaign with a **grab** sampling device.
The primary output of the model is the concentration of the measured quantity:

$$C_m(t) = C(t)$$

where:

- C_m and C are the accumulated- and measured concentrations (g/m3), at time $t_1 < t < t_2$
- t_1 and t_2 denote sampling start- and end time (d)

The current accumulated **load** (g/d), at time $t_1 < t < t_2$ is calculated as follows:

$$L_m = C_m \cdot Q$$

The sampling cost is also calculated:

$$Cost = n \cdot f_{cost}$$

where:

- f_{cost} unit cost for a sample (Eur)

Parameters

Name	Description	Value	Units
C_Sample	Cost of analysis per sample	50	Euro
t_start	Start time for sampling	0	d
t_stop	Stop time for sampling	1	d
C_Lim	Detection limit	0.1	g/m3
dt	Sampling frequency	1	d

State Variables

Name	Description	Units
N_Comp	Accumulated nr of composite samples over sampling period	---
C_M	Measured concentration	g/m3
L_M	Measured load	g/d
Cost	Total sampling cost	Euro
IsNewAliquot	Beginning time of each aliquot	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Quantity to be measured with the sampler	---	g/d
y_Q	in_1	Flow rate	---	g/d
y_Out	out_1	Measured quantity	---	g/m3

kTime

Instances

All

Description

The model computes a set of quantities that are relevant when conducting a sampling campaign with a **time-proportional** sampling device.
The primary output of the model is the concentration of the measured quantity:

$$C_m(t) = \frac{C_m(t - \Delta t) \cdot (n - 1) + C(t)}{n}$$

$$n = N - N_{comp} \cdot N_{bottle}$$

where:

- C_m and C are the accumulated- and measured concentrations (g/m3), at time $t_1 < t < t_2$
- n number of samples collected at time $t_1 < t < t_2$
- N denotes the accumulated number of aliquots
- N_{comp} and N_{bottle} indicate the number of aliquots collected in the "current" bottle and the accumulated number of full bottles respectively
- t_1 and t_2 denote sampling start- and end time (d)

Remark: the value of C_m is 1 time step behind that of C.

The sampling cost is also calculated:

$$Cost = n \cdot f_{cost}$$

where:

- f_{cost} unit cost for a sample (Eur)

Parameters

Name	Description	Value	Units
C_Sample	Cost of analysis per sample	50	Euro
t_start	Start time for sampling	0	d
t_stop	Stop time for sampling	1	d
C_Lim	Detection limit	0.1	g/m3
N_Bottle	Accumulated nr of aliquots collected over the sampling period	0	---
V_Bottle	Volume of composite sample	2	m3
V_Sample	Volume of each aliquot; must be <= V_bottle	1	m3
dt	Sampling frequency	1	d

State Variables

Name	Description	Units
N_Comp	Accumulated nr of composite samples over sampling period	---
C_M	Measured concentration	g/m3
C_M_Comp	Measured concentration in the composite sample before full bottle	g/m3
L_M	Measured load	g/d
Cost	Total sampling cost	Euro
IsNewAliquot	Beginning time of each aliquot	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Quantity to be measured with the sampler	---	g/d
y_Q	in_1	Flow rate	---	g/d
y_Out	out_1	Measured quantity	---	g/m3

kVolume

Instances

All

Description

The model computes a set of quantities that are relevant when conducting a sampling campaign with a **flow-proportional** sampling device.

The primary output of the model is the concentration of the measured quantity:

$$C_m(t) = \frac{C_m(t - \Delta t) \cdot (n - 1) + C(t)}{n}$$

$$n = N - N_{bottle}$$

where:

- C_m and C are the accumulated- and measured concentrations (g/m3), at time $t_1 < t < t_2$
- n number of samples collected at time $t_1 < t < t_2$
- N and N_{bottle} indicate the accumulated number of aliquots and of full bottles respectively
- t_1 and t_2 denote sampling start- and end time (d)

where:

- C_m and C are the accumulated- and measured concentrations (g/m3), at time $t_1 < t < t_2$
- n number of samples collected at time $t_1 < t < t_2$
- t_1 and t_2 denote sampling start- and end time (d)

Remark: the value of C_m is 1 time step behind that of C.

The **load** is calculated as follows:

$$L_m = \frac{C_m \cdot vol \cdot n}{t_2 - t_1}$$

where:

- L_m is the current (accumulated) load (g/d), at time $t_1 < t < t_2$
- vol is the volume of the sample (m3)

The average concentration (over a period T) and the sampling cost are also calculated:

$$\frac{d}{dt} C_{avg} = \frac{C_m - C_{avg}}{T}$$

$$Cost = n \cdot f_{cost}$$

where:

- f_{cost} unit cost for a sample (Eur)

Parameters

Name	Description	Value	Units
C_Sample	Cost of analysis per sample	50	Euro
t_start	Start time for sampling	0	d
t_stop	Stop time for sampling	1	d

Name	Description	Value	Units
C_Lim	Detection limit	0.1	g/m3
Q_Min	Minimum flow above which sampling starts	1,000	m3/d
V_Sample	Volume of each sample	1.0	m3
f_Vol	Volume of water between each sample	100	m3
dt	Sampling frequency	1	d
T	Time frame for average calculation	1.0	d

State Variables

Name	Description	Units
N_Comp	Accumulated nr of composite samples over sampling period	---
C_M	Measured concentration	g/m3
C_M_Comp	Measured conc. in the composite sample before full bottle	g/m3
L_M	Measured load	g/d
Cost	Total sampling cost	Euro

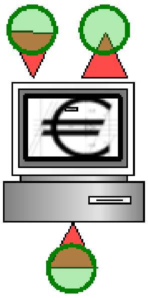
Derived State Variables

Name	Description	Units
C_M_Avg	Measured average concentration	g/m3

Interface Variables

Name	Terminal	Description	Value	Units
y_In	in_1	Quantity to be measured with the sampler	---	g/d
y_Q	in_1	Flow rate	---	g/d
y_Out	out_1	Measured quantity	---	g/m3
C_Sample	*in_2*	*Cost of analysis per sample*	*50*	*Euro*

COST CALCULATORS

	Palette Group	**Sensors**
	Category	Cost
	Icon Name	cost

Operation_Simple

Instances

All

Description

The model computes operational costs (and energy requirements) for the following items:

- Aeration and mixing of activated sludge units – for 10 and 20 units respectively
- Pumping – for 20 units sludge production – for 2 pumps
- Addition of chemicals – 3 contact units can be included (two kinds of chemicals are considered, i.e. metals for phosphorous precipitation and carbon source for denitrification)
- Heating the sludge entering an anaerobic digester, as well as the heat losses in the digestion process
- Biogas production, i.e. income derived from biogas utilisation
- Disposing of the residual sludge

Aeration

$$C_{aer} = \int \left(f_{aer} \cdot P_{aer,tot} \right)$$

where:

- f_{aer} is the unit price for energy (Eur/kWh)
- $P_{aer,tot}$ is the total power consumption (kWh/d) for aeration

The power consumption for aeration is computed elsewhere and given as input to the cost calculator.

Mixing

$$C_{mix} = \int \left(f_{mix} \cdot P_{mix,tot} \right)$$

where:

- f_{mix} is the unit price for energy (Eur/kWh)
- $P_{mix,tot}$ is the total power consumption (kWh/d) for mixing

The power consumption for mixing is computed elsewhere and given as input to the cost calculator.

Pumping

$$C_{pump} = \int \left(f_{pump} \cdot P_{pump,tot} \right)$$

where:

- f_{pump} is the unit price for energy (Eur/kWh)
- $P_{pump,tot}$ is the total power consumption (kWh/d) for pumping

The power consumption for pumping is computed elsewhere and given as input to the cost calculator.

Chemical dosage

$$C_{chem} = \int \sum (f_i \cdot Q_i)$$

where:

- f_i is the unit price for the i-th chemical (Eur/m3)
- Q_i is the flow rate (m3/d) of the i-th pumps

Sludge pre-heating

$$C_{heat,sludge} = \int \left(f_{heat} \cdot P_{heat,sludge} \right)$$

where:

- f_{heat} is the unit price for pre-heating the sludge (Eur/kWh)
- $P_{heat,sludge}$ is the total power required for pre-heating (kWh/d)

The power required for pre-heating the sludge is computed elsewhere and given as input to the cost calculator.

Heat loss around the digester

$$C_{heat,loss} = \int \left(f_{heat} \cdot P_{heat,loss} \right)$$

where:

- f_{heat} is the unit price for heating the digester walls (Eur/kWh)
- $P_{heat,loss}$ is the total power loss as heat dispersion (kWh/d)

The energy lost through heat dispersion is computed elsewhere and given as input to the cost calculator.

Biogas production

$$C_{biogas} = \int (f_{ch4} \cdot P_{ch4})$$

where:

- f_{ch4} is the unit price for selling (or avoided cost for utilising) the energy produced through biogas (Eur/kWh)
- P_{ch4} is the total power generated (kWh/d) through biogas utilisation

The power generated from biogas is computed elsewhere and given as input to the cost calculator.

Sludge production

$$C_{sludge} = \int \left(f_{sludge} \cdot (TSS_{P1} \cdot Q_{P1} + TSS_{P2} \cdot Q_{P2}) \right)$$

where:

- f_{sludge} is the unit price for sludge disposal (Eur/kg)

- TSS_i and Q_i denote the solids concentration (g/m3) and the flow rate (m3/d) of the sludge pumps

Total operational cost

$$R = C_{biogas}$$

$$C_{tot} = C_{aer} + C_{mix} + C_{pump} + C_{chem} + C_{heat,loss} + C_{heat,sludge}$$

$$B = C_{tot} - R$$

Parameters

Name	Description	Value	Units
dt	Period over which costs are computed	1	d

State Variables

Name	Description	Units
V_COD	Total amount of external carbon added	m3
V_COD_dt	Amount of external carbon added over the set period	m3
V_MEOH	Total amount of hydroxide added (or equiv. for P-precipitation)	m3
V_MEOH_dt	Amount of hydroxide added (or equiv.) over the set period	m3
Cost_Aer	Total aeration costs	Eur
Cost_Aer_dt	Aeration costs over the set period	Eur
Cost_Balance	Overall cost-revenue balance	Eur
Cost_Biogas	Total revenue from biogas utilisation	Eur
Cost_Chem	Total costs for addition of chemicals	Eur
Cost_Chem_dt	Costs for addition of chemicals over the set period	Eur
Cost_HeatLoss	Costs for loss of heat	Eur
Cost_HeatLoss_dt	Costs for heat losses over the set period	Eur
Cost_HeatSludge	Costs for heating the sludge	Eur
Cost_HeatSludge_dt	Costs for sludge pre-heating over the set period	Eur
Cost_Mix	Total mixing costs	Eur
Cost_Mix_dt	Mixing costs over the set period	Eur
Cost_Pump	Total pumping costs	Eur
Cost_Pump_dt	Pumping costs over the set period	Eur
Cost_Sludge	Total costs for sludge disposal	Eur
Cost_Sludge_dt	Costs for sludge disposal over the set period	Eur
Cost_Tot	Total costs	Eur
Cost_Tot_dt	Total costs over the set period	Eur
E_Aer_Tot	Total aeration energy	kWh
E_Aer_dt	Aeration energy over the set period	kWh
E_HeatLoss	Total energy for heat losses	kWh
E_HeatLoss_dt	Energy for heat losses over the set period	kWh
E_HeatSludge	Total energy for sludge pre-heating	kWh
E_HeatSludge_dt	Energy for sludge pre-heating over the set period	kWh
E_Mix_Tot	Total mixing energy	kWh
E_Mix_dt	Aeration energy over the set period	kWh
E_Pump_Tot	Total pumping energy	kWh
E_Pump_dt	Aeration energy over the set period	kWh
E_Tot_dt	Total energy over the set period	kWh
P_Aer_Tot	Total aeration power	kWh/d
P_Mix_Tot	Total mixing power	kWh/d
P_Pump_Tot	Total pumping power	kWh/d

Name	Description	Units
M_Sludge	Sludge production	g
M_Sludge_dt	Sludge production over the set period	g

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
P_Aer01 .. P_Aer10	in_1	Aeration power for unit #i (i={1,…,10})	---	kWh/d
P_Methane	in_1	Power generated from biogas utilisation	---	kWh/d
Chem_COD_Q01	in_1	Flow rate #1 for dosage of external carbon	---	m3/d
Chem_COD_Q02	in_1	Flow rate #2 for dosage of external carbon	---	m3/d
Chem_COD_Q03	in_1	Flow rate #3 for dosage of external carbon	---	m3/d
Chem_MEOH_Q01	in_1	Flow rate #1 for dosage of hydroxide (or equiv. for P-precipitation)	---	m3/d
Chem_MEOH_Q02	in_1	Flow rate #2 for dosage of hydroxide (or equiv. for P-precipitation)	---	m3/d
Chem_MEOH_Q03	in_1	Flow rate #3 for dosage of hydroxide (or equiv. for P-precipitation)	---	m3/d
P_HeatLoss	in_1	Heat losses in the digester	---	kWh/d
P_HeatSludge	in_1	Power required for pre-heating the sludge	---	kWh/d
P_Mix01 .. P_Mix20	in_1	Mixing power for unit #i (i={1,…,20})	---	kWh/d
P_Pump01 .. P_Pump20	in_1	Pumping power for unit #i (i={1,…,20})	---	kWh/d
Sl_Q01	in_1	Sludge flow rate #1	---	m3/d
Sl_Q02	in_1	Sludge flow rate #2	---	m3/d
Sl_TSS01	in_1	Solids in sludge flux #1	---	g/m3
Sl_TSS02	in_1	Solids in sludge flux #2	---	g/m3
Tot_Power	out_1	Total power consumption	---	kWh/d
Price_COD1	*in_2*	*Unit price for external carbon source #1*	*0.5*	Euro/m3
Price_COD2	*in_2*	*Unit price for external carbon source #2*	*0.5*	Euro/m3
Price_COD3	*in_2*	*Unit price for external carbon source #3*	*0.5*	Euro/m3
Price_Energy	*in_2*	*Unit price for energy*	*0.07*	Euro/kWh
Price_MEOH1	*in_2*	*Unit price for hydroxide source #1*	*0.5*	Euro/m3
Price_MEOH2	*in_2*	*Unit price for hydroxide source #2*	*0.5*	Euro/m3
Price_MEOH3	*in_2*	*Unit price for hydroxide source #3*	*0.5*	Euro/m3
Price_Methane	*in_2*	*Unit price for energy produce from biogas*	*0.055*	Euro/kWh
Price_Sludge	*in_2*	*Unit price for sludge disposal*	*0.58*	Euro/kg

Operation_wCFootprint

Instances

All

Description

This model is an extension of the Operation_Simple model.
In addition to the operational costs computed in the base model, it calculates the carbon footprint of the following items (in CO-equivalents):

- Electricity and chemicals utilisation
- Process emissions of CO2, CH4 and N2O
- Sludge disposal through farmland application and incineration
- Biogas production, leakage, and utilisation

Electricity

$$CO2_{elec} = \left(P_{aer,tot} + P_{pump,tot} + P_{mix,tot}\right) \cdot f_{elec}$$

where:

- $P_{aer,tot}$, $P_{pump,tot}$ and $P_{mix,tot}$ denote the total power consumption (kWh/d) for aeration, pumping and mixing respectively
- f_{elec} is the emission factor for electricity (kg CO2eq/kWh)

Chemical dosage

$$CO2_{chem} = L_{COD} \cdot f_{COD} + L_{MeOH} \cdot f_{MeOH} + CO2_{COD,DN}$$

$$CO2_{COD,DN} = (1 - Y_H) \cdot L_{COD} \cdot f_{COD} + L_{COD} \cdot EF_{CH4} \cdot GWP_{CH4}$$

where:

- L_{COD} and L_{MeOH} denote the load (kg/d) of external carbon and of precipitant respectively
- f_{COD} and f_{MeOH} are the emission factor for external carbon and precipitant (kg CO2eq/kg)
- $CO2_{COD,DN}$ denotes the CO2 generated from the biological conversion of the carbon dosed
- EF_{CH4} is the mass of methane produced per load of incoming COD (kg CH4/kg COD)
- GWP_{CH4} denotes the Global Warming Potential of methane (kg CO2eq/kg CH4)

Process emissions of carbon dioxide

$$CO2_{CO2,process} = (1 - Y_H) \cdot Q_{in} \cdot (BOD_{in} - BOD_{out}) \cdot EF_{CO2}$$

where:

- Q_{in} is the influent flow (m3/d)
- BOD_{in} and BOD_{out} denote the concentration (kg/m3) of BOD in the influent and in the effluent respectively
- EF_{CO2} is the carbon dioxide produced per unit BOD biodegraded (kg CO2/kg BOD)

Process emissions of methane

$$CO2_{CH4,process} = Q_{in} \cdot (BOD_{in} - BOD_{out}) \cdot EF_{CH4} \cdot GWP_{CH4}$$

where:

- EF_{CH4} is the methane produced per unit BOD biodegraded (kg CH4/kg BOD)

Process emissions of nitrous oxide

$$CO2_{NO2,process} = Q_{in} \cdot C_{TN,in} \cdot EF_{N2O} \cdot GWP_{N2O}$$

where:

- Q_{in} and $C_{TN,in}$ denote the influent flow (m3/d) and the concentration (kg/m3) of total nitrogen respectively
- EF_{N2O} is the mass of nitrous oxide produced per load of incoming nitrogen (kg N2O/kg TN)
- GWP_{N2O} denotes the Global Warming Potential of nitrous oxide (kg CO2eq/kg N2O)

Process emissions of nitrous oxide, including reject water

$$CO2_{NO2,process+reject} = Q_{in,bio} \cdot C_{TN,in} \cdot EF_{N2O} \cdot GWP_{N2O}$$

where:

- $Q_{in,bio}$ is the combined influent (m3/d) to the biological stage, including return streams

Sludge disposal: farmland application

$$CO2_{sludge,soil} = S_{soil} \cdot C_{TN,sludge} \cdot \left(EF_{N2O,soil} \cdot GWP_{N2O} - CO2_{eq,synthN}\right)$$

where:

- S_{soil} and $C_{TN,sludge}$ denote the fraction of sludge that is disposed of on soil and the amount (kg/d) of total nitrogen in the sludge, respectively
- $EF_{N2O,soil}$ is the mass of nitrous oxide produced per load of total nitrogen (kg N2O/kg TN)
- $CO2_{eq,synthN}$ denotes the emission saving that derives from replacing artificial ammonia fertiliser (kg CO2eq/kg TN)

Sludge disposal: incineration

$$CO2_{sludge,comb} = S_{comb} \cdot C_{TN,sludge} \cdot \left(EF_{N2O,comb} \cdot GWP_{N2O} - E_{sludge} \cdot (e_{el} \cdot f_{el} + e_{th} \cdot f_{th})\right)$$

where:

- $EF_{N2O,comb}$ is the mass of nitrous oxide produced per load of total nitrogen (kg N2O/kg TN)
- E_{sludge} is the energy content of the sludge (kWh/kg TSS)
- e_{el} and e_{th} denote the electricity and heat utilisation rates respectively
- f_{el} and f_{th} denote electricity and heat emission factors (kg CO2eq/kWh) respectively

Biogas production, combustion, leakage and utilisation

$$CO2_{biogas,prod} = Q_{gas} \cdot (1 - p_{CH4}) \cdot \frac{44}{24}$$

$$CO2_{biogas,comb} = Q_{gas} \cdot p_{CH4} \cdot \frac{16}{22.4} \cdot CO2_{CH4,comb}$$

$$CO2_{biogas,leak} = Q_{gas} \cdot p_{CH4} \cdot \frac{16}{22.4} \cdot f_{leak} \cdot GWP_{CH4}$$

$$CO2_{biogas,util} = Q_{gas} \cdot p_{CH4} \cdot \frac{16}{22.4} \cdot E_{CH4} \cdot (e_{el} \cdot f_{el} + e_{th} \cdot f_{th})$$

$$CO2_{biogas} = CO2_{biogas,prod} + CO2_{biogas,comb} + CO2_{biogas,leak} + CO2_{biogas,util}$$

where:

- Q_{gas} is the biogas flow rate (m3/d)
- p_{CH4} is the methane partial pressure (%)
- $CO2_{CH4,comb}$ is the stoichiometric CO2 production from CH4 combustion (kg CO2eq/kg CH4)
- f_{leak} is the leakage rate from the biogas installations
- E_{CH4} is the lower heating value of methane (kWh/kg CH4)
- e_{el} and e_{th} denote the electricity and heat utilisation rates respectively

Total CO2-equivalent emission

$$CO2_{tot} = CO2_{elec} + CO2_{chem} + CO2_{CO2,process} + CO2_{CH4,process} + CO2_{NO2,process} + CO2_{sludge,soil} + CO2_{sludge,comb} + CO2_{biogas}$$

Parameters

Name	Description	Value	Units
Biogas_Leak	Biogas leak from gas installations	0.02	---
E_CH4	Energy from methane (kWh / kg CH4)	13.9	---
Gas2El	Electricity utilisation from methane combustion	0.4	dUnit/dUnit
Gas2Th	Heat utilisation from methane combustion	0.5	dUni/dUnit
EF_CH4	Mass of CH4 produced per load of incoming COD (kg N2O-N / kg COD)	0.0075	dUnit/dUnit
EF_N20	Mass of N2O produced per load of incoming N (kgN2O-N/kgN)	0.00084	dUni/dUnit
GWP_CH4	Global warming potential of CH4	34	---
GWP_N2O	Global warming potential of N2O	298	---
E_Sludge	Energy from sludge incineration (kWh / kg TSS)	2.358	---
Sludge2Comb	Fraction of sludge disposed of by incineration	1	dUnit/dUnit
Sludge2El	Electricity utilisation from sludge incineration	0.4	dUnit/dUnit
Sludge2Soil	Fraction of sludge disposed of to farmland	0	dUnit/dUnit
Sludge2Th	Heat utilisation from sludge incineration	0.5	dUnit/dUnit
w_CO2	Weight for CO2 footprint in overall cost function	1	---
w_COD	Tax-related weight for effluent COD	1	---

Name	Description	Value	Units
w_TN	Tax-related weight for effluent TN	1	---
w_TP	Tax-related weight for effluent TP	1	---
w_dosing	Weight for chemical dosing in overall cost function	1	---
w_effluent	Weight for effluent quality in overall cost function	1	---
w_energy	Weigh for energy consumption in overall cost function	1	---
w_opex	Weight for operational cost in overall cost function	1	---

State Variables

Name	Description	Units
CO2eq_CODd	Total CO2eq generation from biological conversion of COD dosed	kg/d
CO2eq_N2O	CO2eq generation from N2O production	kg/d
CO2eq_N2O_rej	CO2eq generation from N2O production, incl. reject water	kg/d
CO2eq_bCOD	CO2eq generation from BOD degradation	kg/d
CO2eq_biogas	Net CO2eq emission from CH4 production and utilisation	kg/d
CO2eq_chem	CO2eq generation from chemical usage	kg/d
CO2eq_elec	CO2eq generation from electricity consumption	kg/d
CO2eq_sludge	Net CO2eq emission from sludge disposal	kg/d
CO2eq_tot	Total CO2eq generation	kg/d
CO2eq_tot_wReject	Total CO2eq generation, incl reject water	kg/d
CO2eq_flow	CO2eq generated per volume wastewater treated	kg/m3
Cost_eq_tot	Overall cost function, accounting for all cost functions	1/m3
Cost_flow	Cost per volume wastewater treated	Eur/m3
EQI	Effluent quality index for COD, N, P	kg/d
En_TPE	Energy consumed per kg pollutant removed	kWh/kg
En_flow	Energy consumed per volume wastewater treated	kWh/m3
TPE	Removal index for COD, N, P	kg/d
r_COD	COD removal efficiency	---
r_TN	TN removal efficiency	---
r_TP	TP removal efficiency	---
r_TSS	TSS removal efficiency	---

Derived State Variables

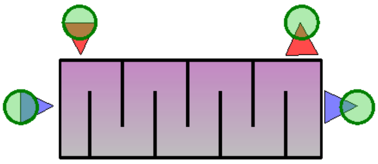
None

Interface Variables

Name	Terminal	Description	Value	Units
Sl_TN01	in_1	Total N concentration in sludge flux #1	---	g/m3
Sl_TN02	in_1	Total N concentration in sludge flux #2	---	g/m3
P_Biogas	in_1	Total headspace pressure	---	bar
P_CH4	in_1	Partial pressure of methane	---	bar
Q_Biogas	in_1	Biogas flow rate	---	m3/d
M1_COD	in_1	Load of carbon solution #1 dosed	---	g/d
M1_MEOH	in_1	Load of precipitant #1 dosed	---	g/d
M2_COD	in_1	Load of carbon solution #2 dosed	---	g/d
M2_MEOH	in_1	Load of precipitant #2 dosed	---	g/d
M3_COD	in_1	Load of carbon solution #3 dosed	---	g/d
M3_MEOH	in_1	Load of precipitant #3 dosed	---	g/d
BOD_Out	in_1	Effluent BOD	---	g/m3
COD_Out	in_1	Effluent COD	---	g/m3
Q_Out	in_1	Effluent flow rate	---	m3/d
TN_Out	in_1	Effluent TN	---	g/m3

Name	Terminal	Description	Value	Units
TP_Out	in_1	Effluent TP	---	g/m3
TSS_Out	in_1	Effluent TSS	---	g/m3
BOD_In	in_1	Influent BOD	---	g/m3
COD_In	in_1	Influent COD	---	g/m3
Q_In	in_1	Influent flow rate	---	m3/d
TN_In	in_1	Influent TN	---	g/m3
TP_In	in_1	Influent TP	---	g/m3
TSS_In	in_1	Influent TSS	---	g/m3
SRT	in_1	Sludge age	---	d

DISINFECTION

	Palette Group	**Tertiary**
	Category	Disinfection
	Icon name	disinfection_unit

Chlorine

Instances

All

Description

A simple disinfection model in which the inactivation is based on residual chlorine and contact time. The residual chlorine is calculated as:

$$Cl_R = Cl_{tot} - (Cl_{imm} + Cl_{dec})$$

where:

- Cl_{tot} is the dose of chlorine
- Cl_{imm} is the immediate demand of chlorine
- Cl_{dec} is the demand of chlorine for decay

The contact time is:

$$HRT = \frac{V}{Q_{In}}$$

where:

- V is the volume
- Q_{In} is the treated flow

The E-Coli count in the influent can be inputted or calculated, based on an average removal across the treatment plant:

$$In_{EColi} = EColi_{ave} \cdot (1 - \rho_{EColi,WWTP})$$

where:

- $EColi_{ave}$ is the average E-Coli count in the WWTP influent
- $\rho_{EColi,WWTP}$ is the E-Coli removal in the WWTP

The E-Coli count in the effluent is calculated as:

$$EColi_{Out} = In_{EColi} \cdot \left(\frac{Cl_R \cdot HRT}{b}\right)^{-n}$$

where: *b* and *n* are empirical coefficients; and HRT is expressed in minutes.

Parameters

Name	Description	Value	Units
b	Empirical coefficient	4	---
n	Empirical coefficient	2.8	---
Cl_Dec	Demand of chlorine for decay	2.5	g/m3
Cl_Imm	Immediate demand of chlorine	4	g/m3
Cl_Tot	Dose of chlorine	10	g/m3
EColi_Ave	Average E-coli count in the WWTP influent	10,000,000	---
Vol	Volume	25	m3

State Variables

Name	Description	Units
HRT	Contact time	d
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
r_EColi	Overall E-coli removal	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	g/d
Cl_R	out_2	Residual chlorine	---	g/m3
EColi_Out	out_2	E-coli count in the effluent	---	---
EColi_In	*in_2*	*E-coli count in the influent (from unit upstream)*	*-1*	---
rho_EColi_WWTP	*in_2*	*E-coli removal in the WWTP*	*0.95*	---

ChlorineInv

Instances

All

Description

A simple disinfection model in which the inactivation is based on residual chlorine and contact time. The model computes the required chlorine concentration to achieve a desired E-coli removal.

The contact time is:

$$HRT = \frac{V}{Q_{In}}$$

where:

- V is the volume
- Q_{In} is the treated flow

The E-Coli count in the influent can be inputted or calculated, based on an average removal across the treatment plant:

$$In_{EColi} = EColi_{ave} \cdot (1 - \rho_{EColi,WWTP})$$

where:

- $EColi_{ave}$ is the average E-Coli count in the WWTP influent
- $\rho_{EColi,WWTP}$ is the E-Coli removal in the WWTP

The residual chlorine is calculated as:

$$Cl_R = \left(\frac{EColi_{Out}}{In_{EColi}}\right)^{-\frac{1}{n}} \cdot \frac{b}{HRT}$$

where: *b* and *n* are empirical coefficients; and HRT is expressed in minutes.

The necessary chlorine concentration is then calculated as:

$$Cl_{tot} = Cl_R + Cl_{imm} + Cl_{dec}$$

where:

- Cl_{imm} and Cl_{dec} denote the immediate demand of chlorine and the demand of chlorine for decay, respectively

Parameters

Name	Description	Value	Units
b	Empirical coefficient	4	---
n	Empirical coefficient	2.8	---
Cl_Dec	Demand of chlorine for decay	2.5	g/m3
Cl_Imm	Immediate demand of chlorine	4	g/m3
EColi_Ave	Average E-coli count in the WWTP influent	10,000,000	---
Vol	Volume	25	m3

State Variables

Name	Description	Units
Cl_R	Residual chlorine	g/m3
HRT	Contact time	d
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
r_EColi	Overall E-coli removal	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	---
Cl_Tot	out_2	Dose of chlorine	---	g/m3
EColi_In	*in_2*	*E-coli count in the influent (from unit upstream)*	*-1*	---
EColi_Out	*in_2*	*Desired E-coli count in the effluent*	*240*	---
rho_EColi_WWTP	*in_2*	*E-coli removal in the WWTP*	*0.95*	---

PAA_02

Instances

All

Description

A disinfection model based on the log-inactivation model by Henao et al. (2018).
It accounts for the influence of suspended solids on the decay of peracetic acid and on the bacterial inactivation kinetics.

The dose of peracetic acid is function of the contact time:

- For TSS < 5 mg/L: $D_{PAA} = C_{PAA} \cdot HRT$
- For TSS > 5 mg/L: $D_{PAA} = \frac{C_{PAA} - OD}{k} \cdot \left(1 - e^{-k \cdot HRT}\right)$

where:

- C_{PAA} is the initial PAA concentration
- OD is the initial oxidative demand
- k is an empirical factor

The contact time is:

$$HRT = \frac{V}{Q_{In}}$$

where:

- V is the volume
- Q_{In} is the treated flow

The E-Coli count in the influent can be inputted or calculated, based on an average removal across the treatment plant:

$$In_{EColi} = EColi_{ave} \cdot (1 - \rho_{EColi,WWTP})$$

where:

- $EColi_{ave}$ is the average E-Coli count in the WWTP influent
- $\rho_{EColi,WWTP}$ is the E-Coli removal in the WWTP

The E-Coli count in the effluent is calculated as:

$$EColi_{Out} = 10^{In_{EColi} + dLog}$$

$$dLog = \log\left(\frac{N}{No}\right) = -k1 \cdot D_{PAA}^{n} \cdot \frac{1}{1 + e^{h - D_{PAA}}}$$

Parameters

Name	Description	Value	Units
F_TSS_COD*	Fraction TSS/COD	0.75	---
h	Empirical factor	6.335	---
k1	Empirical factor	1.851	---
n	Empirical factor	0.328	---

Name	Description	Value	Units
OD	Initial Oxidative Demand	0.01	g/m3
k	Empirical factor	0.05	---
EColi_Ave	Average E-Coli count in the WWTP influent	10,000,000	---
Vol	Volume	25	m3

* only ASM1

State Variables

Name	Description	Units
D_PAA	Dose of PAA	g/(m3*min)
HRT	Contact time	d
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
r_EColi	Overall E-coli removal	---

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	0	g/d
Outflow	out_1	Outflow (component vector)	---	---
EColi_Out	out_2	E-coli count in the influent	---	---
EColi_In	*in_2*	*E-coli count in the influent (from upstream)*	*-1*	---
rho_EColi_WWTP	*in_2*	*E-coli removal in the WWTP*	*0.95*	---
C_PAA	*in_2*	*Initial PAA concentration*	*10*	*g/m3*

UV

Instances

All

Description

A simple disinfection model in which the inactivation is proportional to the intensity of the UV radiation and to the contact time.

The contact time is:

$$HRT = \frac{V}{Q_{In}}$$

where:

- V is the volume
- Q_{In} is the treated flow

The E-Coli count in the influent can be inputted or calculated, based on an average removal across the treatment plant:

$$In_{EColi} = EColi_{ave} \cdot (1 - \rho_{EColi,WWTP})$$

where:

- $EColi_{ave}$ is the average E-Coli count in the WWTP influent
- $\rho_{EColi,WWTP}$ is the E-Coli removal in the WWTP

The dose of UV is:

$$UV_D = UV_I \cdot HRT$$

where:

- UV_I is the UV intensity
- HRT is the contact time in seconds

The E-Coli count in the effluent is calculated as:

$$EColi_{Out} = In_{EColi} \cdot e^{-k \cdot UV_D}$$

where: k is an empirical coefficient.

Parameters

Name	Description	Value	Units
k	Empirical factor	0.05	---
EColi_Ave	Average E-coli count in the WWTP influent	10,000,000	---
Vol	Volume	25	m3

State Variables

Name	Description	Units
HRT	Contact time	d
Q_In	Influent flow rate	m3/d
Q_Out	Effluent flow rate	m3/d
r_EColi	Overall E-coli removal	---

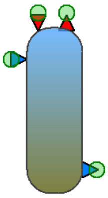
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow (component vector)	---	g/d
Outflow	out_1	Outflow (component vector)	---	---
UV_D	out_2	Dose of UV	---	mJ/cm2
EColi_Out	out_2	E-coli count in the influent	---	---
EColi_In	*in_2*	*E-coli count in the influent (from unit upstream)*	*-1*	---
rho_EColi_WWTP	*in_2*	*E-coli removal in the WWTP*	*0.95*	---
UV_I	*in_2*	*UV intensity*	*0.2*	*mW/cm2*

QUATERNARY TREATMENT

	Palette Group	**Quaternary**
	Category	Carbon Active
	Icon Name	GAC

GAC_01bed

Instances

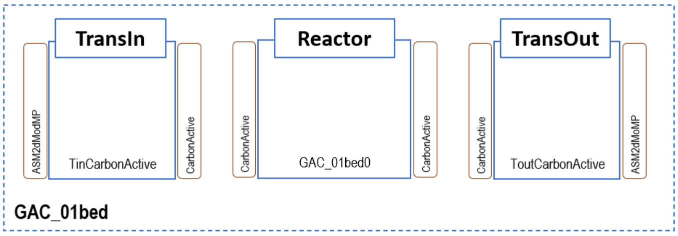
IUWS4

Description

This is a model for a granular activated carbon (GAC) unit process consisting of a single bed, to remove micropollutants due to the adsorptive capacity of carbon.

It combines the following elements (see figure):

- An input interface (TransIn) that converts the influent wwtp state vector to the state vector required by the activated carbon conversion model.
- A process tank (Reactor) where the sorption/desorption processes take place.
- An output interface (TransOut) that converts the activated carbon state vector back into a wwtp state vector.



For a detailed description of the interface models, please refer to MISCELLANEA.

Submodels

Name	Model
TransIn	(ASM2dModMP).TinCarbonActive
Reactor	GAC_01bed0
TransOut	(ASM2dModMP).ToutCarbonActive

Parameters

Name	Description	Value	Units
F_COD_DOC	COD to dissolved organic carbon (DOC) conversion	3	---
A_column	Surface area of the reactor	10	m^2
H	Depth of the reactor	3	m
K_f_MP	Freundlich-based partitioning coefficient for MP	200	---
K_f_OC	Freundlich-based partitioning coefficient for OC	20	---
f_OC_compet	Fraction of OC competing with MP sorption	0.005	---
k_des	Desorption rate	10000	1/d
mode	MP sorption model*	0	---
n_MP	Freundlich coefficient for MP	4	---
n_OC	Freundlich coefficient for OC	1	---

* 0 = Freundlich isotherm; 1 = simplified IAST isotherms (explicit OC competition)

State Variables

Name	Description	Units
C_Bulk	Concentration of each component in the bulk liquid	g/m^3

C_ac	Concentration of each component in the granule's layers	g/m^3
M_ac	Mass of each component in the granule's layers	g
Q_In	Influent flow rate	m^3/d
Q_Out	Effluent flow rate	m^3/d
d	Thickness of the biofilm	m

Derived State Variables

Name	Description	Units
V_Out	Cumulated volume of water treated	m^3

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow	---	m^3/d
Inflow	in_1	Inflow	---	m^3/d
Temp	*in_2*	*Temperature of the liquor*	*15*	*degC*

The physico-chemical processes that characterize an activated carbon unit are implemented in the "Default" conversion model of the "CarbonActive" category.
The GAC_01bed0 model is an extension of the Default model.

CarbonActive.Default

The state components

The components of the ASM2dISS model Category that form the **component vector** are listed in the following table.

Name	Description	Units
Q	Water	m^3/d
DOC	Dissolved Organic Carbon	g/m^3
S_ALK	Alkalinity	mol/m^3
X_DOC	Particulate Dissolved Organic Carbon	g/m^3
S_MP_conj	Conjugated form of the soluble micropollutant	g/m^3
S_N2	Dissolved nitrogen gas	g N/m^3
S_NH	Ammonium + ammonia nitrogen	g N/m^3
S_NO	Nitrate + nitrite nitrogen	g N/m^3
S_O	Dissolved oxygen	g COD/m^3
S_PO	Soluble inorganic phosphorous	g P/m^3
S_MP	Soluble micropollutant	g/m^3
X_MEOH	Metal-hydroxides	g TSS/m^3
X_MEP	Metal-phosphates	g TSS/m^3
X_MP	Particulate micropollutant	g/m^3
X_PP	Stored polyphosphate in PAOs	g P/m^3
X_TSS	Total Suspended Solids	g TSS/m^3

The Conversion Model

The processes modelled within the CarboActive are listed in the following table.

Name	Description
SorptionOfMP	Sorption of micropollutants
DesorptionOfMP	Desorption of micropollutants
SorptionOfDOC	Sorption of DOC
DesorptionOfDOC	Desorption of DOC

The Conversion Model (Gujer Matrix) is illustrated in detail below.

P1: SorptionOfMP	
S_MP	-1
X_MP	1
Rate	$r_{sorption}$

P2: DesorptionOfMP	
S_MP	1
X_MP	-1
Rate	$k_{des} \cdot C_{X_{MP}}$

P3: SorptionOfDOC	
DOC	-1
X_DOC	1
Rate	$k_{des} \cdot f_{OC} \cdot ({C_{DOC}}^{n_{OC}})$

P4: DesorptionOfDOC	
DOC	1
X_DOC	-1
Rate	$k_{des} \cdot C_{X_{DOC}}$

Parameters

Name	Description	Value	Units
K_f MP	MP Freundlich-based partitioning coefficient	200	
K_f OC	OC Freundlich-based partitioning coefficient	20	
f_OC_compet	Fraction of OC competing with MP sorption	0.005	---
k_des	Desorption rate	10,000	
mode	MP sorption model*	0	---
n_MP	Freundlich coefficient for MP	4	
n_OC	Freundlich coefficient for OC	1	

* 0 = Freundlich isotherm; 1 = simplified IAST isotherms (explicit OC competition)

State Variables

Name	Description	Units
Is_React	Conversion processes on (1) / or off (0)	---
C	Concentrations of the components	g/m^3
V	Actual volume of the tank (of liquid)	m^3
r_sorption	Sorption rate	g/m3/d

Derived State Variables

Name	Description	Units
M	Mass of the components	g

Interface Variables

Name	Terminal	Description	Value	Units
Temp	*in_2*	*Temperature of the liquor*	*15*	*degC*
C_ac	*in_2*	*Concentration of activated carbon adsorbent*	*100*	*g/m3*
Inflow	in_1	Inflow	--	g/d
Outflow	out_1	Outflow	--	g/d
V_Tank	out_2	Volume of the tank	--	m3

The sorption rate is calculated as follows:

- mode = 0, i.e., according to Freundlich isotherm

$$r_{sorption} = \mathrm{k_{des}} \cdot \mathrm{K_{f_{MP}}} \cdot \left(10^{-6+\frac{3}{n_{MP}}}\right) \cdot \left({C_{S,MP}}^{\frac{1}{n_{MP}}}\right) \cdot \mathrm{C_{ac}}$$

- mode = 1, i.e., according to the simplified IAST isotherms

$$r_{sorption} = k_{des} \cdot \left(K_{f_{MP}} \cdot 10^{-6+\frac{3}{n_{MP}}} \cdot \frac{n_{MP}}{n_{OC}}\right)^{n_{MP}} \cdot \left(C_{ac} \cdot K_{f_{OC}} \cdot 10^{-3} \cdot \left(f_{OC_{comp}} \cdot C_{DOC}\right)^{\frac{1}{n_{OC}}}\right)^{1-n_{MP}} \cdot C_{S,MP} \cdot C_{ac}$$

GAC_10beds

Instances

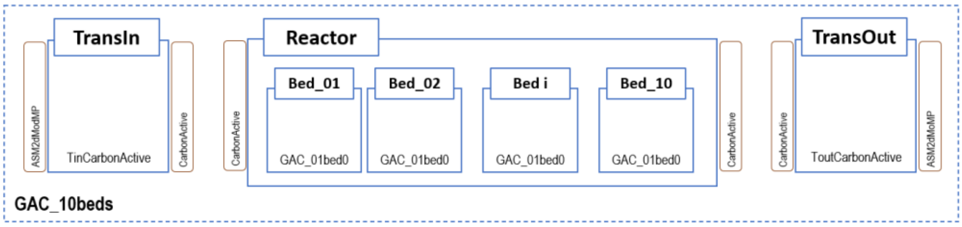
IUWS4

Description

This is a model for a granular activated carbon (GAC) unit process consisting of a series of 10 beds, to remove micropollutants due to the adsorptive capacity of carbon.

It combines the following elements (see figure):

- An input interface (TransIn) that converts the influent wwtp state vector to the state vector required by the activated carbon conversion model.
- A process tank (Reactor), in turns consisting of 10 individual GAC_01bed elements, where the sorption/desorption processes take place.
- An output interface (TransOut) that converts the activated carbon state vector back into a wwtp state vector.



For a detailed description of the interface models, please refer to MISCELLANEA.

Submodels

Name	Model
TransIn	(ASM2dModMP).TinCarbonActive
Reactor	GAC_10bed0
TransOut	(ASM2dModMP).ToutCarbonActive

Parameters

Name	Description	Value	Units
F_COD_DOC	COD to dissolved organic carbon (DOC) conversion	3	---
A_column	Surface area of the reactor	10	m^2
H	Depth of the reactor	3	m
K_f_MP	Freundlich-based partitioning coefficient for MP	200	---
K_f_OC	Freundlich-based partitioning coefficient for OC	20	---
f_OC_compet	Fraction of OC competing with MP sorption	0.005	---
k_des	Desorption rate	10000	1/d
mode	MP sorption model*	0	---
n_MP	Freundlich coefficient for MP	4	---
n_OC	Freundlich coefficient for OC	1	---

* 0 = Freundlich isotherm; 1 = simplified IAST isotherms (explicit OC competition)

State Variables

Name	Description	Units
BV	Number of bed volumes treated	-
Q_In	Influent flow rate	m^3/d
Q_Out	Effluent flow rate	m^3/d

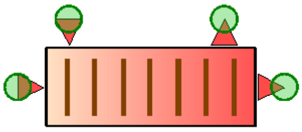
Derived State Variables

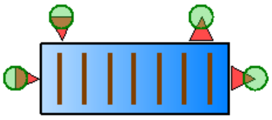
None

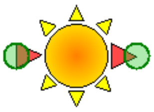
Interface Variables

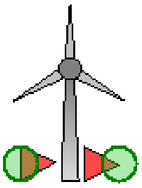
Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow	---	m^3/d
Inflow	in_1	Inflow	---	m^3/d
Temp	*in_2*	*Temperature of the liquor*	*15*	*degC*

ENERGY

	Palette Group	**Energy**
	Category	HeatExchanger
	Icon Name	heat_exchanger

	Palette Group	**Energy**
	Category	HeatExchanger
	Icon name	heat_pump

	Palette Group	**Energy**
	Category	Energy
	Icon name	en_solar

	Palette Group	**Energy**
	Category	Energy
	Icon name	en_wind

HeatExchanger.Simple

Instances

All

Description

A simple model for heat exchange. The model heats up water or sludge flow with a hot gas flow.

The temperature in the tank (same as the temperature of the effluent flow):

$$\frac{dT_{tank}}{dt} = M_{Feed} \cdot Cp \cdot (T_{Feed} - T_{Tank}) + UA \cdot \frac{T_{Gas} - T_{Tank}}{M_{Tank} \cdot Cp}$$

where:

- M_{Feed} and M_{Tank} denote the feed flow rate [kg/d) and the total mass in the tank [kg]
- Cp is the heat capacity
- T_{Feed} and T_{Gas} denote the temperature of the feed and of the gas [°C]
- UA denotes the surface area of the heat exchanger multiplied by the heat transfer coefficient

The required power for heating [kWh/d]:

$$P_{HeatSludge} = c \cdot M_{Feed} \cdot Cp \cdot \left(T_{Target} - T_{Feed}\right)$$

where:

- c is a unit conversion factor, 2.78E-07 kWh/J
- T_{Target} is the desired temperature of the feed flow [°C]

Parameters

Name	Description	Value	Units
Cp	Heat capacity	2	kJ/kg/°C
M_Reactor	Total mass in a tank	1,000	kg
UA	Area x heat transfer coefficient	2,160,000	kJ/d/°C
rho_sludge	Sludge density	1,070,000	g/m3

State Variables

Name	Description	Units
M_Feed	Feed flow rate	g/d

Derived State Variables

Name	Description	Units
T_Tank	Temperature in the tank	°C

Interface Variables

Name	Terminal	Description	Value	Units
Q_Feed	in_1	Feed flow rate	---	m3/d
T_Feed	in_1	Feed temperature	20	°C
T_Gas	in_1	Temperature of the gas	60	°C
T_Out	out_1	Temperature of the effluent flow	---	K
P_HeatSludge	out_2	Power required for heating	---	kWh/d
T_Target	*in_2*	*Target temperature of the feed flow*	*60*	*°C*

HeatExchanger.SludgeRaw

Instances

All

Description

The model describes a, potentially discontinuous gas flow, that heats up the water flow, thus accounting for both the heat exchanger and the digester.

The temperature in the tank (same as the temperature in the tank downstream):

$$\frac{dT_{tank}}{dt} = \frac{M_{Feed} \cdot Cp \cdot (T_{Out} - T_{Tank}) - P_{HeatLoss}}{M_{Tank} \cdot Cp}$$

where:

- M_{Feed} and M_{Tank} denote the feed flow rate [kg/d) and the total mass in the tank [kg]
- Cp is the heat capacity
- T_{Out} and T_{Tank} denote the temperature of the effluent flow and of the tank [°C]
- $P_{HeatLoss}$ is the heat loss in the downstream process unit

The required power for heating [kWh/d]:

$$P_{HeatSludge} = c \cdot M_{Feed} \cdot Cp \cdot \left(T_{Target} - T_{Feed}\right)$$

where:

- c is a unit conversion factor, 2.78E-07 kWh/J
- T_{Target} is the desired temperature of the feed flow [°C]

Heat balance:

$$P_{biogas} = P_{GasTh} + P_{aux}$$

$$P_{loss_{dig}} = P_{HeatLoss}$$

$$P_{sl_{dig}} = c \cdot M_{Feed} \cdot Cp \cdot T_{op}$$

$$P_{sl_{heated}} = c \cdot M_{Feed} \cdot Cp \cdot T_{Out}$$

$$P_{sl_{raw}} = c \cdot M_{Feed} \cdot Cp \cdot T_{Feed}$$

$$dP_{dig} = P_{sl_{heated}} - P_{loss_{dig}} - P_{sl_{dig}}$$

$$dP_{heater} = P_{sl_{raw}} + P_{biogas} - P_{sl_{heated}}$$

$$dP_{tot} = P_{sl_{raw}} + P_{biogas} - P_{loss_{dig}} - P_{sl_{dig}}$$

$$P_{aux} = \eta_{aux} \cdot Q_{aux} \cdot E_{aux_{sp}}$$

$$dt_{ml} = \frac{\left(T_{h2o_{in}} - T_{Out}\right) - \left(T_{h2o_{out}} - T_{Feed}\right)}{\log\left(\frac{T_{h2o_{in}} - T_{Out}}{T_{h2o_{out}} - T_{Feed}}\right)}$$

$$P_{heat} = UA \cdot \frac{dt_{ml}}{3600}$$

$$T_{h2o_{out}} = T_{h2o_{in}} - \frac{P_{GasTh} + P_{aux}}{c \cdot Q_{h2o_{in}} \cdot \rho_{h2o} \cdot Cp_{h2o}}$$

Parameters

Name	Description	Value	Units
A	Area of heat exchanger	10	m2
Cp	Heat capacity	2	kJ/kg/°C
Cp_h2o	Heat capacity of water	4.184	kJ/kg/°C
U	Heat transfer coefficient	100	W/m2/°C
UA	Area x heat transfer coefficient	2,160,000	kJ/d/°C
V_Reactor	Volume of the tank receiving heated stream	1,000	m3
rho_h2o	Density of water	1,000,000	g/m3
rho_sludge	Sludge density	1,070,000	g/m3
T_Out_max	Maximum admissible temperature of the effluent flow	45	°C
dT_h2o_min	Minimum admissible difference T_H2O_out - T_feed	25	°C
eta_aux	Energy conversion efficiency for auxiliary combustible	0.5	---

State Variables

Name	Description	Units
M_Reactor	Total mass in the tank receiving heated stream	kg
P_biogas	Heat of the biogas	kWh/d
P_loss_dig	Heat losses of the digester	kWh/d
P_sl_dig	Heat of the digested sludge	kWh/d
P_sl_heated	Heat of the heated sludge	kWh/d
P_sl_raw	Heat of the raw sludge	kWh/d
dP_dig	Heat balance in the digester	kWh/d
dP_heater	Heat balance in the heater	kWh/d
dP_tot	Overall heat balance	kWh/d
M_Feed	Feed flow rate	g/d
P_aux	Power generated by auxiliary combustible	kWh/d
P_heat	Heat load of the heat exchanger	kWh/d
T_Out	Temperature of the effluent flow	°C
T_h2o_out	Temperature of the effluent water stream	°C

Derived State Variables

Name	Description	Units
T_Tank	Temperature in the tank	°C

Interface Variables

Name	Terminal	Description	Value	Units
Q_Feed	in_1	Feed flow rate	---	m3/d
Q_aux	in_1	Flow rate of auxiliary combustible	---	m3/d
Q_h2o_in	in_1	Flow rate of the hot water stream entering the heat exchanger	100	m3/d
T_Feed	in_1	Feed temperature	20	°C
T_h2o_in	in_1	Temperature of the hot water stream	90	°C
T_Op	out_1	Temperature in the downstream tank	---	K
P_HeatSludge_req	out_2	Power required for heating	---	kWh/d
T_Target	*in_2*	*Target temperature of the feed flow*	*60*	°C

Name	Terminal	Description	Value	Units
E_aux_sp	*in_2*	*Volume-to-energy conversion factor of auxiliary combustible*	*10.842*	*kWh/m3*
P_GasTh	*in_2*	*Available power for heating*	*0*	*kWh/d*
P_HeatLoss	*in_2*	*Heat loss in downstream process unit*	*0*	*kWh/d*

HeatExchanger.SludgeRecirc

Instances

All

Description

The model describes a, potentially discontinuous gas flow, that heats up the water flow, thus accounting for both the heat exchanger and the digester.
The model applies to the sludge recirculation stream.

The temperature in the tank (same as the temperature in the tank downstream):

$$\frac{dT_{tank}}{dt} = \frac{M_{Feed} \cdot Cp \cdot (T_{Out} - T_{Tank}) - Q_{Raw} \cdot \rho_{sludge} \cdot Cp \cdot (T_{Tank} - T_{Raw}) - P_{HeatLoss}}{M_{Tank} \cdot Cp}$$

where:

- M_{Feed} and M_{Tank} denote the feed flow rate [kg/d) and the total mass in the tank [kg]
- Cp is the heat capacity
- T_{Out} , T_{Tank} and T_{Raw} denote the temperature of the effluent flow, of the tank and of the raw sludge [°C]
- Q_{Raw} and ρ_{sludge} denote the flow rate [m3/d] and density [g/m3] of the raw sludge
- $P_{HeatLoss}$ is the heat loss in the downstream process unit

The required power for heating [kWh/d]:

$$P_{HeatSludge} = c \cdot M_{Feed} \cdot Cp \cdot \left(T_{Target} - T_{Feed}\right)$$

where:

- c is a unit conversion factor, 2.78E-07 kWh/J
- T_{Target} is the desired temperature of the feed flow [°C]

Heat balance:

$$P_{extra} = P_{GasTh} + P_{aux} - P_{biogas}$$

$$P_{loss_{dig}} = P_{HeatLoss}$$

$$P_{sl_{dig}} = c \cdot Q_{Raw} \cdot \rho_{sludge} \cdot Cp \cdot T_{op}$$

$$P_{sl_{heated}} = c \cdot M_{Feed} \cdot Cp \cdot T_{Out}$$

$$P_{sl_{raw}} = c \cdot Q_{Raw} \cdot \rho_{sludge} \cdot Cp \cdot T_{Raw}$$

$$P_{sl_{recirc}} = c \cdot M_{Feed} \cdot Cp \cdot T_{op}$$

$$dP_{dig} = P_{sl_{raw}} + P_{sl_{heated}} - P_{sl_{recirc}} - P_{loss_{dig}} - P_{sl_{dig}}$$

$$dP_{heater} = P_{sl_{recirc}} + P_{biogas} - P_{sl_{heated}}$$

$$dP_{tot} = P_{sl_{raw}} + P_{biogas} - P_{loss_{dig}} - P_{sl_{dig}}$$

$$P_{aux} = \eta_{aux} \cdot Q_{aux} \cdot E_{aux_{sp}}$$

$$dt_{ml} = \frac{\left(T_{h2o_{in}} - T_{Out}\right) - \left(T_{h2o_{out}} - T_{Feed}\right)}{\log\left(\frac{T_{h2o_{in}} - T_{Out}}{T_{h2o_{out}} - T_{Feed}}\right)}$$

$$P_{heat} = UA \cdot \frac{dt_{ml}}{3600}$$

$$T_{h2o_{out}} = T_{h2o_{in}} - \frac{P_{GasTh} + P_{aux}}{c \cdot Q_{h2o_{in}} \cdot \rho_{h2o} \cdot Cp_{h2o}}$$

Parameters

Name	Description	Value	Units
A	Area of heat exchanger	10	m2
Cp	Heat capacity	2	kJ/kg/°C
Cp_h2o	Heat capacity of water	4.184	kJ/kg/°C
U	Heat transfer coefficient	100	W/m2/°C
UA	Area x heat transfer coefficient	2,160,000	kJ/d/°C
V_Reactor	Volume of the tank receiving heated stream	1,000	m3
rho_h2o	Density of water	1,000,000	g/m3
rho_sludge	Sludge density	1,070,000	g/m3
T_Out_max	Maximum admissible temperature of the effluent flow	45	°C
dT_h2o_min	Minimum admissible difference T_H2O_out - T_feed	25	°C
eta_aux	Energy conversion efficiency for auxiliary combustible	0.5	---

State Variables

Name	Description	Units
M_Reactor	Total mass in the tank receiving heated stream	kg
P_biogas	Heat of the biogas	kWh/d
P_loss_dig	Heat losses of the digester	kWh/d
P_sl_dig	Heat of the digested sludge	kWh/d
P_sl_heated	Heat of the heated sludge	kWh/d
P_sl_raw	Heat of the raw sludge	kWh/d
P_sl_recirc	Heat of the recirculated sludge	kWh/d
dP_dig	Heat balance in the digester	kWh/d
dP_heater	Heat balance in the heater	kWh/d
dP_tot	Overall heat balance	kWh/d
M_Feed	Feed flow rate	g/d
P_aux	Power generated by auxiliary combustible	kWh/d
P_heat	Heat load of the heat exchanger	kWh/d
T_Out	Temperature of the effluent flow	°C
T_h2o_out	Temperature of the effluent water stream	°C

Derived State Variables

Name	Description	Units
T_Tank	Temperature in the tank	°C

Interface Variables

Name	Terminal	Description	Value	Units
Q_Feed	in_1	Feed flow rate	---	m3/d
Q_aux	in_1	Flow rate of auxiliary combustible	---	m3/d

Name	Terminal	Description	Value	Units
Q_h2o_in	in_1	Flow rate of the hot water stream entering the heat exchanger	100	m3/d
Q_raw	in_1	Flow rate of the untreated sludge (not entering heat exchanger)	---	m3/d
T_Feed	in_1	Feed temperature	20	°C
T_h2o_in	in_1	Temperature of the hot water stream	90	°C
T_raw	in_1	Temperature of untreated sludge (not entering heat exchanger)	20	degC
T_Op	out_1	Temperature in the downstream tank	---	K
P_HeatSludge_req	out_2	Power required for heating	---	kWh/d
T_Target	*in_2*	*Target temperature of the feed flow*	*60*	°C
E_aux_sp	*in_2*	*Volume-to-energy conversion factor of auxiliary combustible*	*10.842*	*kWh/m3*
P_GasTh	*in_2*	*Available power for heating*	*0*	*kWh/d*
P_HeatLoss	*in_2*	*Heat loss in downstream process unit*	*0*	*kWh/d*

HeatExchanger.Heat Pump

Instances

All

Description

This is a model of a heat pump to extract heat from the treated wastewater effluent.

The heat that can be recuperated is a function of the heat contained in the stream ($P_{heat,w}$, kWh/d):

$$P_{heat,rec} = \frac{-COP}{1 - COP} \cdot P_{heat,w} \cdot \epsilon_{heat}$$

where:

- COP is a performance coefficient (-),
- ϵ_{heat} is the heat transfer efficiency of the equipment (-).

The heat contained in the treated wastewater and the performance coefficient are calculates as follows:

$$P_{heat,w} = \frac{1}{3.6} \cdot Q_{in} \cdot C_p \cdot (T_{w,in} - T_{w,out})$$

$$COP = \frac{\epsilon_{Lorenz} \cdot (T_{dh,in} - T_{dh,out})}{log \frac{T_{dh,in}}{T_{dh,out}}} \Bigg/ \left(\frac{(T_{dh,in} - T_{dh,out})}{log \frac{T_{dh,in}}{T_{dh,out}}} - \frac{dT_w}{log \frac{T_{w,in}}{T_{w,out}}} \right)$$

where:

- $\mathrm{Q_{in}}$ denotes the wastewater flow rate (m3/d),
- $\mathrm{C_p}$ is the heat capacity of water (kJ/kg/°C),
- $\mathrm{T_{w,in}}$ and $\mathrm{T_{w,out}}$ denote the temperature of the influent and of the effluent water flows, respectively (K),
- $\mathrm{T_{dh,in}}$ and $\mathrm{T_{dh,out}}$ denote the temperature of the district heating supply and reflux, respectively (K).
- $\epsilon_{\mathrm{Lorenz}}$ is the Lorenz efficiency (-).

Finally, the heat potential ($P_{heat,max}$), the input power to operate the pump (P_{el}) and the net energy production (P_{rec}) are calculated as:

$$P_{heat,max} = \frac{-COP}{1 - COP} \cdot P_{heat,w}$$

$$P_{el} = P_{heat,max} - P_{heat,w}$$

$$P_{rec} = P_{heat,rec} - P_{el}$$

Parameters

Name	Description	Value	Units
Cp	Heat capacity	4.18	KJ/kg/°C
eta_Heat	Efficiency of heat transfer equipment (incl. heat losses)	0.95	---
eta_Lorenz	Lorenz efficiency	0.55	---

State Variables

Name	Description	Units
P_El	Electrical power input to heat pump	kWh/d
P_Heat_max	Heat potential	kWh/d
P_Heat_w	Heat embedded in the wastewater	kWh/d
P_rec	Net energy production	kWh/d
COP	Coefficient of performance	---
Tw_Out	Temperature of the effluent water flow	°C

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Q_in	in_1	Flow rate of wastewater effluent	---	m3/d
Tw_In	in_1	Temperature of the influent water flow	20	°C
deltaTw	in_1	Admissible temperature reduction due to heat extraction	5	°C
P_heat_rec	out_1	Recovered heat to district heating		kWh/d
T_dh_In	*in_2*	*Temperature of the district heating supply*	*75*	*°C*
T_dh_Out	*in_2*	*Temperature of district heating reflux*	*35*	*°C*

Energy.SolarPV_Simple

Instances

All

Description

The model estimates the daily energy output of a photovoltaic (PV) solar panel system, as:

$$P_{pv} = \frac{\epsilon_{\mathrm{pv}} \cdot \mathrm{A}_{\mathrm{pv}} \cdot \mathrm{I0} \cdot 24}{1000}$$

where:

- P_{pv} is the daily energy output (kWh),
- ϵ_{pv} is the efficiency of the PV panels (-),
- A_{pv} is the surface area of the solar panels (m^2).
- I0 is the average solar irradiance (W/m^2).

Parameters

Name	Description	Value	Units
A_panels	Surface area of solar PV panels	2,000	m2
eta_PV	Efficiency of solar conversion to electric power	0.1	-

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
I0	*in_1*	*Solar radiation*	*20*	*W/m2*
P_SolarPV	out_1	Power generated by solar PV	---	kWh/d

Energy.Wind_Simple

Instances

All

Description

The model estimates the daily energy output of a wind turbine, as:

$$P_{wind} = \frac{1}{2} \cdot \rho_{air} \cdot \frac{\pi \cdot D_{rotor}^2}{4} \cdot \frac{v_{wind}^3 \cdot \epsilon_{\mathrm{pv}} \cdot 24}{1000}$$

and:

$$v_{wind} = v_0 \cdot 8.46^{k_R}$$

where:

- P_{wind} is the daily energy output from a wind turbine (kWh),
- ρ_{air} denotes the air density (g/m3)
- D_{rotor} is the diameter of the rotor blades (m)
- v_{wind} denotes the wind speed (m/s),
- ϵ_{wind} is the efficiency of the wind turbine (-),
- v_0 denotes the reference wind speed measured at 10 m from ground level (m/s)
- k_R is a roughness factor (-) which depends on specific atmospheric conditions, terrain, etc.

Parameters

Name	Description	Value	Units
D_rotor	Diameter of wind turbine rotor	100	m
Rho_air	Air density	1230	kg/m³
eta_Wind	Efficiency of wind to electric power conversion	0.5	-
k_R	Roughness factor	0.3	-

State Variables

Name	Description	Units
v_Wind	Average wind speed at rotor elevation from ground level	m/s

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Wind0	*in_1*	*Average wind speed at 10 m from ground level*	*2*	*m/s*
P_Wind	out_1	Power generated by wind turbine	-	kWh/d

EFFLUENT

There is no true effluent block in the WEST library, as it used to be the case in earlier versions.

An influent block represents an entry point for a treatment plant model and allows for the generation of a dynamic influent file. More importantly, it establishes an interface (termed, fractionation model) between a set of conventional measurements and the set of “wwtp” state components.

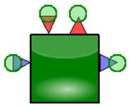
In the scope of an integrated (IUWS) model, the influent block is usually replaced by one or more catchment blocks (optionally followed by a number of sewer pipes), plus a connector which realises the interface between the sewer state vector upstream and the “wwtp” state components at the inlet of the treatment plant.
Similarly, at the outlet of the plant, an interface is needed to convert “wwtp” state components to river state components downstream.

However, if the effluent of a plant is not connected to any other model downstream, a sensor block can be used instead of an effluent block: in reverse to an influent block, a multi-probe model recombines the set of “wwtp” state components into a set of conventional measurements, and is therefore equivalent to a true effluent block.

MISCELLANEA

	Palette Group	**Misc**
	Category	LoopBreakers
	Icon	loop_breaker

	Palette Group	**Misc**
	Category	LoopBreakers
	Icon	loop_breaker_data

	Palette Group	**Misc**
	Category	multiple categories
	Icon	connector

LoopBreakers.MainDiff

Instances

All

Description

The model introduces a small differential delay:

$$\frac{d}{dt}F(t) = -\frac{1}{\tau}\cdot\left(F(t) - I(t)\right)$$

where:

- $F(t)$ and $I(t)$ denote the mass flux through and the influx to the node [g/d]
- τ is the time constant [d]

It is to be used to ‘break’ algebraic loops e.g., on return flows, for *wwtp* type terminals.

Parameters

Name	Description	Value	Units
Tau	Implicit loop breaker time constant	0.0005	d

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Outflow vector	---	g/d

LoopBreakers.MainExplicit

Instances
All

Description
The model introduces a small explicit-implicit delay:

$$O(t) = I(t - dt)$$

where:

- $I(t)$ and $O(t)$ denote the mass influx to and outflux from the node [g/d]

It is to be used to ‘break’ algebraic loops e.g., on return flows, for *wwtp* type terminals.

Parameters
None

State Variables
None

Derived State Variables
None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow vector	---	g/d
Outflow	out_1	Outflow vector	---	g/d

LoopBreakers.SignalDiff

Instances

All

Description

The model introduces a small differential delay:

$$\frac{d}{dt}x(t) = -\frac{1}{\tau} \cdot \left(x(t) - I(t)\right)$$

where:

- $x(t)$ and $I(t)$ denote the data flux through and influx to the node
- τ is the time constant [d]

It is to be used to ‘break’ algebraic loops e.g., on return flows, for *data* type terminals.

Parameters

Name	Description	Value	Units
Tau	Implicit loop breaker time constant	0.0005	d

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
in_1	in_1	Inflow vector	---	g/d
out_1	out_1	Outflow vector	---	g/d

(ASM2dModMP).TinCarbonActive

Instances

IUWS4

Description

This is an interface from a WWTP type component vector (ASM2dModMP) to a component vector for activated carbon processes (CarbonActive).

Parameters

Name	Description	Value	Units
F_COD_DOC	Conversion factor of chemical oxygen demand (COD) to dissolve organic carbon (DOC)	3	---

State Variables

Name	Description	Units
DOC_tot	Total dissolved organic matter (DOC) concentration	g/m^3
Q_In	Influent flow rate	m^3/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow	---	g/d
Inflow	in_1	Inflow	---	g/d

(ASM2dModMP).ToutCarbonActive

Instances

IUWS4

Description

This is an interface from a component vector for activated carbon processes (CarbonActive) to a WWTP type component vector (ASM2dModMP).

Parameters

Name	Description	Value	Units
F_COD_DOC	Conversion factor of chemical oxygen demand (COD) to dissolve organic carbon (DOC)	3	---

State Variables

None

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Outflow	out_1	Outflow	---	g/d
Inflow	in_1	Inflow	---	g/d