

WEST Models Guide

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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
5	15/07/2025	Fifth version	2025
6	03/02/2026	Sixth version	2026
7	22/06/2026	Seventh version	2026-U1

New sections in the 7th version:

- Solvers
- SBR_A
- SBR_B
- SBR_C
- SBR_D
- Sludge Age calculator
- ASM2 – ADM1 transformers

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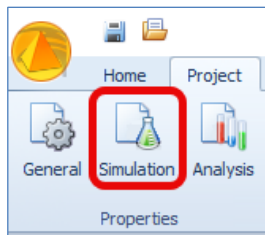
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Working with equation solvers

Last Updated: 22/06/2026



The choice of solvers and solver setting can greatly affect the performance of a model simulation, particularly with large complex models. The Solver settings are specified in the Simulation Properties pane which can be accessed through the Project menu.

There are no universal rules for choosing the best solver for a given model; it is a matter of trying out various options in a systematic way to find the one that works best.

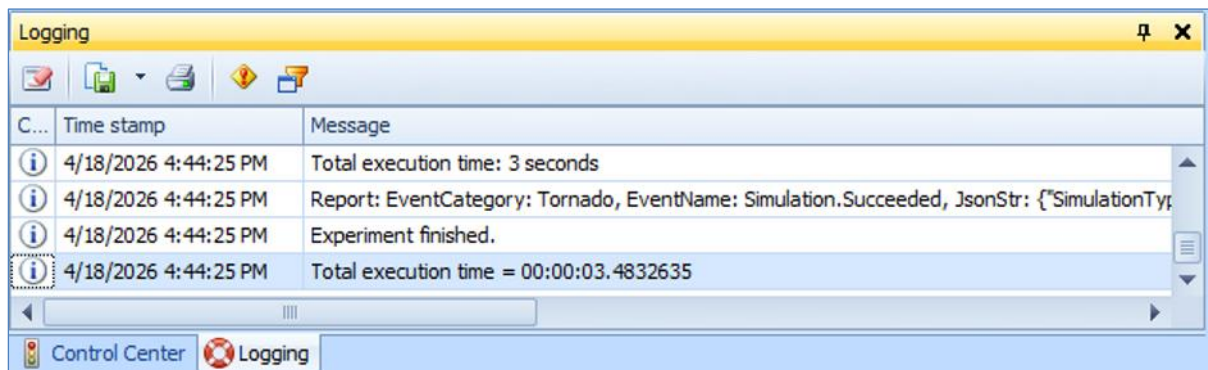
There are two main criteria for solver performance, simulation speed and accuracy; however, accuracy is usually hard to assess in the wastewater context, since there is usually so much uncertainty in the data that the model is being compared with. However, a common situation where accuracy is important is when a variable representing a physical quantity, such as mass or concentration, approaches zero. Insufficient accuracy can lead to the variable becoming negative, which is physically unrealistic.

The variable step-size solvers (RK4ASC and VODE) have parameters that control accuracy by determining the step size at any simulation time. The general idea is that derivatives are evaluated at several points within the time step, and the accuracy of the integration estimated from how much difference there is in derivative values across the interval. If this estimate is larger than the set tolerance, the step-size is reduced. This means that there is usually a trade-off between accuracy and simulation speed, although there are some notable exceptions where reducing the accuracy tolerance actually increases the simulation speed.

The majority of models involve multiple differential equations solved simultaneously: accuracy is related to the derivative that changes most over the time step. A system of simultaneous differential equations is considered “stiff” if some derivatives change very much faster than others do. These usually originate from very fast processes that also settle down very quickly, after which they no longer have much effect on the overall system. “Stiff” solvers have special provision for dealing with these rapid transients without slowing the simulation down excessively to follow them accurately. However, it can happen that the stiffness is due to a variable that oscillates very rapidly, and so does not settle down, in which case the stiff solver loses its advantage.

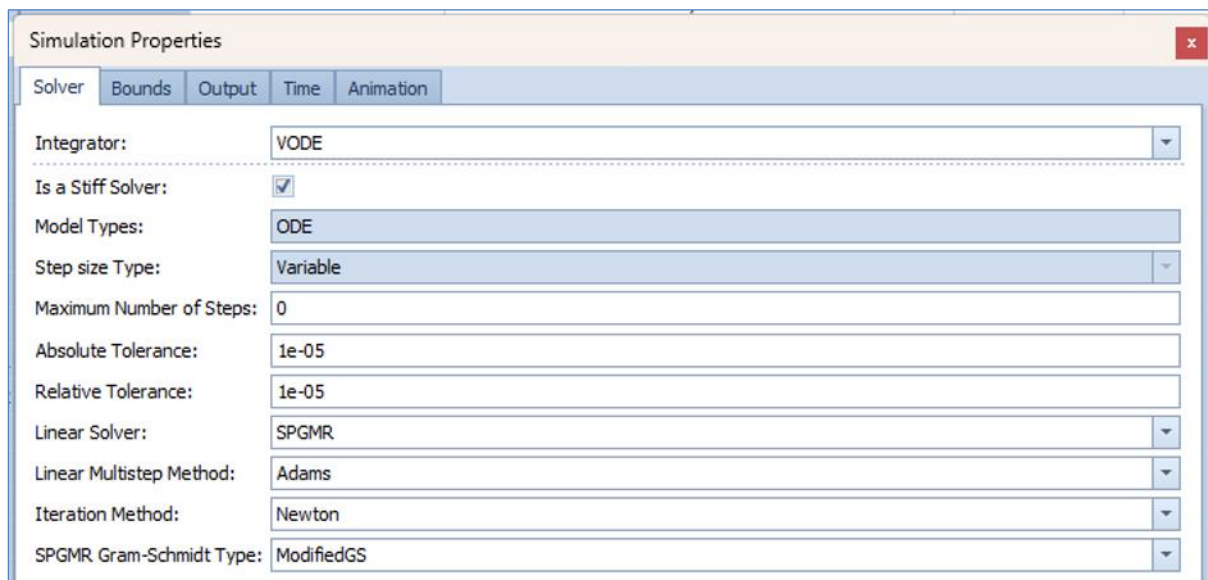
WEST provides four main options for choosing the solver: **Alg** (for models with no differential equations), **RK4** (4th order Runge-Kutta with fixed step size), **RK4ASC** (RK4 with automatic step-size control) and **VODE** (a stiff solver with several sub-options that control how the accuracy criteria are implemented).

WEST models are often at least moderately stiff, so the VODE solver often delivers the best simulation performance. The default settings that appear when VODE is selected are usually a good place to start. Searching for better settings is usually a matter of trial and error. The procedure is to set up a simulation from fixed initial values and a fixed run time and note the simulation time recorded in the Logging pane.



While different models may require different approaches, it is possible to provide a few guidelines based on experience with many models.

The VODE solver



Tolerances

Start by varying the tolerances. The solver accepts a step-size when the integration error falls below the relevant tolerance. The relative tolerance is relative to the magnitude of the variable, and is usually relevant. However, as a variable approaches zero, the absolute tolerance becomes relevant. The absolute and relative tolerance are almost always set to the same value – there is no experience with WEST of a case where it was advantageous to use different values.

The usual situation is that higher tolerances give faster simulations, but more chance of simulation failure as the accuracy decreases. A NAN (not-a-number) error is the usual motivation for tightening the tolerances. However, some models actually run faster with tighter tolerances (notably the biofilm models). This appears to be due to numerical instabilities that cause oscillations in the solution, and tighter tolerances sometimes reduce the oscillations. In searching for an optimum setting, be willing to try apparently extreme values (such as 1e-9).

Linear Solvers

In the process of finding a step-size that satisfies the accuracy criteria, the VODE solver has to solve a set of non-linear algebraic equations. This is achieved iteratively by linearizing the equations and applying a linear equation solver. WEST provides four options for the linear solver: SPGMR, Dense, Band and Diag. SPGMR is usually the best choice for simulation speed; however, the others may be

tried in cases where numerical instability causes simulations to crash. There are no clear guidelines of which one to use when SPGMR is not working well.

Linear Multistep Method

This refers to the formula used to calculate the integrals of variables over the time-step interval from derivatives evaluated at points within the interval. The BDF method is for stiff systems; however, it is difficult to determine whether a system is stiff other than by trying the solver option.

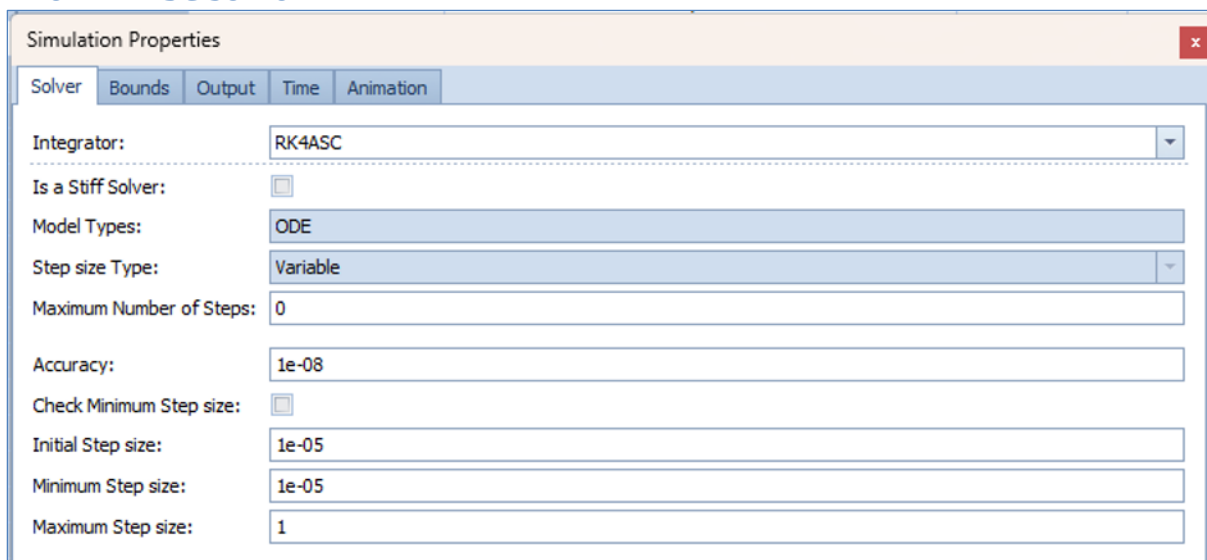
Iteration Method

This refers to the method used to move to the next iteration of the linear solver from previous results of the linear solver.

SPGMR Gram-Schmidt type

This refers to certain matrix calculations in the SPGMR solver. The ModifiedGS type handles round-off errors better than the ClassicalGS.

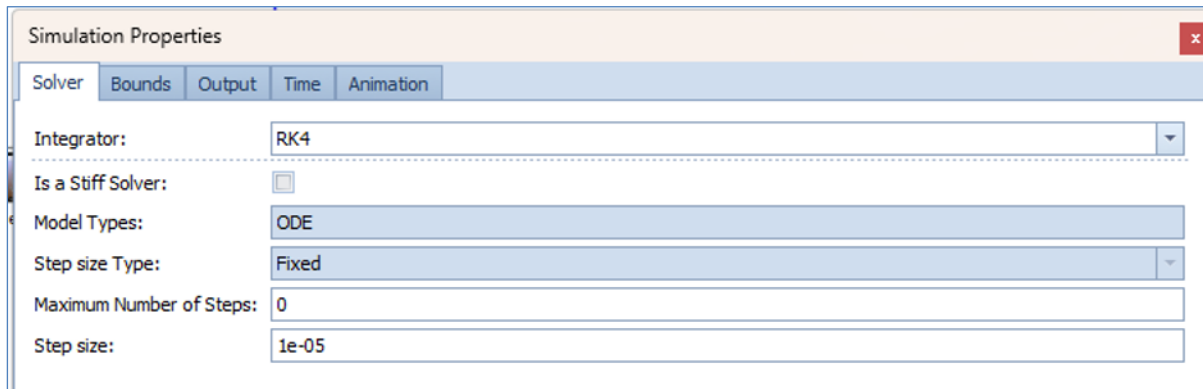
The RK4ASC solver



Simulation Properties	
Solver	
Integrator:	RK4ASC
Is a Stiff Solver:	☐
Model Types:	ODE
Step size Type:	Variable
Maximum Number of Steps:	0
Accuracy:	1e-08
Check Minimum Step size:	☐
Initial Step size:	1e-05
Minimum Step size:	1e-05
Maximum Step size:	1

The 4th order Runge-Kutta with automatic step-size control is WEST's default solver. It usually delivers slower simulations than VODE. Because the fastest changing derivative controls the step-size, it will be very slow for stiff systems. It is likely to be more accurate than VODE, but, as was mentioned, accuracy may not be the main concern in a wastewater treatment model (except where inaccuracy causes simulations to crash). A slow simulation can be overcome by setting the minimum step-size parameter and checking the "Check minimum step-size" box, but this is at the expense of accuracy for the stiff variables, which can sometimes lead to simulation crashes. There is also a maximum step-size setting, which can be important for models that involve timed control actions (e.g. SBRs and models which use timers). For example, a model with a timed event may have very similar conditions before and after the event. If the solver tries a time step that takes it beyond the event, it might encounter derivatives that are close enough to satisfy the accuracy criterion, so that the solver misses the event entirely. The issue can be addressed by setting a maximum time step that is shorter than the event duration. There is no corresponding maximum time-step in VODE to solve this issue.

The RK4 solver



Simulation Properties

Solver Bounds Output Time Animation

Integrator: RK4

Is a Stiff Solver: ☐

Model Types: ODE

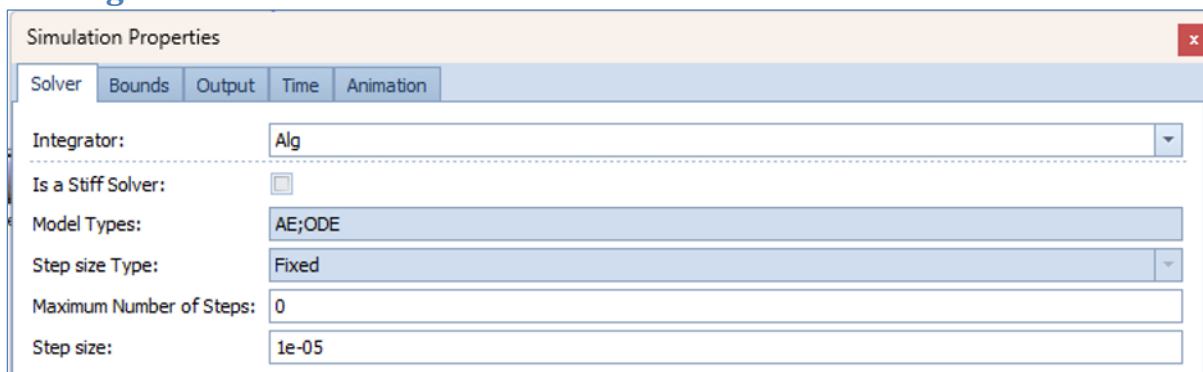
Step size Type: Fixed

Maximum Number of Steps: 0

Step size: 1e-05

This is essentially the same as RK4ASC with a fixed step-size set explicitly by the user.

The Alg solver



Simulation Properties

Solver Bounds Output Time Animation

Integrator: Alg

Is a Stiff Solver: ☐

Model Types: AE;ODE

Step size Type: Fixed

Maximum Number of Steps: 0

Step size: 1e-05

This does no integration at all, and is normally only useful for models that contain no differential equations. However, there is one special situation where it might be useful for a differential equation model.

It can happen that a simulation fails on a NAN error and the NAN value persists so that the simulation cannot be re-started – it immediately stops again with a NAN error. A trick that sometimes works to get the model running again is to do a short run with the Alg solver (which is not affected by NANs because it ignores derivatives). With luck, this will clear the NAN condition. Initialise the simulation to preserve the adjusted initial values and revert to the differential equation solver to continue.

ASM2dMod

Last Updated: 19/06/2026

The activated sludge unit models in this category are based on a modification (Gernaey and Jørgenson, 2004) of the ASM2d (*Activated Sludge Model No. 2d*, IAWQ) model published by the International Association on Water Quality (IAWQ) Task Group on Mathematical Modelling for Design and Operation of Biological Wastewater Treatment Processes. Gernaey and Jørgenson (2004) extended ASM2d to make the decay process rates electron acceptor-dependent.

Category

ASM2dMod

Conversion Model

Default

The biological components

The state variables that identify the components of the ASM2dMod model category (and constitute the **component vector**) are listed in the following table.

Name	Description	Units
Q	Water	m ³ /d
S_I	Inert soluble matter	g COD/m ³
S_O	Dissolved oxygen	g COD/m ³
S_N2	Nitrogen gas	g N/m ³
S_F	Fermentable, readily biodegradable organic matter	g COD/m ³
S_A	Fermentation products, considered to be acetate	g COD/m ³
S_NO	Nitrate (NO ₃ -N) and nitrite (NO ₂ -N) nitrogen	g N/m ³
S_PO	Inorganic soluble phosphorous, primarily ortho-phosphates	g P/m ³
S_NH	Ammonium nitrogen (NH ₄ -N)	g N/m ³
S_ALK	Alkalinity	Mol
X_I	Inert particulate matter	g COD/m ³
X_S	Slowly biodegradable matter	g COD/m ³
X_H	Heterotrophic organisms	g COD/m ³
X_PAO	Phosphorous accumulating organisms	g COD/m ³
X_PP	Poly-phosphate	g COD/m ³
X_PHA	Cell internal storage product of phosphorous accumulating organisms	g COD/m ³
X_AUT	Autotrophic biomass	g COD/m ³
X_TSS	Total Suspended Solids	g TSS/m ³
X_MEOH	Metal hydroxides	g COD/m ³
X_MEP	Metal phosphate	g COD/m ³

ASM2dMod is an extension of ASM2d and takes into account carbon removal, nitrification, denitrification and phosphorus removal.

In ASM2 several changes have been made compared to ASM1 so that phosphorus removal could be implemented. These implementations are still valid for ASM2d. Probably the biggest change is that the biomass is considered to have a cell internal structure.

Denitrifying capacity of phosphorus accumulating organisms has been implemented in ASM2d because experimental evidence is available that some of the phosphorus accumulating organisms can denitrify. ASM2d also includes poly-phosphates and the implementation of TSS.

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.

The readily biodegradable matter is divided into the fermentable, readily biodegradable organic matter **S_F** and the fermentation products **S_A**. For all stoichiometric computations, it is assumed that **S_A** exists only as acetate, where in reality there is a whole range of fermentation products. The slowly biodegradable organic matter **X_S** is assumed to be particulate. The inert soluble organic matter **S_I** cannot be further degraded in the treatment plants considered. The inert particulate organic matter **X_I** is also not degraded in the system.

Organic matter				
Soluble organic matter			Particulate organic matter	
Inert COD	Readily biodegradable matter		Inert COD	Slowly biodegradable
	Fermentable	Fermentation products		
S_I	S_F	S_A	X_I	X_S

The heterogeneity of the biomass is expressed by three kinds of organisms: nitrifying (autotrophic) **X_AUT**, heterotrophic **X_H** and phosphate-accumulating **X_PAO**.

The nitrifying organisms are obligate aerobes and are assumed to oxidise ammonium **S_NH** directly to nitrate **S_NO**.

The heterotrophic organisms are assumed to grow in anoxic as well as aerobic conditions and to be active in anaerobic conditions. Molecular nitrogen **S_N2** is assumed to be the only nitrogen species produced by denitrification (anoxic growth).

The concentration of the phosphate accumulating organisms does not include the internal storage products poly-phosphates **X_PP** and cell internal organic storage products **X_PHA**. However, the poly-phosphates are an inorganic fraction of the activated sludge expressed in terms of gP/m³; they are not expressed in terms of COD. The cell internal organic storage products include poly-hydroxy-alkanoates, glycogen, etc. The cell internal organic storage products 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 (C₄H₆O₂)_n.

Biomass				
Autotrophic organisms	Heterotrophic organisms	Phosphate accumulating organisms		
		Biomass	Cell internal storage products	
			Poly-phosphate	Organics
X_AUT	X_H	X_PAO	X_PP	X_PHA

For the modelling of phosphate removal, inorganic soluble phosphate **S_PO** is added. For the balance of the electrical charges, it is assumed that **S_PO** consists of 50% H₂PO₄⁻ and 50% HPO₄²⁻ independent of the pH.

Nutrients			
Inorganic nitrogen			Inorganic phosphate
Nitrogen gas	Nitrate	Ammonia	
S_NH	S_NO	S_NH	S_PO

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 $\text{Fe}(\text{OH})_3$ and FePO_4 .

Other components in the model are:

S_O: Dissolved oxygen may be subject to gas exchange.

S_ALK: Alkalinity is used in the model to approximate the continuity of the electrical charges. It is assumed to exist only as bicarbonate (HCO_3^-). It can give an early indication of low pH conditions.

X_TSS: Total suspended solids (TSS) allow for the inclusion of mineral particulates and poly-phosphate.

Conversion model

The processes modelled within the ASM2dMod model category are listed in the following table.

Name	Description
AerHydrol	Aerobic hydrolysis
AnHydrol	Anoxic hydrolysis
AnaerHydrol	Anaerobic hydrolysis
AerGrowthOnSf	Heterotrophic growth on fermentable, readily biodegradable matter
AerGrowthOnSa	Heterotrophic growth on fermentation products
AnGrowthOnSfDenitrif	Denitrification on fermentable, readily biodegradable matter
AnGrowthOnSaDenitrif	Denitrification on fermentation products
Fermentation	Fermentation
LysisOfHetero	Lysis of heterotrophic organisms
StorageOfXPHA	Storage of cell internal organic storage material
StorageOfXPP	Aerobic storage of poly-phosphate
AnStorageOfXPP	Anoxic storage of poly-phosphate
AerGrowthOnXPHA	Aerobic growth of phosphate accumulating organisms on cell internal organic storage material
AnGrowthOnXPHADenitrif	Anoxic growth of phosphate accumulating organisms on cell internal organic storage material
LysisOfXPAO	Lysis of phosphorus accumulating organisms
LysisOfXPP	Lysis of poly-phosphate
LysisOfXPHA	Lysis of cell internal organic storage material
GrowthOfAuto	Growth of autotrophic organisms
LysisOfAuto	Lysis of autotrophic organisms
Precipitation	Simultaneous precipitation of phosphorus
Redissolution	Simultaneous redissolution of phosphorus
Aeration	Aeration

Hydrolysis processes

Slowly biodegradable matter **X_S** is converted to fermentable, readily biodegradable matter **S_F** by means of external enzymatic processes. Only heterotrophic organisms **X_H** can catalyse hydrolysis. It is assumed that a small fraction **f_S_I** of inert soluble organic matter **S_I** is also released due to hydrolysis.

There is experimental evidence that the rate of hydrolysis depends on the available electron acceptors. Hydrolysis occurs in close contact between the slowly biodegradable matter and the heterotrophic organisms. Therefore, it is also assumed to be surface limited.

- Aerobic hydrolysis occurs when there is enough dissolved oxygen **S_O**.

- Anoxic hydrolysis occurs when there is little dissolved oxygen S_O and sufficient nitrates S_{NO} present. Anoxic hydrolysis is slower than aerobic hydrolysis and therefore the rate is reduced by a factor n_{NO_Hyd} .
- Anaerobic hydrolysis occurs when there is little dissolved oxygen S_O and nitrate S_{NO} . Anaerobic hydrolysis is slower than aerobic hydrolysis and therefore the rate is reduced by a factor n_{fe} .

The slowly biodegradable matter is assumed to contain a fixed fraction of nitrogen which is released during hydrolysis, so it is not necessary to include a separate hydrolysis process for the particulate organic nitrogen.

The Gujer matrix entries for the hydrolysis reactions are shown below. Monod and Inhibition terms are defined in the **State Variables** section. Temperature corrections of kinetic parameters are discussed in the **Temperature dependency** section.

P1: AerHydrol, P2: AnHydrol, P3: AnaerHydrol	
S_{ALK}	$\frac{1}{14} * \left(-(1 - f_{S_I}) * i_{N_{SF}} - f_{S_I} * i_{N_{S_I}} + i_{N_{XS}} \right) - \frac{1.5}{31} * \left(-(1 - f_{S_I}) * i_{P_{SF}} - f_{S_I} * i_{P_{S_I}} + i_{P_{XS}} \right)$
S_F	$1 - f_{S_I}$
S_{NH}	$-(1 - f_{S_I}) * i_{N_{SF}} - f_{S_I} * i_{N_{S_I}} + i_{N_{XS}}$
S_{PO}	$-(1 - f_{S_I}) * i_{P_{SF}} - f_{S_I} * i_{P_{S_I}} + i_{P_{XS}}$
X_S	-1
T_{SS}	$-i_{TSS_{XS}}$
Rate: P1	$k_{hTemp} * S_{OMonodTerm} * X_{SMonodTerm} * C_{XH}$
Rate: P2	$k_{hTemp} * n_{NOHyd} * S_{OInhibitionTerm} * S_{NOMonodTerm} * X_{SMonodTerm} * C_{XH}$
Rate: P3	$k_{hTemp} * n_{fe} * S_{OInhibitionTerm} * S_{NOInhibitionTerm} * X_{SMonodTerm} * C_{XH}$

Processes of heterotrophic organisms

Aerobic growth of heterotrophic organisms X_H on fermentable, readily biodegradable matter S_F and aerobic growth on fermentation products S_A are modelled as two parallel processes. Both have the same growth rate and yield coefficient.

P4: AerGrowthOnSf	
S_ALK	$-\frac{1}{14} * \left(-\frac{1}{Y_H} * i_{NSF} + i_{NBM}\right) + \frac{1.5}{31} * \left(-\frac{1}{Y_H} * i_{PSF} + i_{PBM}\right)$
S_F	$-\frac{1}{Y_H}$
S_NH	$-\left(-\frac{1}{Y_H} * i_{NSF} + i_{NBM}\right)$
S_O	$1 - \frac{1}{Y_H}$
S_PO	$-\left(-\frac{1}{Y_H} * i_{PSF} + i_{PBM}\right)$
X_H	1
T_SS	$i_{TSS_{BM}}$
Rate:	$\mu_{H_{Temp}} * S_{O_{MonodTerm}} * S_{F_{MonodTerm}} * \frac{C_{SF}}{C_{SF} + C_{SA}} * S_{NH_{MonodTerm}} * S_{PO_{MonodTerm}} * S_{ALK_{MonodTerm}} * C_{XH}$

P5: AerGrowthOnSa	
S_A	$-\frac{1}{Y_H}$
S_ALK	$-\frac{1}{14} * i_{NBM} + \frac{1.5}{31} * i_{PBM} + \frac{1}{64} * \frac{1}{Y_H}$
S_NH	$-i_{NBM}$
S_O	$1 - \frac{1}{Y_H}$
S_PO	$-i_{PBM}$
X_H	1
T_SS	$i_{TSS_{BM}}$
Rate:	$\mu_{H_{Temp}} * S_{O_{MonodTerm}} * S_{A_{MonodTerm}} * \frac{C_{SA}}{C_{SF} + C_{SA}} * S_{NH_{MonodTerm}} * S_{PO_{MonodTerm}} * S_{ALK_{MonodTerm}} * C_{XH}$

Anoxic growth of heterotrophic organisms **X_H** on fermentable, readily biodegradable matter **S_F** and on fermentation products **S_A** is modelled in the same way as aerobic growth except that the electron acceptor is nitrate **S_NO**. A correction factor **n_NO_Het** accounts for the fact that not all heterotrophic organisms **X_H** can grow on nitrate and based on the observation that anoxic growth is generally slower than aerobic growth. The assumption is made that all nitrate **S_NO** is reduced to molecular nitrogen **S_N2**.

P6: AnGrowthOnSfDenitrif	
S_ALK	$-\frac{1}{14} * \left(-\frac{1}{Y_H} * i_{NS_F} + i_{N_{BM}} \right) + \frac{1.5}{31} * \left(-\frac{1}{Y_H} * i_{P_{S_F}} + i_{P_{BM}} \right) + \frac{1}{14} * \frac{(1 - Y_H)}{2.86 * Y_H}$
S_F	$-\frac{1}{Y_H}$
S_N2	$\frac{(1 - Y_H)}{2.86 * Y_H}$
S_NH	$-\left(-\frac{1}{Y_H} * i_{NS_F} + i_{N_{BM}} \right)$
S_NO	$-\frac{(1 - Y_H)}{2.86 * Y_H}$
S_PO	$-\left(-\frac{1}{Y_H} * i_{P_{S_F}} + i_{P_{BM}} \right)$
X_H	1
T_SS	$i_{TSS_{BM}}$
Rate:	$\mu_{H_{Temp}} * n_{NO_{Het}} * S_{O_{InhibitionTermDenit}} * S_{NO_{MonodTerm}} * S_{F_{MonodTerm}} * \frac{C_{S_F}}{C_{S_F} + C_{S_A}} * S_{NH_{MonodTerm}} * S_{PO_{MonodTerm}} * S_{ALK_{MonodTerm}} * C_{X_H}$

P7: AnGrowthOnSaDenitrif	
S_A	$-\frac{1}{Y_H}$
S_ALK	$-\frac{1}{14} * i_{N_{BM}} + \frac{1.5}{31} * i_{P_{BM}} + \frac{1}{14} * \frac{(1 - Y_H)}{2.86 * Y_H} + \frac{1}{64} * \frac{1}{Y_H}$
S_N2	$\frac{(1 - Y_H)}{2.86 * Y_H}$
S_NH	$-i_{N_{BM}}$
S_NO	$-\frac{(1 - Y_H)}{2.86 * Y_H}$
S_PO	$-i_{P_{BM}}$
X_H	1
T_SS	$i_{TSS_{BM}}$
Rate:	$\mu_{H_{Temp}} * n_{NO_{Het}} * S_{O_{InhibitionTermDenit}} * S_{NO_{MonodTerm}} * S_{A_{MonodTerm}} * \frac{C_{S_A}}{C_{S_F} + C_{S_A}} * S_{NH_{MonodTerm}} * S_{PO_{MonodTerm}} * S_{ALK_{MonodTerm}} * C_{X_H}$

Under anaerobic conditions, heterotrophic organisms can transform the fermentable, readily biodegradable matter **S_F** to fermentation products **S_A**. Fermentation is modelled as a simple transformation process. Due to the fact that fermentation releases negatively charged components, alkalinity **S_ALK** is used to maintain electrical continuity.

P8: Fermentation	
S_A	1
S_ALK	$\frac{1}{14} * i_{N_{SF}} - \frac{1.5}{31} * i_{P_{SF}} - \frac{1}{64}$
S_F	-1
S_NH	$i_{N_{SF}}$
S_PO	$i_{P_{SF}}$
Rate:	$Q_{feTemp} * S_{O_{InhibitionTerm}} * S_{NO_{InhibitionTerm}} * \frac{C_{SF}}{K_{fe} + C_{SF}} * S_{ALK_{MonodTerm}} * C_{XH}$

The rate of lysis of heterotrophic organisms **X_H** depends on the electron acceptor and the rate expression includes a correction factor calculated from the dissolved oxygen and nitrate concentrations.

P9: LysisOfHetero	
S_ALK	$-\frac{1}{14} * (f_{X_I} * i_{N_{X_I}} + (1 - f_{X_I}) * i_{N_{X_S}} - i_{N_{BM}}) + \frac{1.5}{31} * (f_{X_I} * i_{P_{X_I}} + (1 - f_{X_I}) * i_{P_{X_S}} - i_{P_{BM}})$
S_NH	$-(f_{X_I} * i_{N_{X_I}} + (1 - f_{X_I}) * i_{N_{X_S}} - i_{N_{BM}})$
S_PO	$-(f_{X_I} * i_{P_{X_I}} + (1 - f_{X_I}) * i_{P_{X_S}} - i_{P_{BM}})$
X_H	-1
X_I	f_{X_I}
X_S	$1 - f_{X_I}$
T_SS	$-i_{TSS_{BM}} + f_{X_I} * i_{TSS_{X_I}} + (1 - f_{X_I}) * i_{TSS_{X_S}}$
Rate:	$b_{HTemp} * (S_{O_{MonodTerm}} + n_{NO_{Het_d}} * S_{O_{InhibitionTerm}} * S_{NO_{MonodTerm}} + n_{fed} * S_{O_{InhibitionTerm}} * S_{NO_{InhibitionTerm}}) * C_{XH}$

Ammonification is not modelled as a separate process in ASM2dMod because of the assumption that the fermentable, readily biodegradable matter **S_F** contains constant fractions of nitrogen and phosphorus which are released when it is consumed.

Processes of phosphate accumulating organisms

Some organisms, named phosphate accumulating organisms **X_PAO**, are known for their potential to accumulate phosphate. The phosphate is accumulated in the form of poly-phosphate **X_PP**.

In the original ASM2 model it was assumed that phosphate accumulating organisms could not denitrify. The denitrifying capacity of phosphate accumulating organisms has been implemented in ASM2d because experimental evidence is available that some of the phosphate accumulating organisms can denitrify. However, the importance of glycogen as cell internal organic storage material is not considered.

The phosphate accumulating organisms **X_PAO** use the energy, from the release of poly-phosphate **X_PP** in the form of phosphate **S_PO**, for storing external fermentation products **S_A** in the form of cell internal storage material **X_PHA**. Although it was initially thought to proceed only under anaerobic conditions, PHA storage has also been observed in anoxic and aerobic conditions. Therefore, the model does not contain inhibition terms for the lack of oxygen **S_O** and the presence of nitrate **S_NO**.

P10: StorageOfXPHA	
S_A	-1
S_ALK	$-\frac{1.5}{31} * Y_{PO} + \frac{1}{64} + \frac{1}{31} * Y_{PO}$
S_PO	Y_{PO}
X_PHA	1
X_PP	$-Y_{PO}$
T_SS	$-Y_{PO} * 3.23 + 0.6$
Rate:	$Q_{PHA_{Temp}} * S_{AMonodTerm} * S_{ALKMonodTerm} * \frac{C_{XPP}}{K_{PP} + \frac{C_{XPP}}{C_{XPAO}}}$

Aerobic and anoxic storage of phosphate **S_PO** in the form of poly-phosphate **X_PP** requires the phosphate accumulating organisms **X_PAO** to obtain energy. The energy can be obtained from the oxidation of cell internal organic storage material **X_PHA**. When the phosphate content of the phosphate accumulating organisms **X_PAO** becomes too high the storage of phosphate **S_PO** tends to stop. This is modelled by specifying a maximum ratio of **X_PP** to **X_PAO**, **K_MAX**.

P11: AerStorageOfXPP	
S_ALK	$\frac{1.5}{31} - \frac{1}{31}$
S_O	$-Y_{PHA}$
S_PO	-1
X_PHA	$-Y_{PHA}$
X_PP	1
T_SS	$3.23 - Y_{PHA} * 0.6$
Rate:	$r_{AerStorageOfXPP}$ $= Q_{PP_{Temp}} * S_{OMonodTerm} * \frac{C_{SPO}}{K_{PS} + C_{SPO}} * S_{ALKMonodTerm}$ $* X_{PHAMonodTerm} * \frac{\left(K_{MAX} - \frac{C_{XPP}}{C_{XPAO}}\right)}{\left(K_{IPP} + K_{MAX} - \frac{C_{XPP}}{C_{XPAO}}\right)} * C_{XPAO}$

P12: AnStorageOfXPP	
S_ALK	$\frac{1.5}{31} + \frac{1}{14} * \frac{Y_{PHA}}{2.86} - \frac{1}{31}$
S_N2	$\frac{Y_{PHA}}{2.86}$
S_NO	$-\frac{Y_{PHA}}{2.86}$
S_PO	-1
X_PHA	$-Y_{PHA}$
X_PP	1
T_SS	$3.23 - Y_{PHA} * 0.6$
Rate:	$kinetics[AerStorageOfXPP] * n_{NO_{PAO}} * \frac{K_O}{C_{SO}} * S_{NO_{MonodTerm}}$

In aerobic and anoxic conditions, the phosphate accumulating organisms **X_PAO** are assumed to grow only on cell internal organic storage products **X_PHA**. While PAOs can grow on VFAs, in practice they are outcompeted by heterotrophs under anoxic and aerobic conditions, therefore growth on **S_A** can be neglected

P13: AerGrowthOnXPHA	
S_ALK	$-\frac{1}{14} * i_{N_{BM}} + \frac{1.5}{31} * i_{P_{BM}}$
S_NH	$-i_{N_{BM}}$
S_O	$1 - \frac{1}{Y_{PAO}}$
S_PO	$-i_{P_{BM}}$
X_PAO	1
X_PHA	$-\frac{1}{Y_{PAO}}$
T_SS	$i_{TSS_{BM}} - \frac{1}{Y_{PAO}} * 0.6$
Rate:	$\mu_{PAO_{Temp}} * S_{O_{MonodTerm}} * X_{PHA_{MonodTerm}} * S_{NH_{MonodTerm}} * S_{PO_{MonodTerm}} * S_{ALK_{MonodTerm}} * C_{X_{PAO}}$

P14: AnGrowthOnXPHADenitrif	
S_ALK	$-\frac{1}{14} * i_{N_{BM}} + \frac{1.5}{31} * i_{P_{BM}} + \frac{1}{14} * \frac{(1 - Y_{PAO})}{2.86 * Y_{PAO}}$
S_N2	$\frac{(1 - Y_{PAO})}{2.86 * Y_{PAO}}$
S_NH	$-i_{N_{BM}}$
S_NO	$-\frac{(1 - Y_{PAO})}{2.86 * Y_{PAO}}$
S_PO	$-i_{P_{BM}}$
X_PAO	1
X_PHA	$-\frac{1}{Y_{PAO}}$
T_SS	$i_{TSS_{BM}} - \frac{1}{Y_{PAO}} * 0.6$
Rate:	$kinetics[AerGrowthOnXPHA] * n_{NO_{PAO}} * \frac{K_O}{C_{S_O}} * S_{NO_{MonodTerm}}$

Death, endogenous respiration and maintenance, combined in lysis, result in the loss of the three fractions of the phosphate accumulating organisms (organisms **X_PAO**, poly-phosphate **X_PP** and cell internal organic storage products **X_PHA**). All three are modelled as a first order process relative to the component in consideration.

- Lysis of phosphate accumulating organisms **X_PAO**. They are assumed to decay to slowly biodegradable substrate **X_S**.
- Lysis of poly-phosphate **X_PP**. There is experimental evidence that the poly-phosphate **X_PP** decays faster than the other two components. This can be modelled by using an increased decay rate **b_PP**. Poly-phosphate **X_PP** is assumed to decay to phosphate **S_PO**.
- Lysis of cell internal organic storage products **X_PHA**, which are assumed to decay to fermentation products **S_A**.

The rate of lysis of **X_PAO**, **X_PHA** and **X_PP** depend on the electron acceptor and the rate expressions include correction factors calculated from the dissolved oxygen and nitrate concentrations.

P15: LysisOfXPAO	
S_ALK	$-\frac{1}{14} * (f_{X_I} * i_{N_{X_I}} + (1 - f_{X_I}) * i_{N_{X_S}} - i_{N_{BM}}) + \frac{1.5}{31} * (f_{X_I} * i_{P_{X_I}} + (1 - f_{X_I}) * i_{P_{X_S}} - i_{P_{BM}})$
S_NH	$-(f_{X_I} * i_{N_{X_I}} + (1 - f_{X_I}) * i_{N_{X_S}} - i_{N_{BM}})$
S_PO	$-(f_{X_I} * i_{P_{X_I}} + (1 - f_{X_I}) * i_{P_{X_S}} - i_{P_{BM}})$
X_I	f_{X_I}
X_PAO	-1
X_S	$1 - f_{X_I}$
T_SS	$-i_{TSS_{BM}} + f_{X_I} * i_{TSS_{X_I}} + (1 - f_{X_I}) * i_{TSS_{X_S}}$
Rate:	$b_{PAO_{Temp}} * (S_{O_{MonodTerm}} + n_{NO_{P_d}} * S_{O_{InhibitionTerm}} * S_{NO_{MonodTerm}} + n_{fed} * S_{O_{InhibitionTerm}} * S_{NO_{InhibitionTerm}}) * C_{X_{PAO}} * S_{ALK_{MonodTerm}}$

P16: LysisOfXPP	
S_ALK	$-\frac{1.5}{31} + \frac{1}{31}$
S_PO	1
X_PP	-1
T_SS	-3.23
Rate:	$b_{PP_{Temp}} * (S_{O_{MonodTerm}} + n_{NO_{P_d}} * S_{O_{InhibitionTerm}} * S_{NO_{MonodTerm}}) * C_{X_{PP}} * S_{ALK_{MonodTerm}}$

P17: LysisOfXPHA	
S_A	1
S_ALK	$-\frac{1}{64}$
X_PHA	-1
T_SS	-0.6
Rate:	$b_{PHA_{Temp}} * (S_{O_{MonodTerm}} + n_{NO_{P_d}} * S_{O_{InhibitionTerm}} * S_{NO_{MonodTerm}} + n_{fed} * S_{O_{InhibitionTerm}} * S_{NO_{InhibitionTerm}}) * C_{X_{PHA}} * S_{ALK_{MonodTerm}}$

Processes of autotrophic organisms

The intermediate component of nitrification, nitrite, is not included in the ASM2dMod model. It is assumed that ammonium **S_NH** is oxidised directly to nitrate **S_NO**.

Growth of autotrophic organisms only occurs under aerobic conditions. Nitrification results in nitrate **S_NO** and therefore the amount of alkalinity **S_ALK** is reduced in order to keep electrical continuity. Autotrophic organisms take up phosphate for growth.

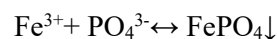
P18: GrowthOfAuto	
S_ALK	$-\frac{1}{14} * \left(i_{N_{BM}} + \frac{1}{Y_{AUT}} \right) - \frac{1}{14} * \frac{1}{Y_{AUT}}$
S_NH	$-i_{N_{BM}} - \frac{1}{Y_{AUT}}$
S_NO	$\frac{1}{Y_{AUT}}$
S_O	$\frac{(Y_{AUT} - 4.57)}{Y_{AUT}}$
S_PO	$-i_{P_{BM}}$
X_AUT	1
T_SS	$i_{TSS_{BM}}$
Rate:	$\mu_{AUT_{Temp}} * \frac{C_{SO}}{K_{O_{AUT}} + C_{SO}} * \frac{C_{SNH}}{K_{NH_{AUT}} + C_{SNH}} * S_{PO_{MonodTerm}} * \frac{C_{S_{ALK}}}{K_{ALK_{AUT}} + C_{S_{ALK}}} * C_{X_{AUT}}$

The rate of lysis of autotrophic organisms **X_AUT** depends on the electron acceptor and the rate expression includes a correction factor calculated from the dissolved oxygen and nitrate concentrations.

P19: LysisOfAuto	
S_ALK	$-\frac{1}{14} * \left(f_{X_I} * i_{N_{X_I}} + (1 - f_{X_I}) * i_{N_{X_S}} - i_{N_{BM}} \right) + \frac{1.5}{31} * \left(f_{X_I} * i_{P_{X_I}} + (1 - f_{X_I}) * i_{P_{X_S}} - i_{P_{BM}} \right)$
S_NH	$-\left(f_{X_I} * i_{N_{X_I}} + (1 - f_{X_I}) * i_{N_{X_S}} - i_{N_{BM}} \right)$
S_PO	$-\left(f_{X_I} * i_{P_{X_I}} + (1 - f_{X_I}) * i_{P_{X_S}} - i_{P_{BM}} \right)$
X_AUT	-1
X_I	f_{X_I}
X_S	$1 - f_{X_I}$
T_SS	$-i_{TSS_{BM}} + f_{X_I} * i_{TSS_{X_I}} + (1 - f_{X_I}) * i_{TSS_{X_S}}$
Rate:	$b_{AUT_{Temp}} * \left(S_{O_{MonodTerm}} + n_{NO_{AUT_d}} * S_{O_{InhibitionTerm}} * S_{NO_{MonodTerm}} + n_{Fe_d} * S_{O_{InhibitionTerm}} * S_{NO_{InhibitionTerm}} \right) * C_{X_{AUT}}$

Processes of chemical precipitation of phosphates

The assumption is made that the metal is iron and thus MeOH and MeP are respectively $Fe(OH)_3$ and $FePO_4$. Precipitation and redissolution are assumed to be reverse processes, which are in equilibrium at steady state according to:



- The presence of metals in the water in combination with high concentrations of phosphate may result in the chemical precipitation of the metal-phosphates.
- Redissolution of metal-phosphate MeP is also possible.

P20: Precipitation	
S_ALK	$\frac{1.5}{31}$
S_PO	-1
X_MeOH	-3.45
X_MeP	4.87
T_SS	1.42
Rate	$k_{PRE} * C_{SPO} * C_{X_{MEOH}}$

P21: Redissolution	
S_ALK	$-\frac{1.5}{31}$
S_PO	1
X_MeOH	3.45
X_MeP	-4.87
T_SS	-1.42
Rate	$k_{RED} * C_{X_{MEP}} * \frac{C_{S_{ALK}}}{K_{ALK_{AUT}} + C_{S_{ALK}}}$

Aeration

The change in oxygen concentration by means of aeration is summarized in the Gujer matrix as:

P22: Aeration	
S_O	1
Rate	$Kla_{Actual} * (S_{O_{Saturation}} - C_{S_O})$

Temperature dependency

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

$$S_{O_{Saturation}} = 14.65 - 0.41 * Temp_{Actual} + 0.00799 * (Temp_{Actual})^2 - 7.78 * 10^{-5} * (Temp_{Actual})^3$$

The temperature corrections for the maximum specific growth rates ($\mu_H, \mu_{AUT}, \mu_{PAO}$), rate constants for hydrolysis, fermentation and **X_PHA** and **X_PP** storage rates ($k_h, Q_{fe}, Q_{PHA}, Q_{PP}$), decay rates ($b_H, b_{AUT}, b_{PAO}, b_{PHA}, b_{PP}$), and the saturation coefficient for particulate substrate K_X are calculated using Arrhenius type expressions:

$$k_{i_{Temp}} = k_{i_{Temp_{Ref}}} * \theta_{k_i}^{(Temp_{Actual} - Temp_{Ref})}$$

where:

$k_{i_{Temp}}$ denotes the kinetic parameter at the actual temperature **Temp**

$Temp_{Ref}$ is the reference temperature (20°C); and

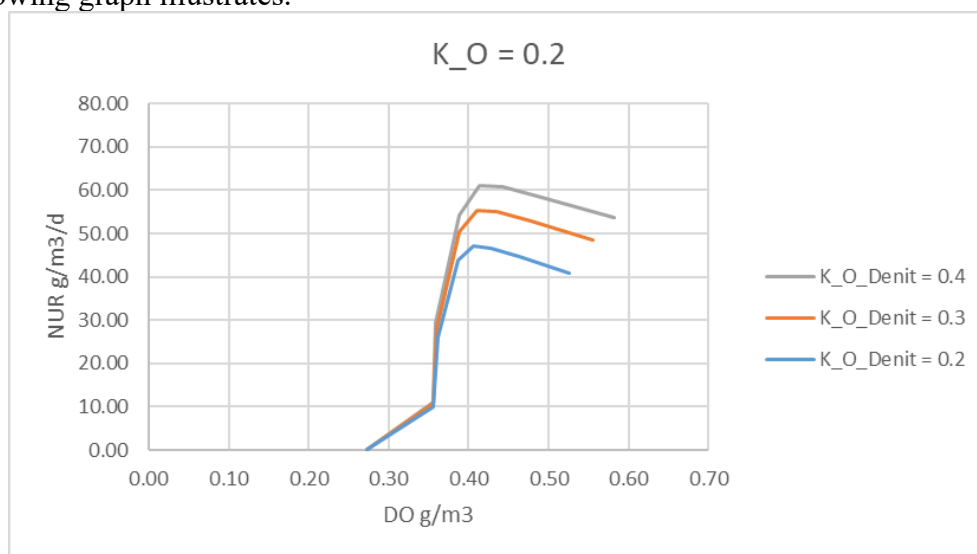
θ_{k_i} is the Arrhenius coefficient for parameter k_i

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. Denitrification 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 additional 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, the same **K_O** parameter 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**.

Parameters

The parameters defined for the ASM2dMod model category are listed in the following tables.

Group: Composition

Name	Description	Value	Units
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_I	Nitrogen content of inert soluble COD S_I	0.01	g N/g COD
i_N_X_I	Nitrogen content of inert particulate COD X_I	0.02	g N/g COD
i_N_X_S	Nitrogen content of particulate substrate X_S	0.04	g N/g COD
i_P_BM	Phosphorous content of biomass	0.02	g P/g COD
i_P_S_F	Phosphorous content of soluble substrate S_F	0.01	g P/g COD
i_P_S_I	Phosphorous content of inert soluble COD S_I	0.0	g P/g COD
i_P_X_I	Phosphorous content of inert particulate COD X_I	0.01	g P/g COD
i_P_X_S	Phosphorous content of particulate substrate X_S	0.01	g P/g COD
i_TSS_BM	TSS to biomass ratio for X_H, X_PAO, X_AUT	0.9	g TSS/g COD

Group: Conversion factors

Name	Description	Value	Units
F_BOD_COD	Conversion factor BOD/COD	0.65	---
i_COD_VSS	VSS to COD conversion	1.42	g COD/g VSS

Group: Stoichiometry

Name	Description	Value	Units
Y_H	Yield for heterotrophic biomass	0.625	g COD/g COD
Y_AUT	Yield for autotrophic biomass	0.24	g COD/g COD
Y_PAO	Yield for PAOs	0.625	g COD/g COD
Y_PHA	PHA requirement for PP storage	0.2	g COD/g COD
Y_PO	PP requirement (S_PO4 release) per PHA stored	0.4	g COD/g COD
f_S_I	Fraction of inert COD in particulate substrate	0.0	---
f_X_I	Fraction of inert COD generated in biomass lysis	0.1	---
i_TSS_X_I	TSS to X_I ratio	0.75	g TSS/g COD
i_TSS_X_S	TSS to X_S ratio	0.75	g TSS/g COD

Group: Kinetics

Name	Description	Value	Units
K_A	Saturation coeff for S_A (acetate)	4	g/m ³
K_ALK	Saturation coeff for alkalinity (HCO ₃ ⁻)	0.1	g/m ³
K_ALK_AUT	Saturation coeff of autotrophs for alkalinity	0.5	g/m ³
K_F	Saturation/inhibition coeff for growth on S_F	4	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_NH	Saturation coeff for ammonium (nutrient)	0.05	g/m ³
K_NH_AUT	Saturation coeff of autotrophs for ammonium	1	g/m ³
K_NO	Saturation/inhibition coeff fir nitrate	0.5	g/m ³
K_O	Saturation/inhibition coeff for oxygen	0.2	g/m ³
K_O_AUT	Saturation/inhibition coeff of autotrophs for oxygen	0.5	g/m ³
K_O_Denit	Saturation/inhibition coeff of denitrifiers for oxygen	0.2	g/m ³
K_P	Saturation coeff for phosphorus (nutrient)	0.01	g/m ³
K_PHA	Saturation coeff for PHA	0.01	g/m ³
K_PP	Saturation coeff for poly-phosphate	0.01	g/g
K_PS	Saturation coeff for phosphorus in PP storage	0.2	g/m ³
K_X	Saturation coeff for particulate COD	0.1	g/g
K_fe	Saturation coeff for fermentation on S_F	4	g/m ³
Q_PHA	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_AUT	Decay rate for autotrophic biomass	0.15	1/d
b_H	Rate constant for lysis and decay	0.4	1/d
b_PAO	Rate constant for lysis of X_PAO	0.2	1/d
b_PHA	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	1/d
mu_AUT	Maximum growth rate	1	1/d
mu_H	Maximum growth rate on substrate	6	1/d
mu_PAO	Maximum growth rate	1	1/d
n_NO_AUT_d	Anoxic reduction factor for decay of autotrophs	0.33	-
n_NO_Het	Reduction factor for denitrification	0.8	-
n_NO_Het_d	Anoxic reduction factor for decay of heterotrophs	0.5	-
n_NO_Hyd	Anoxic hydrolysis reduction factor	0.6	-
n_NO_PAO	Amount of PAO organisms active under anoxic conditions	0.6	-
n_NO_P_d	Anoxic reduction factor for decay of PAO, PP and PHA	0.33	-
n_fe	Anaerobic hydrolysis reduction factor	0.4	-
n_fe_d	Anaerobic reduction factor for decay	0	-

The default values are with reference to a temperature of 20°C (**Temp_Ref**).

Group: Temperature correction factors

Name	Description	Value	Units
Temp_Ref	Reference temperature	20	-
theta_K_X	Temperature correction factor for K_X	0.896	-
theta_Q_PHA	Temperature correction factor for Q_PHA	1.041	-
theta_Q_PP	Temperature correction factor for Q_PP	1.041	-
theta_Q_fe	Temperature correction factor for Q_fe	1.072	-
theta_b_AUT	Temperature correction factor for b_AUT	1.116	-
theta_b_H	Temperature correction factor for b_H	1.072	-
theta_b_PAO	Temperature correction factor for b_PAO	1.072	-
theta_b_PHA	Temperature correction factor for b_PHA	1.072	-
theta_b_PP	Temperature correction factor for b_PP	1.072	-
theta_k_h	Temperature correction factor for k_h	1.041	-
theta_mu_AUT	Temperature correction factor for mu_AUT	1.111	-
theta_mu_H	Temperature correction factor for mu_H	1.072	-
theta_mu_PAO	Temperature correction factor for mu_PAO	1.041	-

State Variables

Algebraic variables

Name	Description	Value
Is_React	Conversion processes on(1) / off(0)	1

Group: Kinetic

Name	Description	Units
K_X_Temp	K_X at the system temperature	---
Q_PHA_Temp	Q_PHA at the system temperature	---
Q_PP_Temp	Q_PP at the system temperature	---
Q_fe_Temp	Q_fe at the system temperature	---
S_O_Saturation	Oxygen saturation concentration	g/m ³
b_AUT_Temp	b_AUT at the system temperature	---
b_H_Temp	b_H at the system temperature	---
b_PAO_Temp	b_PAO at the system temperature	---
b_PHA_Temp	b_PHA at the system temperature	---
b_PP_Temp	b_PP at the system temperature	---
k_h_Temp	k_h at the system temperature	---
mu_AUT_Temp	mu_A at the system temperature	---
mu_H_Temp	mu_H at the system temperature	---
mu_PAO_Temp	mu_PAO at the system temperature	---
r_AerStorageofXPP	Rate of aerobic storage of X_PP	1/d

Group: Inhibition Terms

Name/Description	Expression
S_NO_InhibitionTerm The inhibition term for S_NO	$= \frac{K_{NO}}{C_{SNO} + K_{NO}}$
S_O_InhibitionTerm The inhibition term for oxygen	$= \frac{K_O}{C_{SO} + K_O}$
S_O_InhibitionTermDenit The denitrification inhibition term for oxygen	$= \frac{K_O}{C_{SO} + K_{O_{Denit}}}$

Group: Monod Terms

Name/Description	Expression
S_ALK_MonodTerm Monod terms for alkalinity	$= \frac{C_{SALK}}{C_{SALK} + K_{ALK}}$
S_A_MonodTerm Monod terms for S_A	$= \frac{C_{SA}}{C_{SA} + K_A}$
S_F_MonodTerm Monod terms for S_F	$= \frac{C_{SF}}{C_{SF} + K_F}$
S_NH_MonodTerm Monod terms for ammonium	$= \frac{C_{SNH}}{C_{SNH} + K_{NH}}$
S_NO_MonodTerm Monod terms for S_NO	$= \frac{C_{SNO}}{C_{SNO} + K_{NO}}$
S_O_MonodTerm Monod terms for oxygen	$= \frac{C_{SO}}{C_{SO} + K_O}$
S_PO_MonodTerm Monod terms for S_PO	$= \frac{C_{SPO}}{C_{SPO} + K_P}$
X_PHA_MonodTerm Monod terms for X_PHA	$= \frac{(C_{XPHA}/C_{XPAO})}{(C_{XPHA}/C_{XPAO}) + K_{PHA}}$
X_S_MonodTerm Monod terms for X_S	$= \frac{(C_{XS}/C_{XH})}{(C_{XS}/C_{XH}) + K_X}$

Group: Operation

Name	Description	Units
Kla_Actual	The actual Kla in the system	---
M_O2	Mass of oxygen per unit volume of air	---
Temp_Actual	Actual temperature	---

Derived Variables

Group: Masses

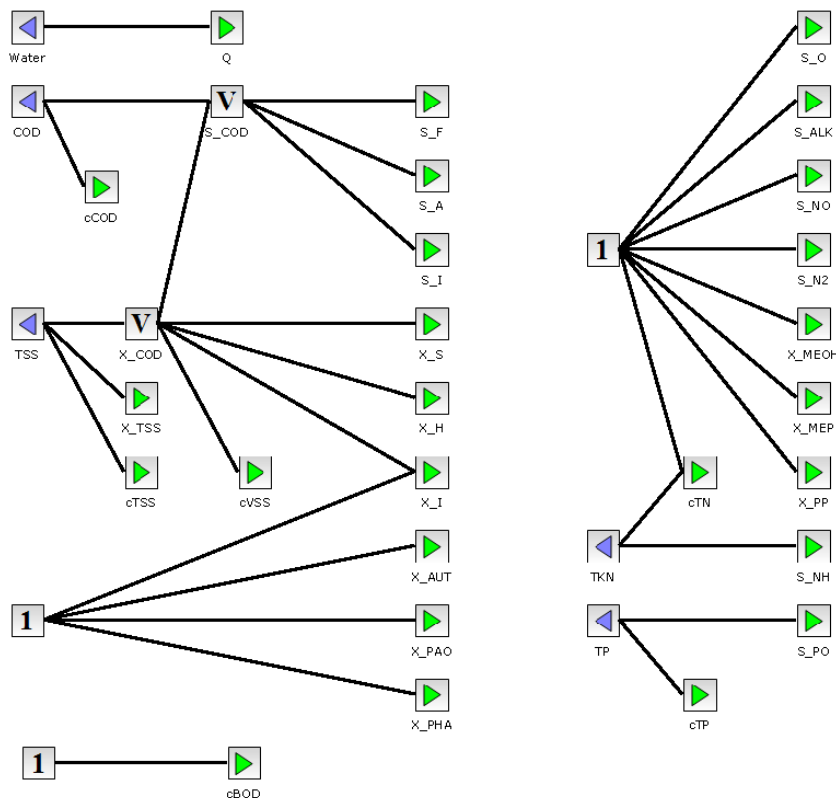
Name	Description	Units
M	Mass vector	g

Interface Variables

Name	Terminal	Description	Value	Units
Lanes	in_2	Number of lanes in parallel lane models	1	-
AUR	out_2	Ammonium Uptake Rate	---	g/m ³ /d
DO	out_2	Dissolved oxygen concentration	---	g/m ³
Kla_ASU	out_2	Kla	---	1/d
NH4	out_2	Ammonium concentration	---	g/m ³
NO3	out_2	Nitrate+Nitrite concentration	---	g/m ³
NPR	out_2	Nitrate Production Rate	---	g/m ³ /d
NUR	out_2	Nitrate Uptake Rate	---	g/m ³ /d
OUR_ASU	out_2	Oxygen Uptake Rate	---	g/m ³ /d
OfflineBOD	out_2	Biological Oxygen Demand	---	g/m ³
OfflineTKN	out_2	Total Kjeldal nitrogen concentration	---	g/m ³
OnlineCOD	out_2	Chemical Oxygen Demand	---	g/m ³
OnlineTN	out_2	Total nitrogen concentration	---	g/m ³
OnlineTP	out_2	Total phosphorous concentration	---	g/m ³
PO4	out_2	Phosphate concentration	---	g/m ³
PUR	out_2	Phosphate Uptake Rate	---	g/m ³ /d
TSS	out_2	Total suspended solids concentration	---	g/m ³
V_ASU	out_2	Volume	---	m ³

The Fractionation Model

The fractionation model is used to convert influent measurements to model components. The default fractionation model for ASM2dMod is illustrated below.



$$X_{COD} = f_{TSS_{COD}} \cdot TSS$$

$$X_{TSS} = TSS$$

$$\begin{aligned}
S_{COD} &= COD - X_{COD} \\
S_F &= f_{S_F} \cdot S_{COD} \\
S_A &= f_{S_A} \cdot S_{COD} \\
S_I &= (1 - f_{S_F} - f_{S_A}) \cdot S_{COD} \\
X_S &= f_{X_S} \cdot X_{COD} \\
X_H &= f_{X_H} \cdot X_{COD} \\
X_{PHA} &= X_{PHAIn} \\
X_{PAO} &= X_{PAOIn} \\
X_{AUT} &= X_{AUTIn} \\
X_I &= (1 - f_{X_S} - f_{X_H}) \cdot X_{COD} - X_{PHAIn} - X_{PAOIn} - X_{AUTIn} \\
S_O &= S_{OIn} \\
S_{ALK} &= S_{ALKIn} \\
S_{NO} &= S_{NOIn} \\
S_{N2} &= S_{N2In} \\
X_{MEOH} &= X_{MEOHIn} \\
X_{MEP} &= X_{MEPIn} \\
X_{PP} &= X_{PPIn} \\
S_{NH} &= f_{S_{NH}} \cdot TKN \\
S_{PO} &= f_{S_{PO}} \cdot TP \\
cCOD &= COD \\
cTSS &= TSS \\
cVSS &= \frac{X_{COD}}{i_{CODVSS}}
\end{aligned}$$

$$\begin{aligned}
cBOD &= F_{BODCOD} \cdot (S_{COD} \cdot (f_{S_F} + f_{S_A}) + f_{X_S} \cdot X_{COD} + X_{PHAIn} \\
&\quad + (1 - f_{X_I}) \cdot (X_{COD} \cdot f_{X_H} + X_{AUTIn} + X_{PAOIn}))
\end{aligned}$$

$$cTN = S_{NOIn} + TKN$$

$$cTP = TP$$

Parameters

Group: Fractionation

Name	Description	Value	Units
F_BOD_COD	Ratio of BOD to COD	0.65	gBOD/gCOD
F_TSS_COD	Ratio of TSS to COD	0.75	gTSS/gCOD
f_S_A	Soluble COD to SA ratio	0.25	---
f_S_F	Soluble COD to SF ratio	0.375	---
f_S_NH	Total nitrogen to ammonia ratio	0.6	---
f_S_PO	Total phosphorous to PO ratio	0.6	---
f_X_H	Particulate COD to XH ratio	0.17	---
f_X_I	Fraction of inert COD generated in biomass lysis	0.1	---
f_X_S	Particulate COD to XS ratio	0.69	---
i_COD_VSS	COD to VSS conversion	1.42	gVSS/gCOD

Group: Influent specs

Name	Description	Value	Units
S_alk_In	Alkalinity	30	---
S_N2_In	Nitrogen	0.01	g/m ³
S_NO_In	Nitrate	0.01	g/m ³
S_O_In	Oxygen	0.01	g/m ³
X_AUT_In	Autotrophic biomass	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_PAO_In	P-accumulating organisms	0.01	g/m ³
X_PHA_In	PHA	0.01	g/m ³
X_PP_In	Poly-phosphate	0.01	g/m ³

State Variables

Name	Description	Units
S_COD	Soluble COD	g/m ³
X_COD	Particulate COD	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
COD	---	Total COD	---	g/m ³
TKN	---	Total Kjeldahl Nitrogen	---	g/m ³
TP	---	Total phosphorous	---	g/m ³
Influent	---	ASM2dMod component vector	---	g/d

References

Gernay, K.V. and Jørgenson, S.B. (2004) Benchmarking combined biological phosphorous and nitrogen removal wastewater treatment processes. Control Engineering Practice 12:357-373
[https://doi.org/10.1016/S0967-0661\(03\)00080-7](https://doi.org/10.1016/S0967-0661(03)00080-7)

Henze, M., Gujer, W., Mino, T. and van Loosdrecht, M. (2006) Activated Sludge Models ASM1, ASM2, ASM2d and ASM3. IWA Publishing. <https://doi.org/10.2166/9781780402369>

ASM2dModNDHA

Last Updated: 22/06/2026

In ASM2dMod, nitrogen removal involves the aerobic oxidation of ammonia to nitrate by autotrophic nitrifying bacteria and the heterotrophic reduction of nitrate to N_2 under anoxic conditions. ASM2dModNDHA (Chrysochoidis et al 2024) is an extension of ASM2dMod based on the NDHA model of Domingo-Félez and Smets (2016, 2017, 2020) which was developed to predict the emissions of N_2O , a potent green house gas, from nitrifying activated sludge systems with diffused bubble aeration.

In WEST 2026 U1, ASM2dModNDHA has been further extended to include four step denitrification by DPAOs (Denitrifying Phosphate Accumulating Organisms), anoxic reduction factors for the heterotroph and PAO yields, and an anoxic adjustment factor for the PHA requirement for polyphosphate storage.

In the NDHA model, nitrification is split between ammonia oxidising bacteria (AOB) which oxidise ammonia to nitrite (NO_2^-) via hydroxylamine (NH_2OH) and nitrite oxidising bacteria (NOB) which oxidise nitrite to nitrate. Heterotrophic denitrification is split into four steps involving intermediate species NO_2^- , NO , N_2O and N_2 . In the NDHA model, N_2O is produced by the reduction of the intermediate species NO catalysed by NO reducing enzymes (NoR) produced by both autotrophic and heterotrophic bacteria. NO production occurs via three biological pathways as illustrated in Figure 1:

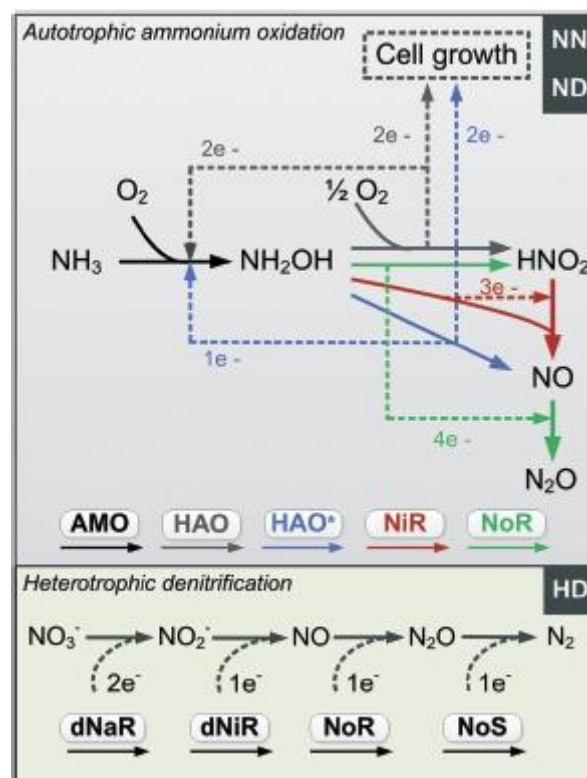


Figure 1. Biological pathways for N_2O production in the NDHA model (Domingo-Félez and Smets, 2016)

- Autotrophic nitrifier nitrification (NN): $NH_2OH \rightarrow NO$ (HAO* in Figure 1, **AerHAO** in ASM2dModNDHA)
- Autotrophic nitrifier denitrification (ND): $NH_2OH + 3HNO_2 \rightarrow 4NO$ (NiR in Figure 1, **AnoxANIR** in ASM2dModNDHA)

- c) Heterotrophic denitrification (HD): $\text{NO}_2^- \rightarrow \text{NO}$ (dNiR in Figure 1, **GrowthAnoxSa_NIR** and **GrowthAnoxSf_NIR** in ASM2dModNDHA)

The NN pathway is expected to be favoured under aerobic conditions while the ND pathway is favoured at low DO and high nitrite concentrations. However, due to the predominance of heterotrophs in activated sludge, the HD path can also be a significant source of N_2O emissions, particularly if there is insufficient readily biodegradable COD (**S_A** and **S_F**) to ensure complete denitrification to N_2 .

A detailed discussion of the mechanisms illustrated in Figure 1 can be found in Section S4 of the supplementary materials for Domingo-Félez et al. (2017).

Abiotic denitrification is assumed to be negligible at typical pH's for AS plants and is not included in the model.

Category

ASM2dModNDHA

Conversion Model

Default_Base

New components

Four nitrogen species have been added to the original ASM2dMod and the autotrophs **X_AUT** in ASM2dMod have been replaced by separate components for ammonia oxidising (AOB) and nitrite oxidising (NOB) bacteria.

Name	Description	Units
S_HNO2	Nitrite nitrogen	g N/m^3
S_NO	Nitric oxide	g N/m^3
S_N2O	Nitrous oxide	g N/m^3
S_NH2OH	Hydroxylamine	g N/m^3
X_AOB	Ammonia Oxidising Bacteria	g COD/m^3
X_NOB	Nitrite Oxidising Bacteria	g COD/m^3

Note that the component **S_HNO2** represents total nitrite nitrogen while free nitrous acid is represented by the state variable **S_FNA**.

The Conversion Model

ASM2dModNDHA also includes twenty-six new processes involving the nitrogen species, AOBs and NOBs. All rate constants have the same temperature dependency as in ASM2dMod. Expressions for other temperature dependent coefficients are provided in the discussion of the relevant processes. All Monod (MT) and Inhibition (IT) functions are defined in the **State Variables** section.

Processes involving AOBs

Name	Description
AerAMO	Ammonia oxidation by AOBs
AerHAO	Growth of AOB with oxidation of NH_2OH to NO
AerHAO2	Growth of AOB with oxidation of NH_2OH to HNO_2
AnoxANIR	Autotrophic production of NO
AnoxANOR	Autotrophic production of N_2O
LysisAOB	Lysis of AOBs

Processes involving NOBs

Name	Description
GrowthAerNOB	Aerobic growth of NOBs
LysisNOB	Lysis of NOBs

Heterotrophic denitrification

Anoxic denitrification by heterotrophs is divided into the four steps illustrated in Figure 1 each for growth on S_A and S_F.

Name	Description
GrowthAnoxSa_NAR	Anoxic growth on S_A with conversion S_NO3 to S_HNO2
GrowthAnoxSa_NIR	Anoxic growth on S_A with conversion S_HNO2 to S_NO
GrowthAnoxSa_NOR	Anoxic growth on S_A with conversion S_NO to S_N2O
GrowthAnoxSa_NOS	Anoxic growth on S_A with conversion S_N2O to S_N2
GrowthAnoxSf_NAR	Anoxic growth on S_F with conversion S_NO3 to S_HNO2
GrowthAnoxSf_NIR	Anoxic growth on S_F with conversion S_HNO2 to S_NO
GrowthAnoxSf_NOR	Anoxic growth on S_F with conversion S_NO to S_N2O
GrowthAnoxSf_NOS	Anoxic growth on S_F with conversion S_N2O to S_N2

The NDHA model of Domingo-Félez and Smets did not include phosphorous removal although the model was calibrated using sludge from the Lynetten plant in Copenhagen which does have biological phosphorous removal. Therefore, while PAOs were not included in the original NDHA model implementation, the original calibration may have been affected by their presence in the sludge.

DPAO denitrification

Anoxic denitrification by PAOs is divided into the same four steps as heterotrophs for growth on X_PHA and storage of X_PP.

Name	Description
GrowthAnoxXPHA_NAR	Anoxic growth on X_PHA with conversion S_NO3 to S_HNO2
GrowthAnoxXPHA_NIR	Anoxic growth on X_PHA with conversion S_HNO2 to S_NO
GrowthAnoxXPHA_NOR	Anoxic growth on X_PHA with conversion S_NO to S_N2O
GrowthAnoxXPHA_NOS	Anoxic growth on X_PHA with conversion S_N2O to S_N2
StorageAnoxXPP_NAR	Anoxic storage of X_PP with conversion S_NO3 to S_HNO2
StorageAnoxXPP_NIR	Anoxic storage of X_PP with conversion S_HNO2 to S_NO
StorageAnoxXPP_NOR	Anoxic storage of X_PP with conversion S_NO to S_N2O
StorageAnoxXPP_NOS	Anoxic storage of X_PP with conversion S_N2O to S_N2

Stripping

Stripping reactions for both NO and N₂O have been added.

Name	Description
StrippingNO	Stripping of nitric oxide
StrippingN2O	Stripping of nitrous oxide

Conversion model for AOBs

The conversion model for the AOBs consists of the five NN/ND processes illustrated in Figure 1 with some simplifications, plus AOB lysis. In the NDHA AOB model, only the HAO processes result in biomass growth. While the model treats all five reactions as independent processes, they are actually linked by the electrons shared between them as illustrated in Figure 1.

AerAMO	
S_O	$-\frac{1.14}{Y_{AOB}}$
S_NH	$-\frac{1}{Y_{AOB}}$
S_NH2OH	$\frac{1}{Y_{AOB}}$
S_Alk	$-\frac{1}{14 \cdot Y_{AOB}}$
Rate	$r_{AerAMO} = \mu_{AOB_{AMO_T}} * \frac{C_{S_O}}{C_{S_O} + K_{O_{AMO}}} IT_{AOB_{NH}} * IT_{AOB_{HNO_2}} * C_{X_{AOB}}$

The true substrate for the AMO enzyme is free ammonia (**S_FA**). **S_FA** is related to the total ammonia concentration by

$$S_{FA} = C_{S_{NH}} * \frac{10^{pH}}{Kb_{KW} + 10^{pH}}$$

Where Kb_{KW} is a function of temperature

$$Kb_{KW} = \exp\left(\frac{6344.0}{273.15 + Temp_{Actual}}\right)$$

S_FA is required as a substrate but is also inhibitory at high concentrations. This is expressed as a Haldene inhibition function.

$$IT_{AOB_{NH}} = \frac{S_{FA}}{S_{FA} + K_{NH_{AOB}} + \frac{(S_{FA})^2}{K_{AOB_{INH}}}}$$

Where $K_{NH_{AOB}}$ is the AOB saturation coefficient for S_{FA} and $K_{AOB_{INH}}$ is the inhibition coefficient.

AMO is also suppressed by high concentrations of free nitrous acid **S_FNA** calculated as

$$S_{FNA} = C_{S_{HNO_2}} * \frac{1}{1 + K_{ANO_2} * 10^{pH}}$$

where K_{ANO_2} is the temperature dependent dissociation constant of nitrous acid

$$K_{ANO_2} = \exp\left(\frac{2300.0}{273.15 + Temp_{Actual}}\right)$$

The inhibitory effect of FNA is expressed as a Monod inhibition function with inhibition coefficient $K_{AOB_{iHNO_2}}$.

$$IT_{AOB_{HNO_2}} = \frac{K_{AOB_{iHNO_2}}}{C_{S_{FNA}} + K_{AOB_{iHNO_2}}}$$

AerHAO	
S_NH	$-i_{N_{BM}}$
S_NH2OH	$-\frac{1}{Y_{AOB}}$
S_NO	$\frac{1}{Y_{AOB}}$
S_PO	$-i_{P_{BM}}$
S_Alk	$-\frac{1}{14}i_{N_{BM}} - \frac{1.5}{31}i_{P_{BM}}$
X_AOB	1
X_TSS	$i_{TSS_{BM}}$
Rate	$r_{AerHAO} = \mu_{AOB_{HAOTemp}} * \varepsilon_{HAO} * \frac{C_{SNH_2OH}}{C_{SNH_2OH} + K_{SNH_2OH}} MT_{AUT_{Alk}} * MT_{SPO} * MT_{SNH} * C_{X_{AOB}}$

AerHAO2	
S_O	$-\frac{(2.29 - Y_{AOB})}{Y_{AOB}}$
S_NH	$-i_{N_{BM}}$
S_NH2OH	$-\frac{1}{Y_{AOB}}$
S_HNO2	$\frac{1}{Y_{AOB}}$
S_PO	$-i_{P_{BM}}$
S_Alk	$-\frac{1}{14}i_{N_{BM}} + \frac{1.5}{31}i_{P_{BM}} - \frac{1}{14} \frac{1}{Y_{AOB}}$
X_AOB	1
X_TSS	$i_{TSS_{BM}}$
Rate	$r_{AerHAO2} = \mu_{AOB_{HAOTemp}} * (1 - \varepsilon_{HAO}) \frac{C_{SO}}{C_{SO} + K_{O_{HAO}}} * \frac{C_{SNH_2OH}}{C_{SNH_2OH} + K_{SNH_2OH}} * MT_{AUT_{Alk}} * MT_{SPO} * MT_{SNH} * C_{X_{AOB}}$

AnoxANIR	
S_NH2OH	$-\frac{1}{Y_{AOB}}$
S_HNO2	$-\frac{3}{Y_{AOB}}$
S_NO	$\frac{4}{Y_{AOB}}$
S_Alk	$\frac{3}{14} \frac{1}{Y_{AOB}}$
Rate	$r_{AnoxANIR} = \mu_{AOBH_{AO}Temp} * n_{AOBNIR} \frac{K_{O_{iAOB}}}{C_{SO} + K_{O_{iAOB}}} * \frac{C_{SNH_2OH}}{C_{SNH_2OH} + K_{SNH_2OH}} * MT_{AOBHNO_2} * MT_{AUTAlk} * C_{X_{AOB}}$

AnoxANOR	
S_NH2OH	$-\frac{1}{Y_{AOB}}$
S_NO	$-\frac{2}{Y_{AOB}}$
S_N2O	$\frac{3}{Y_{AOB}}$
S_Alk	$-\frac{1}{14} \frac{1}{Y_{AOB}}$
Rate	$r_{AnoxANOR} = \mu_{AOBH_{AO}Temp} * n_{AOBNOR} * \frac{C_{SNH_2OH}}{C_{SNH_2OH} + K_{SNH_2OH,ND}} * \frac{C_{SNO}}{K_{NO_{AOB}} + C_{SNO}} * MT_{AUTAlk} * C_{X_{AOB}}$

LysisAOB	
S_NH	$i_{NB_{BM}} - i_{NX_I} * f_{X_I} - i_{NX_S} * (1 - f_{X_I})$
S_PO	$i_{BM} - i_{PX_I} * f_{X_I} - i_{PX_S} * (1 - f_{X_I})$
S_Alk	$\frac{1}{14} (i_{NB_{BM}} - i_{NX_I} * f_{X_I} - i_{NX_S} * (1 - f_{X_I})) - \frac{1.5}{31} (i_{BM} - i_{PX_I} * f_{X_I} - i_{PX_S} * (1 - f_{X_I}))$
X_I	f_{X_I}
X_S	$(1 - f_{X_I})$
X_AOB	-1
X_TSS	$i_{TSS_{BM}} - i_{TSS_{X_I}} * f_{X_I} - i_{TSS_{X_S}} * (1 - f_{X_I})$
Rate	$r_{LysisAOB} = b_{AOBTemp} * \left(\frac{C_{SO}}{C_{SO} + K_{O_{AUT}}} + n_{NO_{AUT,d}} * \frac{K_{O_{AUT}}}{C_{SO} + K_{O_{AUT}}} * MT_{SNOx} + n_{fed} * \frac{K_{O_{AUT}}}{C_{SO} + K_{O_{AUT}}} * IT_{SNOx} \right) * C_{X_{AOB}}$

Conversion model for NOBs

GrowthAerNOB	
S_O	$-\frac{(1.14 - Y_{NOB})}{Y_{NOB}}$
S_NH	$-i_{N_{BM}}$
S_HNO2	$-\frac{1}{Y_{NOB}}$
S_NO3	$\frac{1}{Y_{NOB}}$
S_PO	$-i_{P_{BM}}$
S_Alk	$-\frac{1}{14}i_{N_{BM}} - \frac{1.5}{31}i_{P_{BM}} - \frac{1}{14}\frac{1}{Y_{AOB}}$
X_NOB	1
X_TSS	$i_{TSS_{BM}}$
Rate	$r_{AerGrowthNOB} = \mu_{NOB_{Temp}} * IT_{FNA_{10}} * IT_{FA_{10}} * MT_{NOB_O} * MT_{AUT_{Alk}} * MT_{SPO} * MT_{SNH} * C_{X_{NOB}}$

LysisNOB	
S_NH	$i_{N_{BM}} - i_{N_{X_I}} * f_{X_I} - i_{N_{X_S}} * (1 - f_{X_I})$
S_PO	$i_{BM} - i_{P_{X_I}} * f_{X_I} - i_{P_{X_S}} * (1 - f_{X_I})$
S_Alk	$\frac{1}{14}(i_{N_{BM}} - i_{N_{X_I}} * f_{X_I} - i_{N_{X_S}} * (1 - f_{X_I})) - \frac{1.5}{31}(i_{BM} - i_{P_{X_I}} * f_{X_I} - i_{P_{X_S}} * (1 - f_{X_I}))$
X_I	f_{X_I}
X_S	$(1 - f_{X_I})$
X_NOB	-1
X_TSS	$i_{TSS_{BM}} - i_{TSS_{X_I}} * f_{X_I} - i_{TSS_{X_S}} * (1 - f_{X_I})$
Rate	$r_{LysisNOB} = b_{NOB_{Temp}} * \left(\frac{C_{SO}}{C_{SO} + K_{O_{AUT}}} + n_{NO_{AUT,d}} * \frac{K_{O_{AUT}}}{C_{SO} + K_{O_{AUT}}} * MT_{SNOx} + n_{fed} * \frac{K_{O_{AUT}}}{C_{SO} + K_{O_{AUT}}} * IT_{SNOx} \right) * C_{X_{AOB}}$

Heterotrophic denitrification

Anoxic denitrification by heterotrophs is divided into four steps:

Nitrate reduction (NAR): $NO_3^- \rightarrow HNO_2$

Nitrite reduction(NIR): $HNO_2 \rightarrow NO$

Nirtic oxide reduction(NOR): $NO \rightarrow N_2O$

Nitrous oxide reduction (NOS): $N_2O \rightarrow N_2$

each for growth on S_F and S_A as shown below.

GrowthAnoxSf_NAR	
S_F	$-\frac{1}{Y_H}$
S_Alk	$\left(\frac{1}{14}\right) * \left(-\left(-\frac{1}{Y_H}\right) * i_{N_{SF}} + i_{N_{BM}}\right) - \left(\frac{1.5}{31}\right) * \left(-\left(-\frac{1}{Y_H}\right) * i_{P_{SF}} + i_{P_{BM}}\right)$
S_HNO2	$\frac{(1 - Y_H * n_Y)}{1.143 * Y_H * n_Y}$
S_NH	$-\left(-\frac{1}{Y_H}\right) * i_{N_{SF}} + i_{N_{BM}}$
S_NO3	$-\frac{(1 - Y_H * n_Y)}{1.143 * Y_H * n_Y}$
S_PO	$-\left(-\frac{1}{Y_H}\right) * i_{P_{SF}} + i_{P_{BM}}$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$n_{HD} * \mu_{HBNAR_{Temp}} * IT_{SO,NAR} * MT_{SF,NAR} * CT_{SFSA} * MT_{SNO3} * MT_{SAlk} * MT_{SPO} * MT_{SNH} * C_{XH}$

$CT_{SFSA} = \frac{C_{SF}}{C_{SA} + C_{SF}}$ is the ratio of fermentable to total soluble substrate.

GrowthAnoxSf_NIR	
S_F	$-\frac{1}{Y_H}$
S_Alk	1.05
S_HNO2	$\frac{-(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_NH	$-\left(-\frac{1}{Y_H}\right) * i_{N_{SF}} + i_{N_{BM}}$
S_NO	$\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_PO	$-\left(-\frac{1}{Y_H}\right) * i_{P_{SF}} + i_{P_{BM}}$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$n_{HD} * \mu_{HBNIR_{Temp}} * IT_{SO,NIR} * MT_{SF,NIR} * CT_{SFSA} * MT_{SAlk} * MT_{SNH} * MT_{SPO} * MT_{SHNO2} * IT_{SNO,NIR} * C_{XH}$

GrowthAnoxSf_NOR	
S_F	$-\frac{1}{Y_H}$
S_Alk	-0.004
S_N2O	$\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_NH	$-\left(\left(-\frac{1}{Y_H}\right) * i_{N_{SF}} + i_{N_{BM}}\right)$
S_NO	$\frac{-(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_PO	$-\left(\left(-\frac{1}{Y_H}\right) * i_{P_{SF}} + i_{P_{BM}}\right)$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$n_{HD} * \mu_{HB_{NOR_{Temp}}} * IT_{S_{O,NOR}} * MT_{S_{F,NOR}} * CT_{S_{FSA}} * MT_{S_{Alk}} * MT_{S_{NH}} * MT_{S_{PO}} * IT_{S_{NO,NOR}} * C_{X_H}$

GrowthAnoxSA_NOS	
S_F	$-\frac{1}{Y_H}$
S_Alk	-0.004
S_N2O	$\frac{-(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_NH	$-\left(\left(-\frac{1}{Y_H}\right) * i_{N_{SF}} + i_{N_{BM}}\right)$
S_N2	$\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_PO	$-\left(\left(-\frac{1}{Y_H}\right) * i_{P_{SF}} + i_{P_{BM}}\right)$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$pH_{corr} * n_{HD} * \mu_{HB_{NOS_{Temp}}} * IT_{S_{O,NOS}} * MT_{S_{F,NOS}} * CT_{S_{FSA}} * MT_{S_{Alk}} * MT_{S_{NH}} * MT_{S_{PO}} * MT_{S_{N2O}} * IT_{S_{NO,NOS}} * C_{X_H}$

The pH correction function pH_{corr} is given by

$$pH_{corr} = 0.5 * \left(1 + \cos \left(\frac{\pi}{\omega_{NOS_z}} * (pH - pH_{opt}) \right) \right)$$

based on an empirical function for the pH dependence of the maximum specific nitrification rate proposed by (Park et al., 2007).

GrowthAnoxSA_NAR	
S_A	$-\frac{1}{Y_H}$
S_Alk	1.6
S_HNO2	$\frac{(1 - Y_H * n_Y)}{1.143 * Y_H * n_Y}$
S_NH	$-i_{N_{BM}}$
S_NO3	$-\frac{(1 - Y_H * n_Y)}{1.143 * Y_H * n_Y}$
S_PO	$-i_{P_{BM}}$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$n_{HD} * \mu_{HBNA_{Temp}} * IT_{SO,NAR} * MT_{SA,NAR} * CT_{SASF} * MT_{SNO3} * MT_{SAlk} * MT_{SPO} * MT_{SNH} * C_{XH}$

$CT_{SASF} = \frac{C_{SA}}{C_{SA} + C_{SF}}$ is the ratio of acetate to total soluble substrate.

GrowthAnoxSA_NIR	
S_A	$-\frac{1}{Y_H}$
S_Alk	1.67
S_HNO2	$-\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_NH	$-i_{N_{BM}}$
S_NO	$\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_PO	$-i_{P_{BM}}$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$n_{HD} * \mu_{HBNIR_{Temp}} * IT_{SO,NIR} * MT_{SA,NIR} * CT_{SASF} * MT_{SAlk} * MT_{SNH} * MT_{SPO} * MT_{SHNO2} * IT_{SNO,NIR} * C_{XH}$

GrowthAnoxSA_NOR	
S_A	$-\frac{1}{Y_H}$
S_Alk	1.6
S_N2O	$\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_NH	$-i_{N_{BM}}$
S_NO	$\frac{-(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_PO	$-i_{P_{BM}}$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$n_{HD} * \mu_{HB_{NOR_{Temp}}} * IT_{SO,NOR} * MT_{SA,NOR} * CT_{SASF} * MT_{SAIk} * MT_{SNH} * MT_{SPO} * IT_{SNO,NOR} * C_{XH}$

GrowthAnoxSA_NOS	
S_A	$-\frac{1}{Y_H}$
S_Alk	1.6
S_N2O	$\frac{-(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_NH	$-i_{N_{BM}}$
S_N2	$\frac{(1 - Y_H * n_Y)}{0.571 * Y_H * n_Y}$
S_PO	$-i_{P_{BM}}$
X_H	1
X_TSS	$i_{TSS_{BM}}$
Rate	$pH_{corr} * n_{HD} * \mu_{HB_{NOS_{Temp}}} * IT_{SO,NOS} * MT_{SA,NOS} * CT_{SASF} * MT_{SAIk} * MT_{SNH} * MT_{SPO} * MT_{SN2O} * IT_{SNO,NOS} * C_{XH}$

DPAO denitrification

Anoxic growth and denitrification by DPAOs is divided into the same four steps as the heterotrophs. However, whereas the rates of the heterotrophic denitrification processes are expressed in terms of a single anoxic reduction factor n_{HD} and different values of $\mu_{HB_{NAR}}$, $\mu_{HB_{NIR}}$, etc, the DPAO rates are expressed in terms of a single μ_{PAO} and different reduction factors $n_{PAO_{NAR}}$, $n_{PAO_{NIR}}$, etc since the reaction rates are expressed in terms of the aerobic growth rate with correction factors.

GrowthAnoxXPHA_NAR	
S_ALK	$-\frac{1}{14} * i_{N_{BM}} + \frac{1.5}{31} * i_{P_{BM}}$
S_HNO2	$\frac{(1 - Y_{PAO} * n_{Y_{PAO}})}{1.143 * Y_{PAO} * n_{Y_{PAO}}}$
S_NH	$-i_{N_{BM}}$
S_NO3	$-\frac{(1 - Y_{PAO} * n_{Y_{PAO}})}{1.143 * Y_{PAO} * n_{Y_{PAO}}}$
S_PO	$-i_{P_{BM}}$
X_PAO	1
X_PHA	$-\frac{1}{Y_{PAO} * n_{Y_{PAO}}}$
T_SS	$i_{TSS_{BM}} - \frac{1}{Y_{PAO} * n_{Y_{PAO}}} * 0.6$
Rate:	$kinetics[GrowthAerXPHA] * n_{PAO_{NAR}} * \frac{K_{OP}}{C_{SO}} * MT_{SNO3P}$

GrowthAnoxXPHA_NIR	
S_ALK	$-\frac{1}{14} * i_{N_{BM}} + \frac{1.5}{31} * i_{P_{BM}} + \frac{1}{14} * \frac{(1 - Y_{PAO} * n_{Y_{PAO}})}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_HNO2	$-\frac{(1 - Y_{PAO} * n_{Y_{PAO}})}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_NH	$-i_{N_{BM}}$
S_NO	$\frac{(1 - Y_{PAO} * n_{Y_{PAO}})}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_PO	$-i_{P_{BM}}$
X_PAO	1
X_PHA	$-\frac{1}{Y_{PAO} * n_{Y_{PAO}}}$
T_SS	$i_{TSS_{BM}} - \frac{1}{Y_{PAO} * n_{Y_{PAO}}} * 0.6$
Rate:	$kinetics[GrowthAerXPHA] * n_{PAO_{NIR}} * \frac{K_{OP}}{C_{SO}} * MT_{SHNO2P} * IT_{SNO_{NIR,P}}$

GrowthAnoxXPHA_NOR	
S_ALK	$-\frac{1}{14} * i_{NBM} + \frac{1.5}{31} * i_{PBM}$
S_NH	$-i_{NBM}$
S_NO	$-\frac{(1 - Y_{PAO} * n_{YPAO})}{0.5715 * Y_{PAO} * n_{YPAO}}$
S_N2O	$\frac{(1 - Y_{PAO} * n_{YPAO})}{0.5715 * Y_{PAO} * n_{YPAO}}$
S_PO	$-i_{PBM}$
X_PAO	1
X_PHA	$-\frac{1}{Y_{PAO} * n_{YPAO}}$
T_SS	$i_{TSSBM} - \frac{1}{Y_{PAO} * n_{YPAO}} * 0.6$
Rate:	$kinetics[GrowthAerXPHA] * n_{PAONOR} * \frac{K_{OP}}{C_{SO}} * IT_{SNO_{NOR,P}}$

GrowthAnoxXPHA_NOS	
S_ALK	$-\frac{1}{14} * i_{NBM} + \frac{1.5}{31} * i_{PBM}$
S_NH	$-i_{NBM}$
S_N2	$\frac{(1 - Y_{PAO} * n_{YPAO})}{0.5715 * Y_{PAO} * n_{YPAO}}$
S_N2O	$-\frac{(1 - Y_{PAO} * n_{YPAO})}{0.5715 * Y_{PAO} * n_{YPAO}}$
S_PO	$-i_{PBM}$
X_PAO	1
X_PHA	$-\frac{1}{Y_{PAO} * n_{YPAO}}$
T_SS	$i_{TSSBM} - \frac{1}{Y_{PAO} * n_{YPAO}} * 0.6$
Rate:	$kinetics[GrowthAerXPHA] * n_{PAONOS} * \frac{K_{OP}}{C_{SO}} * MT_{SN2OP} * IT_{SNO_{NOS,P}}$

Polyphosphate storage under anoxic conditions is also divided into four steps as shown below. Note that while the parameter Y_{PHA} looks like a yield coefficient, it is actually the PHA requirement per gram of polyphosphate stored, which increases under anoxic conditions. Therefore, the adjustment factor $n_{YPHA} \geq 1$ and is grouped with the Stoichiometry parameters rather than the Reduction factors.

The ratios between the DPAO anoxic reduction factors (n_{PAONAR} , n_{PAONIR} , n_{PAONOR} and n_{PAONOS}) are based on the ratios of the specific growth rates (μ_{DPAO*}) at 20°C for Case II in Liu et al. (2015) while the NOx affinity parameters (K_{NO3P} , K_{HNO2P} , K_{NODP} and K_{N2OP}) are taken from Table S_3 in the same paper.

StorageAnoxXPP_NAR	
S_ALK	$\frac{1.5}{31} - \frac{1}{31}$
S_HNO2	$\frac{Y_{PHA} * n_{Y_{PHA}}}{1.143}$
S_NO3	$-\frac{Y_{PHA} * n_{Y_{PHA}}}{1.143}$
S_PO	-1
X_PHA	$-Y_{PHA} * n_{Y_{PHA}}$
X_PP	1
T_SS	$3.23 - Y_{PHA} * n_{Y_{PHA}} * 0.6$
Rate:	$Kinetics[StorageAerXPP] * n_{PAO_{NAR}} * \frac{K_{OP}}{C_{SO}} * MT_{S_{NO3P}}$

StorageAnoxXPP_NIR	
S_ALK	$\frac{1.5}{31} + \frac{1}{14} * \frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715} - \frac{1}{31}$
S_HNO2	$-\frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715}$
S_NO	$\frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715}$
S_PO	-1
X_PHA	$-Y_{PHA} * n_{Y_{PHA}}$
X_PP	1
T_SS	$3.23 - Y_{PHA} * n_{Y_{PHA}} * 0.6$
Rate:	$kinetics[StorageAerXPP] * n_{PAO_{NIR}} * \frac{K_{OP}}{C_{SO}} * MT_{S_{HNO2P}} * IT_{S_{NO_{NIR,P}}}$

StorageAnoxXPP_NOR	
S_ALK	$\frac{1.5}{31} - \frac{1}{31}$
S_N2O	$\frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715}$
S_NO	$-\frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715}$
S_PO	-1
X_PHA	$-Y_{PHA} * n_{Y_{PHA}}$
X_PP	1
T_SS	$3.23 - Y_{PHA} * n_{Y_{PHA}} * 0.6$
Rate:	$kinetics[StorageAerXPP] * n_{PAO_{NOR}} * \frac{K_{OP}}{C_{SO}} * IT_{S_{NO_{NOR,P}}}$

StorageAnoxXPP_NOS	
S_ALK	$\frac{1.5}{31} - \frac{1}{31}$
S_N2	$\frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715}$
S_N2O	$-\frac{Y_{PHA} * n_{Y_{PHA}}}{0.5715}$
S_PO	-1
X_PHA	$-Y_{PHA} * n_{Y_{PHA}}$
X_PP	1
T_SS	$3.23 - Y_{PHA} * n_{Y_{PHA}} * 0.6$
Rate:	$kinetics[StorageAerXPP] * n_{PAONOS} * \frac{K_{OP}}{C_{SO}} * MT_{SN2OP} * IT_{SNO_{NOS,P}}$

NO and N2O stripping

The equation for N₂O stripping is summarized below

StrippingN2O	
S_N2O	1
Rate	$-\frac{Q_{N2O_{gas}}}{V}$

$Q_{N2O_{gas}}$ is the flow of N₂O gas in g/d which is calculated using Mass Transfer Model 3 for diffused aeration in (Chrysochoidis et al., 2024)

$$Q_{N2O_{gas}} = KLa_{N2O_{mod}} * (C_{SN2O} - C_{SatN2O}) * V$$

C_{SatN2O} is the saturated concentration of N₂O given by

$$C_{SatN2O} = \frac{H_{N2O} * \left(P_{atm} + \frac{\rho_{H2O} * g * H_{tank}}{1000 * 2} \right)}{R_{Gas} * 10^3 * (Temp_{Actual} + 273.15)} * M_{N2O} * x_{i_{gas}}$$

where $R_{Gas} = 8.314 * 10^{-3}$ kJ/mol/K is the gas constant, $x_{i_{gas}}$ is the mol fraction of N₂O in the inlet gas (usually = 0) and $KLa_{N2O_{mod}}$ is the N₂O mass transfer coefficient modified to account for changes in the molar composition of air bubbles, changes in hydrostatic pressure and consequently also gas solubility as the bubbles rise to the surface of the reactor

$$KLa_{N2O_{mod}} = \frac{KLa_{N2O}}{\left(1 + \frac{KLa_{N2O} * V * H_{N2O} * \left(P_{atm} + \frac{\rho_{H2O} * g * H_{tank}}{1000 * 2} \right)}{2 * P_{atm} * Q_{air}} \right)}$$

KLa_{N2O} is the mass transfer coefficient for N₂O and depends on the oxygen mass transfer coefficient KLa_{Actual} .

For unaerated tanks ($KLa_{actual} = 0$) KLa_{N2O} is assigned a fixed value of $KLa_{N2O_{anox}}$.

If $KLa_{actual} > 0$ (aerated tanks) then

$$Kla_{N_2O} = Kla_{N_2O_{aer}} = help_{Kla_{Actual}} * \sqrt{\frac{10^{-9} * 2.718^{0.0294 * Temp_{Actual}}}{10^{-9} * 2.718^{0.0255 * Temp_{Actual}}}}$$

where the term in the square root is the ratio of the liquid phase diffusivities of N₂O and O₂ as a function of temperature and $help_{Kla_{Actual}}$ is Kla_{Actual} corrected for temperature using an Arrhenius type expression. (See **Temperature dependency** in ASM2dMod chapter).

Kla_{N_2O} should not be confused with kLa_{N_2O} which is used only in experimental set-ups where pure N₂O is bubbled through a reactor and should otherwise be set to 0.

Q_{air} is the air flow from the diffusers and can either be an output ($Q_{air_{mode}} = 0$: $Q_{air} = Q_{air_{calc}}$) calculated from the oxygen mass transfer coefficient or an input ($Q_{air_{mode}} = 1$: $Q_{air} = Q_{air_{inp}}$)

If the dissolved oxygen DO is less than saturation $S_{O_{saturation}}$ then

$$Q_{air_{calc}} = help_{Kla_{Actual}} * \frac{V * (S_{O_{saturation}} - DO)}{M_{O_2} * \left(\frac{OTE}{100}\right)}$$

M_{O_2} is the mass of oxygen per volume air given by

$$M_{O_2} = \frac{0.2085 * 32}{10^{-3} * R * \frac{(T_{air} + 273.15)}{101325}}$$

and the temperature dependency of $S_{O_{saturation}}$ is the same as in ASM2dMod.

For stripping of NO:

StrippingNO	
S_NO	1
Rate	$-\frac{Q_{NO_{gas}}}{V}$

$$Q_{NO_{gas}} = -Kla_{NO} * (C_{S_{NO,saturation}} - C_{S_{NO}}) * V$$

where Kla_{NO} is calculated from the ratio of the diffusivities of NO and N₂O

$$Kla_{NO} = Kla_{N_2O} * \sqrt{\frac{10^{-9} * 2.718^{0.023 * Temp_{Actual}}}{10^{-9} * 2.718^{0.0294 * Temp_{Actual}}}}$$

$$\text{And } S_{NO,saturation} = 3.2259 * 14 * 2.718^{-0.022 * Temp_{Actual}} * 40 * 10^{-9}$$

Pathway contributions and competition variables

ASM2dModNDHA is characterized by several competing pathways for the consumption of acetate and nitrogen species as well as the production of NO and N₂O. Several new state variables have been created to facilitate tracking the contribution of each pathway to the performance of system under varying conditions. Understanding the relative contribution of the different pathways to N₂O emissions is important for developing effective mitigation strategies.

As shown in Figure 1, N_2O is produced by the reduction of NO and there are several pathways for the production of NO . The relative contributions of the autotrophic nitrifier nitrification (NN) and nitrifier denitrification (ND) pathways are described by the state variables **NO_NN** and **ND_NN** (rates of NO production in gN/d), **r_NO_NN** and **r_NO_ND** (fractions of autotrophic N production for each pathway), **Q_NO_NN** and **Q_NO_ND** (flux of NO due to each pathway).

Competition variables are state variables which describe the fraction of different reactants consumed by different organism groups and processes. PAOs and OHOs compete for acetate (**VFA_PAO** and **VFA_OHO**) and nitrate (**NO3_PAO** and **NO3_OHO**). AOBs, NOBs, OHOs and PAOs compete for HNO_2 (**HNO2_AOB**, **HNO2_NOB**, **HNO2_OHO** and **HNO2_PAO**). NO is consumed by AOBs, OHOs and PAOs or removed by stripping (**NO_AOB**, **NO_OHO**, **NO_PAO** and **NO_Strip**). Finally, N_2O is consumed by OHOs and PAOs or removed by stripping (**N2O_OHO**, **N2O_PAO** and **N2O_Strip**).

Parameters

The NDHA model was originally calibrated using nitrifier enriched (Domingo-Félez et al., 2017) and activated sludge from the Lynetten plant in Copenhagen (Domingo-Félez and Smets, 2020). In WEST 2026, the calibration has been adjusted to agree more closely with overall N and P removal in the ASM2dMod model with default parameters. The parameters of the ASM2dModNDHA model and their default values are listed below:

Group: Composition

Name	Description	Value	Units
i_N_BM	Nitrogen content of biomass X_H, X_PAO, X_AUT	0.07	g/gCOD
i_N_S_F	Nitrogen content of soluble substrate S_F	0.03	g/gCOD
i_N_S_I	Nitrogen content of inert soluble COD S_I	0.01	g/gCOD
i_N_X_I	Nitrogen content of inert particulate COD X_I	0.02	g/gCOD
i_N_X_S	Nitrogen content of particulate substrate X_S	0.04	g/gCOD
i_P_BM	Phosphorus content of biomass X_H, X_PAO, X_AUT	0.02	g/gCOD
i_P_S_F	Phosphorus content of soluble substrate S_F	0.01	g/gCOD
i_P_S_I	Phosphorus content of inert soluble COD S_I	0	g/gCOD
i_P_X_I	Phosphorus content of inert particulate COD X_I	0.01	g/gCOD
i_P_X_S	Phosphorus content of particulate substrate X_S	0.01	g/gCOD
i_TSS_BM	TSS to biomass ratio for X_H, X_PAO, X_AUT	0.9	g/gCOD
i_TSS_X_I	TSS to X_I ratio	0.75	g/gCOD
i_TSS_X_S	TSS to X_S ratio	0.75	g/gCOD

Group: Conversion

Name	Description	Value	Units
F_BOD5_BOD20	Conversion BOD5/BOD20	0.66	---
F_BOD_COD	Conversion factor BOD/COD	0.65	---
F_BOD_COD_X	Conversion factor X_BOD/COD	0.65	---
i_COD_VSS	VSS content of other X_COD components	1.64	gCOD/gVS
i_COD_VSS_AOB	VSS content of AOBs	1.42	gCOD/gVS
i_COD_VSS_NOB	VSS content of NOBs	1.42	gCOD/gVS
i_COD_VSS_OHO	VSS content of OHOs	1.42	gCOD/gVS
i_COD_VSS_PAO	VSS content of PAOs	1.42	gCOD/gVS

Group: Dimensions

Name	Description	Value	Units
A_tank	Area of the tank (or lane)		
L_tank	Length of tank (or lane)	25	m
W_tank	Width of tank (or lane)	10	m

Note that although A_{tank} is listed as a parameter, it is calculated from the other tank dimensions (L_{tank} , W_{tank}) and cannot be modified directly by the user.

Note that in the case of Parallel_VolVar, the Dimensions parameters refer to one lane with volume $LaneVolume$. For this tank model, the user specified parameter H is the height of the tank under the weir. The user should check that $H_{tank} = H$ when all active lanes are full and check that the total calculated tank area $A = Lanes * A_{tank}$.

Group: Kinetics

Name	Description	Value	Units
K_A	Saturation coeff for S_A (acetate)	4	g/m ³
K_ALK	Saturation coeff for alkalinity (HCO ₃ ⁻)	0.1	
K_ALK_AUT	Saturation coeff of autotrophs for alkalinity	0.5	
K_ALK_NOB	Saturation coeff for alkalinity for NOB	0.5	
K_AOB_iHNO2	S_HNO ₂ inhibition constant for AOB	0.75	g/m ³
K_AOB_iNH	S_NH ₃ inhibition constant for AOB	10	g/m ³
K_A_NAR	Saturation/inhibition coeff for growth on S_A NAR	5	g/m ³
K_A_NIR	Saturation/inhibition coeff for growth on S_A NIR	4.3	g/m ³
K_A_NOR	Saturation/inhibition coeff for growth on S_A NOR	5.3	g/m ³
K_A_NOS	Saturation/inhibition coeff for growth on S_A NOS	4	g/m ³
K_F	Saturation/inhibition coeff for growth on S_F	4	g/m ³
K_FAi_NOB	Inhibition coeff for free ammonia for NOB	0.5	g/m ³
K_F_NAR	Saturation/inhibition coeff for growth on S_F NAR	5	g/m ³
K_F_NIR	Saturation/inhibition coeff for growth on S_F NIR	4.3	g/m ³
K_F_NOR	Saturation/inhibition coeff for growth on S_F NOR	5.3	g/m ³
K_F_NOS	Saturation/inhibition coeff for growth on S_F NOS	4	g/m ³
K_HNO2	Saturation/inhibition coeff for nitrite for HB	0.8	g/m ³
K_HNO2_AOB	Saturation coeff of AOB for nitrite	5e-5	g/m ³
K_HNO2_NOB	Saturation/inhibition coeff for nitrite for NOB	2.7e-5	g/m ³
K_HNO2_P	Saturation/inhibition coeff for nitrite for DPAOs	0.81	g/m ³
K_IPP	Inhibition coeff for X_PP storage	0.02	
K_MAX	Maximum ratio of X_PP/X_PAO	0.34	
K_N2O	Saturation/inhibition coeff for nitrous oxide HB	0.08	g/m ³
K_N2O_P	Saturation/inhibition coeff for nitrous oxide DPAO	0.0052	g/m ³
K_NH	Saturation coeff for ammonium (nutrient)	0.01	g/m ³
K_NH2OH	Saturation coeff of AOB for hydroxylamine	0.2	g/m ³
K_NH2OH_ND	Saturation coeff of AOB for hydroxylamine ND	0.2	g/m ³
K_NH_AOB	Saturation coeff of AOB for ammonium	0.00274	g/m ³

Name	Description	Value	Units
K_NO	Saturation/inhibition coeff for NO ₃ +NO ₃ decay	1	g/m ³
K_NO3	Saturation/inhibition coeff for nitrate HB	0.2	g/m ³
K_NO3_P	Saturation/Inhibition coeff for XPP storage	0.251	g/m ³
K_NOB_iHNO2	Inhibition coeff for HNO ₂ NOB	0.1	g/m ³
K_NO_AOB	Saturation coeff of AOB for nitric oxide	0.015	g/m ³
K_NO_iNIR	Inhibition coeff for NO NIR	0.5	g/m ³
K_NO_iNIR_P	Inhibition coeff for NO for DPAO NIR	0.5	g/m ³
K_NO_iNOR	Inhibition coeff for NO NOR	0.3	g/m ³
K_NO_iNOR_P	Inhibition coeff for NO for DPAO NOR	0.3	g/m ³
K_NO_iNOS	Inhibition coeff for NO NOS	0.075	g/m ³
K_NO_iNOS_P	Inhibition coeff for NO for DPAO NOS	0.075	g/m ³
K_NOd	Saturation/inhibition coeff for nitric oxide HB	0.02	g/m ³
K_NOd_P	Saturation/inhibition coeff for nitric oxide DPAO	0.0021	g/m ³
K_O	Saturation/inhibition coeff for oxygen HB	0.1	g/m ³
K_O_AMO	Saturation/inhibition coeff for oxygen for AMO	0.4	g/m ³
K_O_AUT	Saturation/inhibition coeff of autotrophs for oxygen	0.2	g/m ³
K_O_HAO	Saturation/inhibition coeff for oxygen for HAO	0.4	g/m ³
K_O_NOB	Saturation/inhibition coeff for oxygen for NOB	0.5	g/m ³
K_O_P	Saturation/inhibition coeff for oxygen PAO	0.1	g/m ³
K_O_Pdenit	Inhibition coeff for oxygen for denitrification by PAOs	0.1	g/m ³
K_O_iAOB	Inhibition coeff for oxygen for ND	0.1	g/m ³
K_O_iNAR	Inhibition coeff for oxygen in NAR	0.087	g/m ³
K_O_iNIR	Inhibition coeff for oxygen NIR	0.1	g/m ³
K_O_iNOR	Inhibition coeff for oxygen NOR	0.067	g/m ³
K_O_iNOS	Inhibition coeff for oxygen NOS	0.031	g/m ³
K_P	Saturation coeff for phosphorus (nutrient)	0.01	g/m ³
K_PHA	Saturation coeff for PHA	0.01	g/g
K_PP	Saturation coeff for poly-phosphate	0.01	g/g
K_PS	Saturation coeff for phosphorus in PP storage	0.2	
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_PHA	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
epsHAO	Reduction factor for HAO1	0.0031	
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	1/d
pH_opt	Optimum pH for sinusoidal correction factor	7.9	-
wNOS_z	Sinusoidal correction factor for pH dependence of NOS	2.2	

Group: Kinetics-Growth

Name	Description	Value	Units
mu_AOB_AMO	Maximum growth rate	1	---
mu_AOB_HAO	Maximum growth rate	1	---
mu_H	Maximum growth rate for OHOs	6	---
mu_HB_NAR	Maximum growth rate for OHO in NAR	1.58	---
mu_HB_NIR	Maximum growth rate for OHO in NIR	1.02	---
mu_HB_NOR	Maximum growth rate for OHO in NOR	2.82	---
mu_HB_NOS	Maximum growth rate for OHO in NOS	1.07	---
mu_NOB	Maximum growth rate for NOBs	1.04	---
mu_PAO	Maximum growth rate for PAOs	1	---

Group: Kinetics-Reduction Factors

Name	Description	Value	Units
n_AOB_NIR	Reduction factor for autotrophic denitrification1	0.22	---
n_AOB_NOR	Reduction factor for autotrophic denitrification2	0.36	---
n_HD	Reduction factor for HB denitrification	0.8	---
n_NO_AUT_d	Anoxic reduction factor for decay of autotrophs	0.33	---
n_NO_Het_d	Anoxic reduction factor for decay of heterotrophs	0.5	---
n_NO_Hyd	Anoxic hydrolysis reduction factor	0.6	---
n_NO_PAO	Amount of PAO organisms active under anoxic conditions	0.6	---
n_NO_P_d	Anoxic reduction factor for decay of PAO, PP and PHA	0.33	---
n_PAO_NAR	Reduction factor for PAO denitrification: NO ₃ to HNO ₂	0.128	---
n_PAO_NIR	Reduction factor for PAO denitrification: HNO ₂ to NO	0.037	---
n_PAO_NOR	Reduction factor for PAO denitrification: NO to N ₂ O	0.166	---
n_PAO_NOS	Reduction factor for PAO denitrification: N ₂ O to N ₂	0.019	---
n_Y	Anoxic reduction factor for heterotrophic growth	0.8	---
n_Y_PAO	Anoxic reduction factor for PAO growth yield	0.8	---
n_fe	Anaerobic hydrolysis reduction factor	0.4	---
n_fe_d	Anaerobic reduction factor for decay (AOB, NOB, PAO, PHA)	0	---
n_fe_H	Anaerobic hydrolysis reduction factor for lysis of OHOs	0	---
n_AOB_NIR	Reduction factor for autotrophic denitrification1	0.22	---
n_AOB_NOR	Reduction factor for autotrophic denitrification2	0.36	---
n_HD	Reduction factor for HB denitrification	1	---
n_NO_AUT_d	Anoxic reduction factor for decay of autotrophs	0.33	---
n_NO_Het_d	Anoxic reduction factor for decay of heterotrophs	0.5	---
n_NO_Hyd	Anoxic hydrolysis reduction factor	0.6	---

Group: Lysis

Name	Description	Value	Units
b_AOB	Decay rate	0.15	1/d
b_AUT	Decay rate	0.15	1/d
b_H	Rate constant for lysis and decay	0.4	1/d
b_NOB	Decay rate	0.15	1/d
b_PAO	Rate constant for lysis of X_PAO	0.2	1/d
b_PHA	Rate constant for lysis of X_PHA	0.2	1/d
b_PP	Rate constant for lysis of X_PP	0.2	1/d

Group: Operation

Name	Description	Value	Units
KLa_N2O_anox	Kla N2O under anoxic conditions	4	1/d
beta_ww	Correction factor for the wastewater characteristics	1	

Group: Stoichiometry

Name	Description	Value	Units
Y_AOB	Yield For AOB	0.18	gCOD/gN
Y_AUT	Yield For Autotrophic Biomass	0.24	gCOD/gN
Y_H	Yield For Heterotrophic Biomass	0.625	gCOD/gCOD
Y_MEOH	Yield of MEOH in redissolution process	3.45	
Y_MEP	Yield of MEP in precipitation process	4.87	
Y_NOB	Yield For NOB	0.06	gCOD/gN
Y_PAO	Yield coeff (biomass/PHA)	0.625	
Y_PHA	PHA requirement for PP storage	0.2	
Y_PO	PP requirement (S_PO4 release) per PHA stored	0.4	
f_S_I	Fraction of inert COD in particulate substrate	0	
f_X_I	Fraction of inert COD generated in biomass lysis	0.1	
n_Y_PHA	Anoxic factor for X_PHA requirement for X_PP storage	1.2	---

Group: Temperature correction

Name	Description	Value	Units
Temp_Ref	Reference temperature of the activated sludge	20	---
theta_K_X	Temperature correction factor for K_X	0.896	---
theta_Q_PHA	Temperature correction factor for Q_PHA	1.041	---
theta_Q_PP	Temperature correction factor for Q_PP	1.041	---
theta_Q_fe	Temperature correction factor for Q_fe	1.072	---
theta_b_AOB	Temperature correction factor for b_AOB	1.116	---
theta_b_H	Temperature correction factor for b_H	1.072	---
theta_b_NOB	Temperature correction factor for mu_NOB	1.116	---
theta_b_PAO	Temperature correction factor for b_PAO	1.072	---
theta_b_PHA	Temperature correction factor for b_PHA	1.072	---
theta_b_PP	Temperature correction factor for b_PP	1.072	---
theta_k_h	Temperature correction factor for k_h	1.041	---
theta_kla	Arrhenius parameter for kLa	1.024	---
theta_mu_AUT	Temperature correction factor for mu_AUT	1.111	---
theta_mu_H	Temperature correction factor for mu_H	1.072	---
theta_mu_NOB	Temperature correction factor for mu_NOB	1.11	---
theta_mu_PAO	Temperature correction factor for mu_PAO	1.041	---

State Variables

Algebraic Variables

Group: Competition

Name	Description	Units
HNO2_AOB	Fraction of HNO ₂ consumed by AOBs	---
HNO2_NOB	Fraction of HNO ₂ consumed by NOBs	---
HNO2_OHO	Fraction of HNO ₂ consumed by OHOs	---
HNO2_PAO	Fraction of HNO ₂ consumed by PAOs	---
N2O_OHO	Fraction of N ₂ O consumed by OHOs	---
N2O_PAO	Fraction of N ₂ O consumed by PAOs	---
N2O_Strip	Fraction of N ₂ O removed by stripping	---
NO3_OHO	Fraction of NO ₃ ⁻ consumed by OHOs	---
NO3_PAO	Fraction of NO ₃ ⁻ consumed by PAOs	---
NO_AOB	Fraction of NO consumed by AOBs	---
NO_OHO	Fraction of NO consumed by OHOs	---
NO_PAO	Fraction of NO consumed by PAOs	---
NO_Strip	Fraction of NO removed by stripping	---
VFA_OHO	Fraction of VFAs consumed by OHOs	---
VFA_PAO	Fraction of VFAs consumed by PAOs	---

Group: Concentrations

Name	Description	Units
CT_SA_SF	Competition term	g/m ³
CT_SF_SA	Competition term	g/m ³
S_FA	Concentration of Free Ammonia	g/m ³
S_FNA	Concentration of Free Nitric Acid	g/m ³
S_N2O_Saturation	N2O saturation concentration from atmospheric sources	g/m ³
S_N2O_Saturation_pure	N2O saturation concentration from atmospheric sources	g/m ³
S_NO_Saturation	NO saturation concentration	g/m ³
S_NOx	Concentration of NOx species	g/m ³
S_O_Saturation	Oxygen saturation concentration	g/m ³
X_VSS	Volatile Suspended Solids	g/m ³

Note that Monod and Inhibition functions in terms of **S_NOx** (oxidized nitrogen species) replace the equivalent terms expressed in terms of S_NO (nitrate in ASM2dMod) in hydrolysis, fermentation and lysis reactions in ASM2dModND. **S_NOx** is calculated as

$$S_{NOx} = C_{S_{NO3}} + C_{S_{HNO2}} + C_{S_{NO}} + C_{S_{N2O}}$$

Group: Inhibition Terms

Name/Description	Expression
IT_AOB_HNO2 FNA inhibition term for AOBs	$= \frac{K_{AOB_{iHNO2}}}{S_{FNA} + K_{AOB_{iHNO2}}}$
IT_AOB_NH FA inhibition term for AOBs	$= \frac{S_{FA}}{S_{FA} + K_{NH_{AOB}} + \frac{(S_{FA})^2}{K_{AOB_{iNH}}}}$
IT_FA_10 Inhibition of Free Ammonia on Autotrophic Growth of NOB	$= \frac{K_{FAi_{NOB}}}{S_{FA} + K_{FAi_{NOB}}}$
IT_FNA_10 Inhibition of Free Nitric Acid on Autotrophic Growth of NOB	$= \frac{S_{FNA}}{S_{FNA} + K_{HNO2_{NOB}} + \frac{(S_{FNA})^2}{K_{NOB_{iHNO2}}}}$
IT_S_NO_NIR S_NO inhibition for NIR	$= \frac{K_{NO_{iNIR}}}{C_{SNO} + K_{NO_{iNIR}}}$
IT_S_NO_NIR_P S_NO inhibition for DPAO NIR	$= \frac{K_{NO_{iNIR_P}}}{C_{SNO} + K_{NO_{iNIR_P}}}$
IT_S_NO_NOR S_NO inhibition for NOR	$= \frac{C_{SNO}}{C_{SNO} + K_{NOd} + \frac{(C_{SNO})^2}{K_{NO_{iNOR}}}}$
IT_S_NO_NOR_P S_NO inhibition for DPAO NOR	$= \frac{C_{SNO}}{C_{SNO} + K_{NOd_P} + \frac{(C_{SNO})^2}{K_{NO_{iNOR_P}}}}$
IT_S_NO_NOS S_NO inhibition for NOS	$= \frac{K_{NO_{iNOS}}}{C_{SNO} + K_{NO_{iNOS}}}$
IT_S_NO_NOS_P S_NO inhibition for DPAO NOS	$= \frac{K_{NO_{iNOS_P}}}{C_{SNO} + K_{NO_{iNOS_P}}}$
IT_S_NOx Inhibition term for S_NOx	$= \frac{K_{NOx}}{S_{NOx} + K_{NOx}}$
IT_S_O Inhibition term for oxygen	$= \frac{K_O}{S_O + K_O}$
IT_S_O_NAR S_O inhibition for NAR	$= \frac{K_{O_{iNAR}}}{S_O + K_{O_{iNAR}}}$
IT_S_O_NIR The inhibition term for oxygen	$= \frac{K_{O_{iNIR}}}{S_O + K_{O_{iNIR}}}$
IT_S_O_NOR The inhibition term for oxygen	$= \frac{K_{O_{iNOR}}}{S_O + K_{O_{iNOR}}}$
IT_S_O_NOS The inhibition term for oxygen	$= \frac{K_{O_{iNOS}}}{S_O + K_{O_{iNOS}}}$
IT_S_O_P Inhibition term for oxygen	$= \frac{K_{O_P}}{S_O + K_{O_P}}$
IT_S_O_Pdenit Inhibition term for oxygen for denitrification by PAOs	$= \frac{K_{O_{Pdenit}}}{S_O + K_{O_{Pdenit}}}$

Group: Kinetics

Name	Description	Units
K_A_NO2	Factor to calculate FNA	
K_X_Temp	K_X at the system temperature	
Kb_Kw	Factor to calculate FA	
Q_PHA_Temp	Q_PHA 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
k_h_Temp	k_h at the system temperature	1/d

Group: Kinetics-Growth

Name	Description	Units
mu_AOB_AMO_Temp	mu_AOB at the system temperature	1/d
mu_AOB_HAO_Temp	mu_AOB at the system temperature	1/d
mu_HB_NAR_Temp	mu_H for NAR on S_F at the system temperature	1/d
mu_HB_NIR_Temp	mu_H for NIR on S_F at the system temperature	1/d
mu_HB_NOR_Temp	mu_H for NOR on S_F at the system temperature	1/d
mu_HB_NOS_Temp	mu_H for NOS on S_F at the system temperature	1/d
mu_H_Temp	mu_H at the system temperature	1/d
mu_NOB_Temp	mu_NOB at the system temperature	1/d
mu_PAO_Temp	mu_PAO at the system temperature	1/d

Group: Lysis

Name	Description	Units
b_AOB_Temp	b_AOB at the system temperature	1/d
b_H_Temp	b_H at the system temperature	1/d
b_NOB_Temp	b_NOB at the system temperature	1/d
b_PAO_Temp	b_PAO at the system temperature	1/d
b_PHA_Temp	b_PHA at the system temperature	1/d
b_PP_Temp	b_PP at the system temperature	1/d

Group: Monod terms

Name/Description	Expression
MT_AOB_HNO2 FNA Monod term AOBs	$= \frac{S_{FNA}}{S_{FNA} + K_{HNO2_{AOB}}}$
MT_AUT_Alk S_Alk Monod term for AOBs	$= \frac{C_{S_{ALK}}}{C_{S_{ALK}} + K_{ALK_{AUT}}}$
MT_NOB_Alk Monod term for alkalinity	$= \frac{C_{S_{ALK}}}{C_{S_{ALK}} + K_{ALK_{NOB}}}$
MT_NOB_O S_O Monod term for autotrophic growth of NOBs	$= \frac{C_{S_O}}{C_{S_O} + K_{O_{NOB}}}$
MT_S_A Monod term for S_A	$= \frac{C_{S_A}}{C_{S_A} + K_A}$
MT_S_A_NAR S_A Monod term for NAR	$= \frac{C_{S_A}}{C_{S_A} + K_{A_{NAR}}}$

Name/Description	Expression
MT_S_A_NIR S_A Monod term for NIR	$= \frac{C_{SA}}{C_{SA} + K_{ANIR}}$
MT_S_A_NOR S_A Monod term for NOR	$= \frac{C_{SA}}{C_{SA} + K_{ANOR}}$
MT_S_A_NOS S_A Monod term for NOS	$= \frac{C_{SA}}{C_{SA} + K_{ANOS}}$
MT_S_Alk Monod term for alkalinity	$= \frac{C_{SALK}}{C_{SALK} + K_{ALK}}$
MT_S_F Monod term for S_F	$= \frac{C_{SF}}{C_{SF} + K_F}$
MT_S_F_NAR S_F Monod term for NAR	$= \frac{C_{SF}}{C_{SF} + K_{FNAR}}$
MT_S_F_NIR S_F Monod term for NIR	$= \frac{C_{SF}}{C_{SF} + K_{FNIR}}$
MT_S_F_NOR S_F Monod term for NOR	$= \frac{C_{SF}}{C_{SF} + K_{FNOR}}$
MT_S_F_NOS S_F Monod term for NOS	$= \frac{C_{SF}}{C_{SF} + K_{FNOS}}$
MT_S_HNO2 Monod term for S_HNO2	$= \frac{C_{SHNO2}}{C_{SHNO2} + K_{HNO2}}$
MT_S_HNO2_P Monod term for S_HNO2 for DPAOs	$= \frac{C_{SHNO2}}{C_{SHNO2} + K_{HNO2P}}$
MT_S_N2O Monod term for S_N2O	$= \frac{C_{SN2O}}{C_{SN2O} + K_{N2O}}$
MT_S_N2O_P Monod term for S_N2O for DPAOs	$= \frac{C_{SN2O}}{C_{SN2O} + K_{N2OP}}$
MT_S_NH Monod term for ammonium	$= \frac{C_{SNH}}{C_{SNH} + K_{NH}}$
MT_S_NO3 Monod term for S_NO3	$= \frac{C_{SNO3}}{C_{SNO3} + K_{NO3}}$
MT_S_NO3_P Monod terms for NO3 PAO	$= \frac{C_{SNO3}}{C_{SNO3} + K_{NO3P}}$
MT_S_NOx Monod term for S_NO	$= \frac{C_{SNOx}}{C_{SNOx} + K_{NO}}$
MT_S_O Monod term for oxygen HB	$= \frac{C_{SO}}{C_{SO} + K_O}$
MT_S_O_P Monod term for oxygen PAO	$= \frac{C_{SO}}{C_{SO} + K_{OP}}$
MT_S_PO Monod term for S_PO	$= \frac{C_{SPO}}{C_{SPO} + K_P}$
MT_X_PHA Monod term for X_PHA	$= \frac{(C_{XPHA}/C_{XPAO})}{(C_{XPHA}/C_{XPAO}) + K_{PHA}}$
MT_X_S Monod term for X_S	$= \frac{(C_{XS}/C_{XH})}{(C_{XS}/C_{XH}) + K_X}$

Group: N2O

Name	Description	Units
N2O_prod_AOB	Fraction of N2O produced by AOBs	---
N2O_prod_OHO	Fraction of N2O produced by OHOs	---
N2O_prod_PAO	Fraction of N2O produced by PAOs	---
NO_ND	NO produced by ND pathway	gN/d
NO_NN	NO produced by NN pathway	gN/d
Q_N2O_ND	Flux N2O from ND pathway	gN/d
Q_N2O_NN	Flux N2O from NN pathway	gN/d
Q_N2O_gas	Flow Rate of N2O gas going into the air	gN/d
Q_NO_gas	Flow Rate of NO gas going into the air	gN/d
r_NO_ND	Ratio for NO production in ND pathway	---
r_NO_NN	Ratio for NO production in NN pathway	---

Group: Operation

Name	Description	Units
Is_React	Conversion processes on(1) / off(0)	---
Kla_Actual	The actual kLa in the system	1/d
Kla_N2O	kLa for N2O	1/d
Kla_N2O_aer	Aerobic kLa for N2O	1/d
Kla_NO	Kla for NO	1/d
Temp_Actual	Actual temperature	°C
help_Kla_Actual	The actual kLa in the system, with temperature correction	1/d
pH_corr	Correction factor for N2O reduction HB	---

Group: Rates

Name	Description	Units
r_AerAMO	Nitrification step_NH to NH2OH	1/d
r_AerGrowthNOB	Nitrification step_NO2 to NO3	1/d
r_AerHAO	NN_NH2OH to NO	1/d
r_AerHAO2	Nitrification step_NH2OH to NO2	1/d
r_AnoxANIR	ND_NO2 to NO	1/d
r_AnoxANOR	ND_NO to N2O	1/d
r_LysisAOB	Decay of AOB bacteria	1/d
r_LysisNOB	Decay of NOB bacteria	1/d
r_StorageAerXPP	Aerobic storage of X_PP	1/d

Derived Variables

Group: Masses

Name	Description	Units
M	Mass vector	g

Interface Variables

Group: Dimensions

Name	Terminal	Description	Value	Units
Lanes	in_2	Number of lanes in parallel lane models	-	---
H_tank	out_2	Depth of the tank (or lane)	-	m

Group: Measurement data

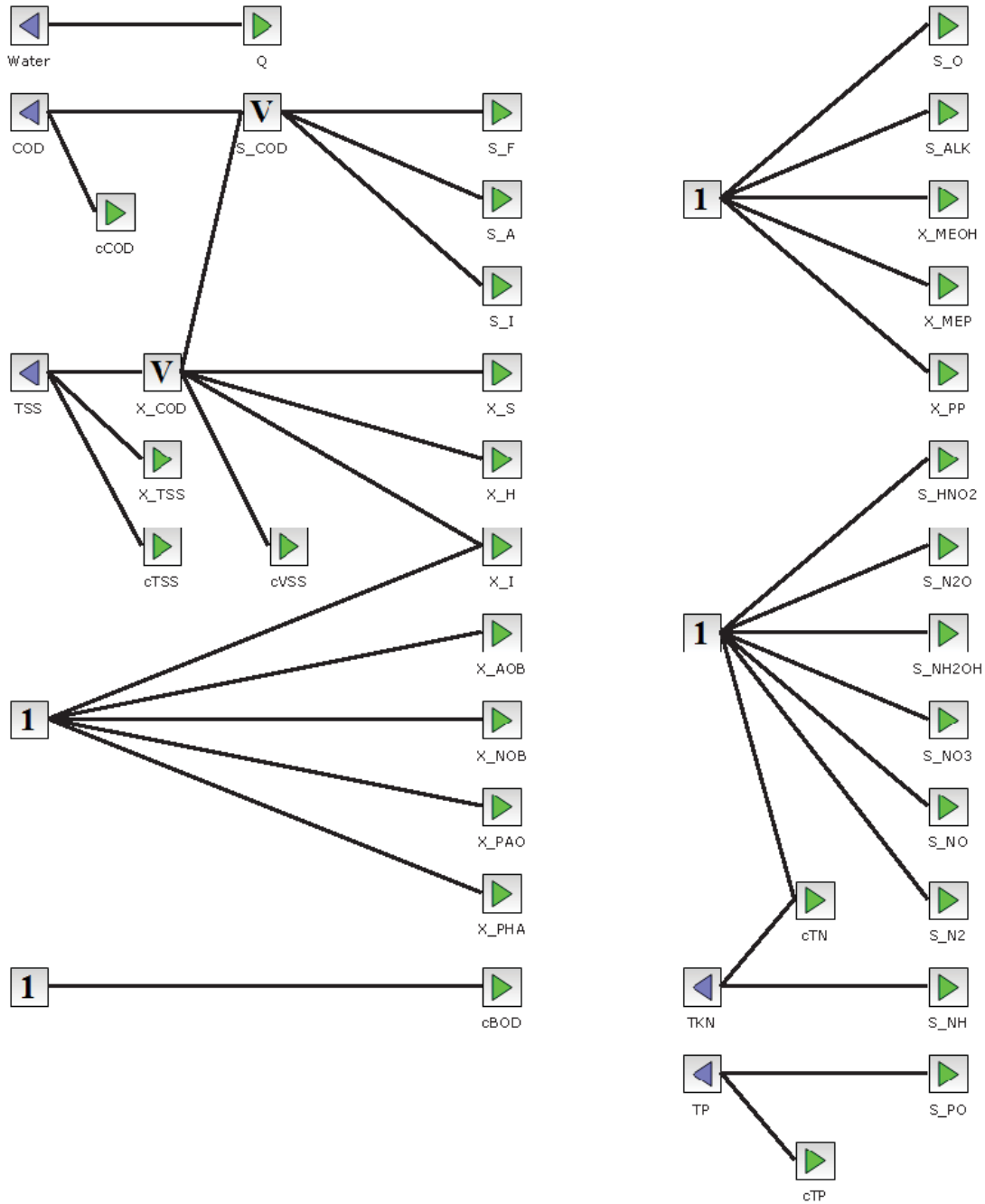
Name	Terminal	Description	Value	Units
AUR	out_2	Ammonium Uptake Rate measurement data	-	g/(m ³ .d)
BOD	out_2	Biological Oxygen Demand measurement	-	g/m ³
COD	out_2	Chemical Oxygen Demand measurement	-	g/m ³
DO	out_2	Dissolved oxygen concentration measurement	-	gO ₂ /m ³
Kla_ASU	out_2	Kla measurement data	-	1/d
N ₂ O_prod	out_2	Nitrous oxide emissions	-	g/d
NH ₄	out_2	Ammonium concentration measurement	-	g/m ³
NO ₂	out_2	Nitrite concentration measurement	-	g/m ³
NO ₃	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	OUR measurement data	-	g/(m ³ .d)
PO ₄	out_2	Phosphorous concentration measurement	-	g/m ³
PUR	out_2	Phosphate Uptake Rate measurement data	-	g/(m ³ .d)
S_BOD	out_2	Concentration of soluble BOD	-	g/m ³
S_COD	out_2	Soluble COD	-	g/m ³
TKN	out_2	Total Kjeldal 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
V_ASU	out_2	Volume measurement data	-	m ³
X_BOD	out_2	Concentration of particulate BOD	-	g/m ³
X_COD	out_2	Particulate COD	-	g/m ³

Group: Operation

Name	Terminal	Description	Value	Units
T_air	in_2	Air temperature	15	°C
Temp	in_2	Temperature of the liquor	15	°C
kLa_N ₂ O	in_2	kLa for pure N ₂ O bubbling in reactor volume	0.0001	1/d
pH	in_2	pH of water	7	-

The Fractionation Model

The default fractionation model for ASM2dMod is shown below.



$$\begin{aligned}
 X_{COD} &= f_{TSS_{COD}} \cdot TSS \\
 X_{TSS} &= TSS \\
 S_{COD} &= COD - X_{COD} \\
 S_F &= f_{S_F} \cdot S_{COD} \\
 S_A &= f_{S_A} \cdot S_{COD} \\
 S_I &= (1 - f_{S_F} - f_{S_A}) \cdot S_{COD} \\
 X_S &= f_{X_S} \cdot X_{COD} \\
 X_H &= f_{X_H} \cdot X_{COD} \\
 X_{PHA} &= X_{PHA_{In}}
 \end{aligned}$$

$$\begin{aligned}
X_{PAO} &= X_{PAO_{In}} \\
X_{NOB} &= X_{NOB_{In}} \\
X_{AOB} &= X_{AOB_{In}} \\
X_I &= (1 - f_{X_S} - f_{X_H}) \cdot X_{COD} - X_{PHA_{In}} - X_{PAO_{In}} - X_{NOB_{In}} - X_{AOB_{In}} \\
S_O &= S_{O_{In}} \\
S_{ALK} &= S_{ALK_{In}} \\
X_{MEOH} &= X_{MEOH_{In}} \\
X_{MEP} &= X_{MEP_{In}} \\
X_{PP} &= X_{PP_{In}} \\
S_{HNO2} &= S_{HNO2_{In}} \\
S_{N2O} &= S_{N2O_{In}} \\
S_{NH2OH} &= S_{NH2OH_{In}} \\
S_{NO3} &= S_{NO3_{In}} \\
S_{NO} &= S_{NO_{In}} \\
S_{N2} &= S_{N2_{In}} \\
S_{NH} &= f_{S_{NH}} \cdot TKN \\
S_{PO} &= f_{S_{PO}} \cdot TP \\
cCOD &= COD \\
cTSS &= TSS \\
cVSS &= \frac{X_{COD}}{i_{COD_{VSS}}} \\
cBOD &= F_{BOD_{COD}} \\
&\quad \cdot (S_{COD} \cdot (f_{S_F} + f_{S_A}) + f_{X_S} \cdot X_{COD} + X_{PHA_{In}} + (1 - f_{X_I}) \\
&\quad \cdot (X_{COD} \cdot f_{X_H} + X_{AOB_{In}} + X_{NOB_{In}} + X_{PAO_{In}})) \\
cTN &= S_{HNO2_{In}} + S_{N2O_{In}} + S_{NO3_{In}} + S_{NO_{In}} + TKN \\
cTP &= TP
\end{aligned}$$

Parameters

Group: Fractionation

Name	Description	Value	Units
F_BOD_COD	COD to BOD conversion factor	0.65	
F_TSS_COD	COD to TSS conversion factor	0.75	
f_S_A	Soluble COD to SA ratio	0.25	-
f_S_F	Soluble COD to SF ratio	0.375	-
f_S_NH	Total nitrogen to ammonia ratio	0.6	-
f_S_PO	Total phosphorous to PO ratio	0.6	-
f_X_H	Particulate COD to XH ratio	0.17	-
f_X_I	Fraction of inert COD generated in biomass lysis	0.1	-
f_X_S	Particulate COD to XS ratio	0.69	-
i_COD_VSS	VSS to COD conversion	1.42	

Group: Influent specs

Name	Description	Value	Units
S_Alk_In	Alkalinity	30	g/m ³
S_HNO2_In	Concentration of nitrite	0.01	g/m ³
S_N2O_In	Concentration of nitrous oxide	0.01	g/m ³
S_N2_In	Nitrogen	0.01	g/m ³
S_NH2OH_In	Concentration of hydroxylamine	0.01	m ³ /d
S_NO3_In	Concentration of nitrate	0.01	g/m ³
S_NO_In	Concentration of nitric oxide	0.01	g/m ³
S_O_In	Oxygen	0.01	g/m ³
X_AOB_In	Concentration of AOBs	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_NOB_In	Concentration of NOBs	0.01	g/m ³
X_PAO_In	P-accumulating organisms	0.01	g/m ³
X_PHA_In	PHA	0.01	g/m ³
X_PP_In	Poly-phosphate	0.01	g/m ³

State Variables

Name	Description	Units
S_COD	Soluble COD	g/m ³
X_COD	Particulate COD	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
COD	---	Total COD	---	g/m ³
TKN	---	Total Kjeldahl Nitrogen	---	g/m ³
TP	---	Total phosphorous	---	g/m ³
Influent	---	ASM2dModNDHA component vector	---	g/d

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ASM2dISS

Last Updated: 12/06/2024

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/m ³
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 Oxidising 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.

Organic matter				
Soluble organic matter			Particulate organic matter	
Inert COD S_U	Readily biodegradable matter		Inert COD X_U	Slowly biodegr. COD XC_B
	Readily biodegr. COD S_F	Fermentation products S_VFA		

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 (C₄H₆O₂)_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% H₂PO₄⁻ and 50% HPO₄²⁻ 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 FePO₄.

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_{SU}
S_F	$1 - f_{SU}$
S_PO	$-i_{P,SF} \cdot (1 - f_{SU}) - i_{P,SU} \cdot f_{SU} + i_{P,XCB}$
S_NHx	$-i_{N,SF} \cdot (1 - f_{SU}) - i_{N,SU} \cdot f_{SU} + i_{N,XCB}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot Monod_{SO} \cdot Monod_{XCB} \cdot C_{XOHO}$

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

P3: HydrolAnaer	
S_U	f_{SU}
S_F	$1 - f_{SU}$
S_PO	$-i_{P,SF} \cdot (1 - f_{SU}) - i_{P,SU} \cdot f_{SU} + i_{P,XCB}$
S_NHx	$-i_{N,SF} \cdot (1 - f_{SU}) - i_{N,SU} \cdot f_{SU} + i_{N,XCB}$
S_Alk	$\frac{1}{14} \cdot Sto[P_1, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_1, S_{PO}]$
XC_B	-1
Rate	$k_{h,Temp} \cdot n_{fe} \cdot Inhib_{SO} \cdot Monod_{SNO} \cdot Monod_{XCB} \cdot C_{XOHO}$

P4: Fermentation	
S_F	-1
S_VFA	1
S_PO	$i_{P,SF}$
S_NHx	$i_{N,SF}$
S_Alk	$\frac{1}{14} \cdot Sto[P_4, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_4, S_{PO}] - \frac{1}{64} \cdot Sto[P_4, S_{VFA}]$
Rate	$Q_{fe,Temp} \cdot Inhib_{SO} \cdot Inhib_{SNO} \cdot Monod_{SAlk} \cdot \frac{C_{SF}}{C_{SF} + K_{fe}} \cdot C_{XOHO}$

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

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	$\frac{1}{14} \cdot Sto[P_6, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_6, S_{PO}] - \frac{1}{64} \cdot Sto[P_6, S_{VFA}]$
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	$-\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO3	$-\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{1.1429 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO2	$\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{1.1429 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{P,SF} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{N,SF} - i_{N,BM}$
S_alk	$\frac{1}{14} \cdot Sto[P_7, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_7, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n_{2_{g_{OHO}}} \cdot Inhib_{OH_2} \cdot Monod_{S_F} \cdot \frac{C_{S_F}}{C_{S_F} + C_{SVFA}} \cdot Monod_{S_{NH}} \cdot Monod_{OHO_{NO_3}} \cdot Monod_{S_{PO}} \cdot Monod_{S_{alk}} \cdot C_{X_{OHO}}$

P8: GrowthAnoxSf_NO2toNO	
S_F	$-\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO2	$-\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{0,5715 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO	$\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{0,5715 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{P,SF} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{N,SF} - i_{N,BM}$
S_alk	$\frac{1}{14} \cdot Sto[P_8, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_8, S_{PO}] - \frac{1}{14} \cdot Sto[P_8, S_{NO2}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n_{3_{OHO}} \cdot Inhib_{OHO3} \cdot Monod_{SF} \cdot \frac{C_{SF}}{C_{SF} + C_{SVFA}} \cdot Monod_{SNH} \cdot Inhib_{3_{OHO}NO} \cdot Monod_{OHO_{NO2}} \cdot Monod_{SPO} \cdot Monod_{SAlk} \cdot C_{X_{OHO}}$

P9: GrowthAnoxSf_NOtoN2O	
S_F	$-\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO	$-\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{0,5715 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_N2O	$\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{0,5715 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{P,SF} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{N,SF} - i_{N,BM}$
S_alk	$\frac{1}{14} \cdot Sto[P_9, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_9, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n_{4_{OHO}} \cdot Inhib_{OHO4} \cdot Monod_{SF} \cdot \frac{C_{SF}}{C_{SF} + C_{SVFA}} \cdot Monod_{SNH} \cdot Monod_{OHO_{NO}} \cdot Monod_{SPO} \cdot Monod_{SAlk} \cdot C_{X_{OHO}}$

P10: GrowthAnoxSf_N2OtoN2	
S_F	$-\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}}$
S_N2O	$-\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{0,5715 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_N2	$\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{0,5715 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_PO	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{P,SF} - i_{P,BM}$
S_NHx	$\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}} \cdot i_{N,SF} - i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{10}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{10}, S_{PO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n5_{gOHO} \cdot Inhib_{OHO5} \cdot Monod_{SF5} \cdot \frac{C_{SF}}{C_{SF} + C_{SVFA}} \cdot Monod_{SNH} \cdot Inhib5_{OHOONO}$ $\cdot Monod_{OHOON2O} \cdot Monod_{SPO} \cdot Monod_{SAlk} \cdot C_{XOHO}$

P11: GrowthAnoxSvfa_NO3toNO2	
S_VFA	$-\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO3	$-\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{1.1429 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO2	$\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{1.1429 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{11}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{11}, S_{PO}] - \frac{1}{64} \cdot Sto[P_{11}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n2_{gOHO} \cdot Inhib_{OHO2} \cdot Monod_{SVFA2} \cdot Monod_{OHOONO3} \cdot Monod_{SNH} \cdot Monod_{SPO}$ $\cdot Monod_{SAlk} \cdot \frac{C_{SVFA}}{C_{SF} + C_{SVFA}} \cdot C_{XOHO}$

P12: GrowthAnoxSvfa_NO2toNO	
S_VFA	$-\frac{1}{Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO2	$-\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{1.1429 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_NO	$\frac{1 - Y_{OHO} \cdot n_{Y_{OHO}}}{1.1429 \cdot Y_{OHO} \cdot n_{Y_{OHO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{12}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{12}, S_{PO}] - \frac{1}{64} \cdot Sto[P_{12}, S_{VFA}] - \frac{1}{14} \cdot Sto[P_{10}, S_{NO}]$
X_OHO	1
Rate	$\mu_{OHO,T} \cdot n3_{gOHO} \cdot Inhib_{OHO3} \cdot Monod_{SVFA3} \cdot Monod_{OHOONO2} \cdot Monod_{SNH} \cdot Inhib3_{OHOONO}$ $\cdot Monod_{SPO} \cdot Monod_{SAlk} \cdot \frac{C_{SVFA}}{C_{SF} + C_{SVFA}} \cdot C_{XOHO}$

P13: GrowthAnoxSvfa_NOtoN2O	
S_VFA	$-\frac{1}{Y_{OHO} * n_{Y_{OHO}}}$
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	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} * Sto[P_{13}, S_{NHx}] - \frac{1.5}{31} * Sto[P_{13}, S_{PO}] - \frac{1}{64} * Sto[P_{13}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} * n_{4_{GOHO}} * Inhib_{OH4} * Monod_{SVFA4} * Monod_{OHO_{NO}} * Monod_{SNH} * Monod_{SPO} * Monod_{SAlk} * \frac{C_{SVFA}}{C_{SF} + C_{SVFA}} * C_{X_{OHO}}$

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	$\frac{1}{14} * Sto[P_{14}, S_{NHx}] - \frac{1.5}{31} * Sto[P_{14}, S_{PO}] - \frac{1}{64} * Sto[P_{14}, S_{VFA}]$
X_OHO	1
Rate	$\mu_{OHO,T} * n_{5_{GOHO}} * Inhib_{OH5} * Monod_{SVFA5} * Monod_{OHO_{NO}} * Monod_{SNH} * Monod_{SPO} * Monod_{SAlk} * \frac{C_{SVFA}}{C_{SF} + C_{SVFA}} * C_{X_{OHO}}$

P15: DenAOB_NO2toNO	
S_O	$-\left(\frac{2.2857}{Y_{AOB}} - 1\right) * n_{Y_{AOB}}$
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	$-\frac{1}{Y_{AOB} * n_{Y_{AOB}}} - i_{N,BM}$
S_Alk	$\frac{1}{14} * Sto[P_{15}, S_{NHx}] - \frac{1.5}{31} * Sto[P_{15}, S_{PO}] - \frac{1}{14} * Sto[P_{15}, S_{NO2}]$
X_AOB	1
Rate	$n_{1_{AOB}} * \mu_{AOB,T} * C_{X_{AOB}} * \frac{S_{FNA}}{K_{FNA_{AOBden}} + S_{FNA}} * \frac{S_{FA}}{K_{FA_{AOBden}} + S_{FA}} * Inhib_{AOBdenSO} * Monod_{AUT_{PQ}} * Monod_{AUT_{ALK}}$

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	$\frac{1}{14} \cdot Sto[P_{16}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{16}, S_{PO}] - \frac{1}{14} \cdot Sto[P_{16}, S_{NO2}]$
X_AOB	1
Rate	$n2_{AOB} * \mu_{AOB,T} * C_{X_{AOB}} * \frac{C_{SNO}}{K_{SNO_{AOBden}} + C_{SNO}} * \frac{S_{FA}}{K_{FA_{AOBden}} + S_{FA}} * Inhib_{AOBdenSO} * Monod_{AUTPO} * Monod_{AUTALK}$

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	$\frac{1}{14} \cdot Sto[P_{17}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{17}, S_{PO}] - \frac{1}{14} \cdot Sto[P_{17}, S_{NO2}]$
X_AOB	1
Rate	$\mu_{AOB,T} * Inhib_{FA9} * Inhib_{FNA9} * Monod_{AUTPO} * Monod_{AUTALK} * C_{X_{AOB}}$

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	$\frac{1}{14} \cdot Sto[P_{18}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{18}, S_{PO}]$
X_NOB	1
Rate	$\mu_{NOB,T} * Inhib_{FNA10} * Inhib_{FA10} * Monod_{NOB0} * Monod_{AUTPO} * Monod_{AUTALK} * C_{X_{AOB}}$

P19: GrowthAerXPHA	
S_O	$1 - \frac{1}{Y_{PAO}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{19}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{19}, S_{PO}]$
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	$-\frac{1 - Y_{PAO} \cdot n_{Y_{PAO}}}{1.1429 \cdot Y_{PAO} \cdot n_{Y_{PAO}}}$
S_NO2	$\frac{1 - Y_{PAO} \cdot n_{Y_{PAO}}}{1.1429 \cdot Y_{PAO} \cdot n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{20}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{20}, S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO} \cdot n_{Y_{PAO}}}$
Rate	$Rate_{19} \cdot n_{2_{PAO}} \cdot \frac{K_{O_{PAO}}}{C_{S_O}} \cdot Monod_{PAO_{NO3}}$

P21: GrowthAnoxXPHA_NO2toNO	
S_NO2	$-\frac{1 - Y_{PAO} \cdot n_{Y_{PAO}}}{0.5715 \cdot Y_{PAO} \cdot n_{Y_{PAO}}}$
S_NO	$\frac{1 - Y_{PAO} \cdot n_{Y_{PAO}}}{0.5715 \cdot Y_{PAO} \cdot n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_Alk	$\frac{1}{14} \cdot Sto[P_{21}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{21}, S_{PO}] - \frac{1}{14} \cdot \frac{-1 + Y_{PAO} \cdot n_{Y_{PAO}}}{0.5715 \cdot Y_{PAO} \cdot n_{Y_{PAO}}}$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO} \cdot n_{Y_{PAO}}}$
Rate	$Rate_{19} \cdot n_{3_{PAO}} \cdot \frac{K_{O_{PAO}}}{C_{S_O}} \cdot Monod_{PAO_{NO2}} \cdot Inhib3_{PAO_{NO}}$

P22: GrowthAnoxXPHA_NOtoN2O	
S_NO	$-\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_N2O	$\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_alk	$\frac{1}{14} \cdot Sto[P_{22}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{22}, S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO} * n_{Y_{PAO}}}$
Rate	$Rate_{19} * n_{4_{PAO}} * \frac{K_{O_{PAO}}}{C_{SO}} * Monod_{PAONO}$

P23: GrowthAnoxXPHA_N2OtoN2	
S_N2O	$-\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_N2	$\frac{1 - Y_{PAO} * n_{Y_{PAO}}}{0.5715 * Y_{PAO} * n_{Y_{PAO}}}$
S_PO	$-i_{P,BM}$
S_NHx	$-i_{N,BM}$
S_alk	$\frac{1}{14} \cdot Sto[P_{23}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{23}, S_{PO}]$
X_PAO	1
X_PAO_Stor	$-\frac{1}{Y_{PAO} * n_{Y_{PAO}}}$
Rate	$Rate_{19} * n_{45_{PAO}} * \frac{K_{O_{PAO}}}{C_{SO}} * Monod_{PAON_2O} * Inhib5_{PAONO}$

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	$\mu_{ANA,T} * \frac{C_{SNO_2}}{K_{NO_2ANA} + C_{SNO_2} + \frac{S_{NO_2}^2}{KI_{NO_2ANA}}} * \frac{C_{SNHx}}{K_{NHANA} + C_{SNHx}} * \frac{K_{OANA}}{K_{OANA} + C_{SO}} * C_{XANA}$

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	$Q_{PAO,Stor,Temp} \cdot Monod_{S_{VFA}} \cdot Monod_{S_{Alk}} \cdot \frac{C_{X_{PAO,PP}}}{(C_{X_{PAO,PP}}/C_{X_{PAO}}) + K_{PP}}$

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	$Q_{PP,Temp} \cdot Monod_{S_O} \cdot Monod_{S_{Alk}} \cdot Monod_{X_{PAO,Stor}} \cdot \frac{C_{S_{PO}}}{C_{S_{PO}} + K_{PS}} \cdot \frac{K_{max} - (C_{X_{PAO,PP}}/C_{X_{PAO}})}{K_{IPP} + K_{max} - (C_{X_{PAO,PP}}/C_{X_{PAO}})} \cdot C_{X_{PAO}}$

P27: StorageAnoxXPP_NO3toNO2	
S_NO3	$-\frac{Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}}{1.1429}$
S_NO2	$\frac{Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}}{1.1429}$
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	$-Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}$
Rate	$Rate_{26} * n_{2_{PAO}} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO3}}$

P28: StorageAnoxXPP_NO2toNO	
S_NO2	$-\frac{Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}}{0.5715}$
S_NO	$\frac{Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}}{0.5715}$
S_PO	-1
S_Alk	$-\frac{1.5}{31} \cdot Sto[P_{28}, S_{PO}] - \frac{1}{31} \cdot Sto[P_{28}, X_{PAO,PP}] - \frac{1}{14} \cdot \frac{-Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}}{0.5715}$
X_PAO_PP	1
X_PAO_Stor	$-Y_{PAO,Stor} \cdot n_{Y_{PAO,stor}}$
Rate	$Rate_{26} * n_{3_{PAO}} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO2}} * Inhib_{3_{PAO_{NO}}}$

P29: StorageAnoxXPP_NOtoN2O	
S_NO	$-\frac{Y_{PAO,Stor} * n_{Y_{PAO,stor}}}{0.5715}$
S_N2O	$\frac{Y_{PAO,Stor} * n_{Y_{PAO,stor}}}{0.5715}$
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_PAOPP	1
X_PAO_Stor	$-Y_{PAO,Stor} * n_{Y_{PAO,stor}}$
Rate	$Rate_{26} * n_{4PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO}}$

P30: StorageAnoxXPP_N2OtoN2	
S_N2O	$-\frac{Y_{PAO,Stor} * n_{Y_{PAO,stor}}}{0.5715}$
S_N2	$\frac{Y_{PAO,Stor} * n_{Y_{PAO,stor}}}{0.5715}$
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_PAOPP	1
X_PAO_Stor	$-Y_{PAO,Stor} * n_{Y_{PAO,stor}}$
Rate	$Rate_{26} * n_{4PAO} * \frac{K_{O_{PAO}}}{C_{S_O}} * Monod_{PAO_{NO}}$

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	$b_{OHO,T} \cdot (Monod_{S_O} + n_{d,OHO} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{xOHO}$

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	$b_{AOB,T} \cdot (Monod_{S_O} + n_{d,AOB} \cdot Inhib_{S_O} \cdot Monod_{S_{NOx}}) \cdot C_{xAOB}$

P33: LysisNOB	
S_PO	$i_{P,BM} - i_{P,XU} \cdot f_{XU} - i_{P,XCB} \cdot (1 - f_{XU})$
S_NHx	$i_{N,BM} - i_{N,XU} \cdot f_{XU} - i_{N,XCB} \cdot (1 - f_{XU})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{33}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{33}, S_{PO}]$
X_U	f_{XU}
XC_B	$1 - f_{XU}$
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	$i_{P,BM} - i_{P,XU} \cdot f_{XU} - i_{P,XCB} \cdot (1 - f_{XU})$
S_NHx	$i_{N,BM} - i_{N,XU} \cdot f_{XU} - i_{N,XCB} \cdot (1 - f_{XU})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{34}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{34}, S_{PO}]$
X_U	f_{XU}
XC_B	$1 - f_{XU}$
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	$i_{P,BM} - i_{P,XU} \cdot f_{XU} - i_{P,XCB} \cdot (1 - f_{XU})$
S_NHx	$i_{N,BM} - i_{N,XU} \cdot f_{XU} - i_{N,XCB} \cdot (1 - f_{XU})$
S_Alk	$\frac{1}{14} \cdot Sto[P_{35}, S_{NHx}] - \frac{1.5}{31} \cdot Sto[P_{35}, S_{PO}]$
X_U	f_{XU}
XC_B	$1 - f_{XU}$
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	$k_{pre} \cdot C_{SPO} \cdot C_{X_{MEOH}}$

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	$k_{La} \cdot (C_{SO} - S_{O_{sat}})$

P41: StrippingN2	
S_N2	1
Rate	$rate_{stripN2}$

P42: StrippingNO	
S_NO	1
Rate	$rate_{stripNO}$

P43: StrippingN2O	
S_N2O	1
Rate	$rate_{stripN2O}$

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/Inhibition coeff for OHO's growth, NO3 to NO2	0.2	g/m ³
K3_O_OHO	Saturation/Inhibition coeff for OHO's growth, NO2 to NO	0.2	g/m ³
K4_O_OHO	Saturation/Inhibition coeff for OHO's growth, NO to N2O	0.2	g/m ³
K5_O_OHO	Saturation/Inhibition 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
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 denitrification	0.0006	g/m ³

Name	Description	Value	Units
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/ (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

Name	Description	Value	Units
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

State Variables

Name / Description	Expression
IT3_OHO_NO Inhibition of NO on OHOs growth	$= \frac{KI3_{NO_{OHO}}}{KI3_{NO_{OHO}} + C_{SNO}}$
IT3_PAO_NO Inhibition of NO on PAOs growth	$= \frac{KI3_{NO_{PAO}}}{KI3_{NO_{PAO}} + C_{SNO}}$
IT5_OHO_NO Inhibition of NO on OHOs growth	$= \frac{KI5_{NO_{OHO}}}{KI5_{NO_{OHO}} + C_{SNO}}$
IT5_PAO_NO Inhibition of NO on PAOs growth	$= \frac{KI5_{NO_{PAO}}}{KI5_{NO_{PAO}} + C_{SNO}}$
IT_AOBden_SO Haldane inhibition term of oxygen for AOB denitrification	$= \frac{C_{SO}}{K_{O_{AOBden}} + \left(1 - 2 * \left(\frac{K_{O_{AOBden}}}{KI_{O_{AOBden}}}\right)^{0.5}\right) * C_{SO} + \frac{C_{SO}^2}{KI_{O_{AOBden}}}}$
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	$= \frac{K2_{O_{OHO}}}{K2_{O_{OHO}} + C_{SO}}$
IT_OH3 Oxygen inhibition on OHO's growth, NO2 to NO	$= \frac{K3_{O_{OHO}}}{K3_{O_{OHO}} + C_{SO}}$
IT_OH4 Oxygen inhibition on OHO's growth, NO to N2O	$= \frac{K4_{O_{OHO}}}{K4_{O_{OHO}} + C_{SO}}$
IT_OH5 Oxygen inhibition on OHO's growth, N2O to N2	$= \frac{K5_{O_{OHO}}}{K5_{O_{OHO}} + C_{SO}}$
IT_S_NOx Inhibition term for S_NOx	$= \frac{K_{NOx}}{K_{NOx} + S_{NOx}}$
IT_S_O The inhibition term for oxygen	$= \frac{K_O}{K_O + C_{SO}}$
MT_AOB_O S_O Monod term for autotrophic growth of AOBs	$= \frac{C_{SO}}{K_{O_{AOB}} + C_{SO}}$
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	$= \frac{C_{SO}}{K_{O_{NOB}} + C_{SO}}$

Name / Description	Expression
MT_OHO_N2O N2O Monod term for anoxic growth of OHOs	$= \frac{C_{SN2O}}{K_{N2O_{OHO}} + C_{SN2O}}$
MT_OHO_NO NO Monod term for anoxic growth of OHOs	$= \frac{C_{SNO}}{(K_{NO_{OHO}} + C_{SNO}) + \frac{C_{SNO}^2}{KI4_{NO_{OHO}}}}$
MT_OHO_NO2 NO2 Monod term for anoxic growth of OHOs	$= \frac{C_{SNO2}}{K_{NO2_{OHO}} + C_{SNO2}}$
MT_OHO_NO3 NO3 Monod term for anoxic growth of OHOs	$= \frac{C_{SNO3}}{K_{NO3_{OHO}} + C_{SNO3}}$
MT_PAO_N2O N2O Monod term for anoxic growth of PAOs	$= \frac{C_{SN2O}}{K_{N2O_{PAO}} + C_{SN2O}}$
MT_PAO_NO NO Monod term for anoxic growth of PAOs	$= \frac{C_{SNO}}{K_{NO_{PAO}} + C_{SNO} + \frac{C_{SNO}^2}{KI4_{NO_{PAO}}}}$
MT_PAO_NO2 NO2 Monod term for anoxic growth of PAOs	$= \frac{C_{SNO2}}{K_{NO2_{PAO}} + C_{SNO2}}$
MT_PAO_NO3 NO3 Monod term for anoxic growth of PAOs	$= \frac{C_{SNO3}}{K_{NO3_{PAO}} + C_{SNO3}}$
MT_S_ALK Monod term for alkalinity	$= \frac{C_{SAlk}}{K_{Alk} + C_{SAlk}}$
MT_S_F1 Monod term for S_F	$= \frac{C_{SF}}{K_{F1} + C_{SF}}$
MT_S_F2 Monod term for S_F, NO3 to NO2	$= \frac{C_{SF}}{K_{F2} + C_{SF}}$
MT_S_F3 Monod term for S_F, NO2 to NO	$= \frac{C_{SF}}{K_{F3} + C_{SF}}$
MT_S_F4 Monod term for S_F, NO to N2O	$= \frac{C_{SF}}{K_{F4} + C_{SF}}$
MT_S_F5 Monod term for S_F, N2O to N2	$= \frac{C_{SF}}{K_{F5} + C_{SF}}$
MT_S_NH Monod term for ammonium	$= \frac{C_{SNHx}}{K_{NH} + C_{SNHx}}$
MT_S_NOx Monod term for S_NO	$= \frac{S_{NOx}}{K_{NOx} + S_{NOx}}$
MT_S_O Monod term for oxygen	$= \frac{C_{SO}}{K_O + C_{SO}}$
MT_S_PO Monod term for S_PO	$= \frac{C_{SPO}}{K_P + C_{SPO}}$
MT_S_VFA1 Monod term for S_VFA	$= \frac{C_{SVFA}}{K_{VFA1} + C_{SVFA}}$
MT_S_VFA2 Substrate Monod term for anoxic growth of OHOs, NO3 to NO2	$= \frac{C_{SVFA}}{K_{VFA2} + C_{SVFA}}$

Name / Description	Expression
MT_S_VFA3 Substrate Monod term for anoxic growth of OHOs, NO ₂ to NO	$= \frac{C_{SVFA}}{K_{VFA3} + C_{SVFA}}$
MT_S_VFA4 Substrate Monod term for anoxic growth of OHOs, NO to N ₂ O	$= \frac{C_{SVFA}}{K_{VFA4} + C_{SVFA}}$
MT_S_VFA5 Substrate Monod term for anoxic growth of OHOs, N ₂ O to N ₂	$= \frac{C_{SVFA}}{K_{VFA5} + C_{SVFA}}$
MT_XC_B Monod term for XC_B	$= \frac{(C_{XC_B}/C_{XOHO})}{K_{X,Temp} + (C_{XC_B}/C_{XOHO})}$
MT_X_PAO_Stor Monod term for X_PAO_Stor	$= \frac{(C_{XPAO,Stor}/C_{XPAO})}{K_{PAO,Stor} + (C_{XPAO,Stor}/C_{XPAO})}$

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
H_Tank	out_2	Depth of the tank	---	m
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 data	---	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:

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

$$X_U = X_{COD} - X_{OHO} - X_{CB} - X_{AOB,in} - X_{NOB,in} - X_{ANA,in} - X_{PAO,in} - X_{PAO,Stor,in}$$

$$= X_{COD} \cdot (1 - (f_{X_{CB}} + f_{X_{OHO}})) - (X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{PAO,Stor,in})$$

$$X_{Ash} = i_{ISS,BM} \cdot (X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + X_{OHO})$$

$$= i_{ISS,BM} \cdot (X_{AOB,in} + X_{NOB,in} + X_{ANA,in} + X_{PAO,in} + (i_{COD,VSS} \cdot f_{X_{OHO}}) \cdot X_{VSS})$$

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

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

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

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

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

$$S_{SO} = SO_4$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Last Updated: 12/06/2024

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 ₃ COO ⁻	Acetate	gAc/m ³
S_Pr	CH ₃ CH ₂ COO ⁻	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 _{Y_u} O _{Z_u} N _{A_u} P _{B_u}	Unbiodegradable Soluble Organics	g/m ³
S_F	CH _{Y_f} O _{Z_f} N _{A_f} P _{B_f}	Fermentable Biodegradable Soluble Organics	g/m ³

Name	Empirical formula	Description	Units
S_Glu	$C_6H_{12}O_6$	Glucose	g/m^3
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_NH ₄	$MgNH_4PO_4 \cdot 6H_2O$	Struvite	g/m^3
X_ACP	$Ca_3(PO_4)_2$	Calcium Phosphate	g/m^3
X_Str_K	$MgKPO_4 \cdot 6H_2O$	K-struvite	g/m^3
X_Cal	$CaCO_3$	Calcite	g/m^3
X_Mag	$MgCO_3$	Magnesite	g/m^3
X_Newb	$MgHPO_4$	Newberyite	g/m^3
X_OHO	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	Ordinary heterotrophic organisms	g/m^3
X_PAO	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	Phosphate accumulating organisms	g/m^3
X_AD	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	Acidogens	g/m^3
X_AC	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	Acetogens	g/m^3
X_AM	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	Acetoclastic Methanogens	g/m^3
X_HM	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	Hydrogenotrophic methanogens	g/m^3
X_U_Org	$CH_{Y_e}O_{Z_e}N_{A_e}P_{B_e}$	Endogenous residue	g/m^3
X_B_Inf	$CH_{Y_{bps}}O_{Z_{bps}}N_{A_{bps}}P_{B_{bps}}$	Primary sludge biodegradable particulate organics	g/m^3
X_ANO	$CH_{Y_o}O_{Z_o}N_{A_o}P_{B_o}$	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_N ₂	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, $Mg_dK_cCa_fPO_3$) and polyhydroxy alkanoates

(PHA, C₄H₆O₂) 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/m³ 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. CO₃ represents CO₃²⁻ plus HCO₃⁻ plus H₂CO₃ plus various other aqueous ion pair (not precipitates) carbonate complexes present in the solution, such as MgCO₃ and CaHCO₃⁺. 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.

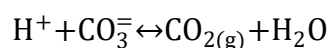
Interphase transfer

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.:



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 ($\text{Ca}(\text{PO}_4)_2$), 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-hydroxyalkanoates 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. $\text{C}_x\text{H}_y\text{O}_z\text{N}_a$. 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 pairing 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_{H_2}) Acidogenesis
Acidogenesis H	High p_{H_2} 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

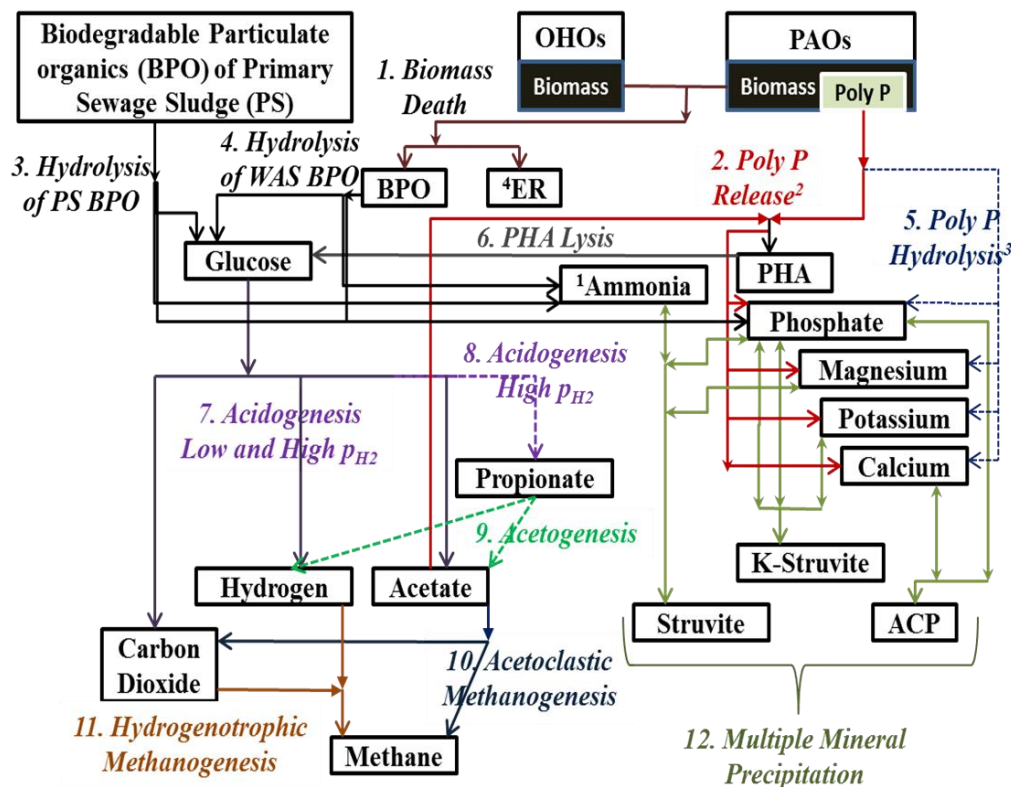


Figure 1 - Process scheme for the anaerobic sub-model of the PWM_SA model.
 Note that (1) ammonia is released in the NH_3 form and picks up a proton from H_2CO_3 to form NH_4^+ (the N content of influent organics is alkalinity fed to the AD), (2) Process 2 is for PP release with the uptake of acetate 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. $\text{ISS}_{\text{BM}} = 0.15 \text{ mgISS/mg biomassVSS}$), the stored PP in the PAOs, all precipitates (struvite, K-struvite, 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 mgCaCO₃/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	l/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
KL_a_CO2	Rate of active CO2 gas exchange rate with aeration	1	l/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/inhibition 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	molH/l
K_I_H_HM	H ⁺ inhibition for hydrogenotrophic methanogens	0.00053	molH/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/m ³

Name	Description	Value	Units
K_S_NHx_ANO	Saturation coeff of autotrophs for ammonium	1	gNH ₃ -N/m ³
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 H ₂ Acetogenesis yield	0.1074	mol/mol
Y_AH	Hi H ₂ 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 X _{ac}	0.015	/d
b_AD	Decay rate constant for X _{ad}	0.041	/d
b_AM	Decay rate constant for X _{am}	0.037	/d
b_ANO	Decay rate	0.15	/d
b_HM	Decay rate constant for X _{hm}	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.

CH4 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.

CO2 evolution is similar, except that its equilibrium vapour pressure is a complex function of ionic component concentration, although principally **S_CO3** and **S_H**.

N2 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 CH4 and CO2, 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 m³ 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 masses of the other liquid components.

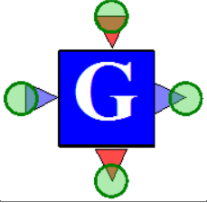
The aerobic reactor model has a similar rescale facility, except that it has no gas space, so only the liquid phase components get rescaled.

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GENERATORS

	Palette Group	Input and Output
	Category	IUWS_Generators
	Icon	generator

DWF2

Last Updated: 12/06/2024

Instances

IUWS1, IUWS2

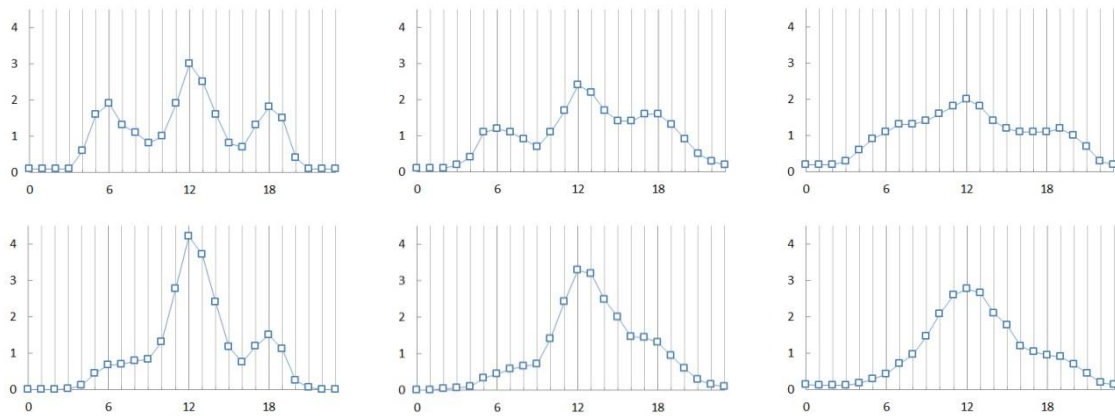
Description

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:

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

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

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

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	m ²
Inh	Number of inhabitants	3,000	---
Qavg_tot	Average volume produced	---	m ³ /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 (NH ₄ , PO ₄) (per hour)	---	---

Name	Description	Value	Units
PP_NP_corr	Corrected pollution pattern (NH ₄ , PO ₄) (per hour)	---	---
PPwe_NP	Actual pollution pattern for weekends (NH ₄ , PO ₄) (per hour)	---	---
PPwe_NP_corr	Corrected pollution pattern for weekends (NH ₄ , PO ₄) (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 (NH ₄ , PO ₄) (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 (NH ₄ , PO ₄) 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	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 (component vector)	---	---
Q_DWF	Out 2	Dry weather flow	---	m ³ /d

Calc_Evaporation

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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:

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

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

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

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:

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

$$Out_i = M_i \quad \text{if accumulation is present; or}$$

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

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	l/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

Last Updated: 12/06/2024

Instances

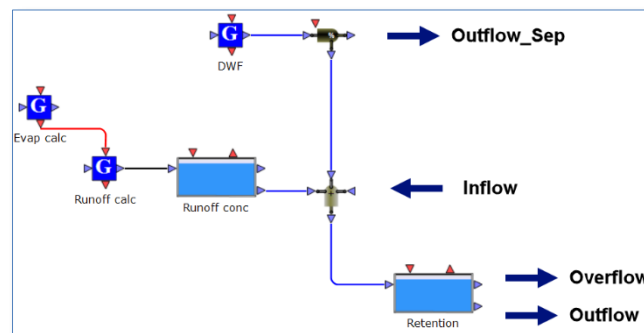
IUWS1, IUWS2

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

Name	Description	Value	Units
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
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	l/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	<i>Solar radiation</i>	15	W/m2
Q_Max	in_2	<i>Maximum outflow</i>	10	m3/d
Rain	in_2	<i>Input from the rain influent file</i>	0	mm/d
T_Air	in_2	<i>Air temperature</i>	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

Last Updated: 12/06/2024

Instances

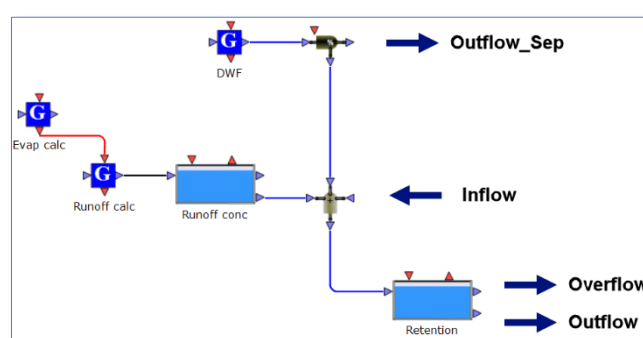
IUWS1, IUWS2

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

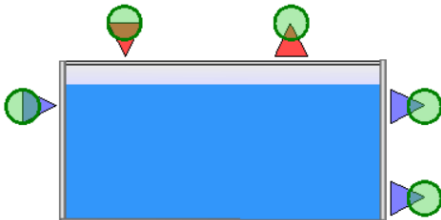
Name	Description	Value	Units
Mean_LxIE[NH4]	Vector containing the mean loads	10	g/inh/d
Mean_LxIE[PO4]	Vector containing the mean loads	2	g/inh/d
Mean_LxIE[SCOD]	Vector containing the mean loads	30	g/inh/d
Mean_LxIE[XCOD]	Vector containing the mean loads	70	g/inh/d
Mean_LxIE[XTSS]	Vector containing the 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	---
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 resuspension 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 resuspension 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/m ²
Q_Max	in_2	Maximum outflow	10	m ³ /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/m ³
Q_Pump	in_2	Maximum pumped outflow	1	m ³ /d
E_Pump	out_2	Pumping energy	---	kW/d
FD	out_2	Filling degree	---	---
Q_DWF	out_2	Dry weather flow	---	m ³ /d
Q_Out	out_2	Outflow from dry and wet weather	---	m ³ /d
Q_Over	out_2	Overflow from dry and wet weather	---	m ³ /d
Q_WWF	out_2	Wet-weather outflow	---	m ³ /d
V_Over	out_2	Cumulated overflown volume (in wet-weather)	---	m ³

SEWER TANK

	Palette Group	Sewer
	Category	Tanks_Sewer
	Icon	sewer_tank

Freeflow

Last Updated: 12/06/2024

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:

$$(V < V_{min}): Q_{pump}^* = 0$$

$$(Q_{in} \geq Q_{pump} \parallel V \geq f \cdot V_{max}): Q_{pump}^* = Q_{pump}$$

$$(Q_{in} < Q_{pump} \parallel V < f \cdot V_{max}): Q_{pump}^* = Q_{in}$$

The actual maximum flow rate, as:

$$(FD_{dw} < FD_{dw,lim} \parallel FD^* > FD): Q_{max}^* = Q_{max}$$

$$(FD_{dw} \geq FD_{dw,lim} \parallel FD^* \leq FD): Q_{max}^* = Q_{max,lim}$$

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 $Q_{out}=Q_{pump}$	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
Overflow	out_3	Overflow (component vector)	---	g/d
<i>E_Pump_sp</i>	<i>in_2</i>		<i>0.04</i>	<i>kWh/m3</i>
<i>FD_In</i>	<i>in_2</i>		<i>0</i>	
<i>Q_Max</i>	<i>in_2</i>		<i>10</i>	<i>m3/d</i>
<i>Q_Pump</i>	<i>in_2</i>		<i>1</i>	<i>m3/d</i>
V_Over	out_3	Accumulated overflowed 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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

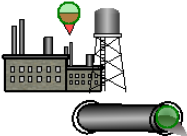
None

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) Municipality

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

	Palette Group	Input and Output
	Category	
	Icon	inwwtp

ASM2dMod.Influent_ASM2a

Last Updated: 12/06/2024

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 by 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.

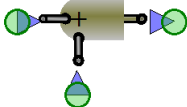
Evaluating Results

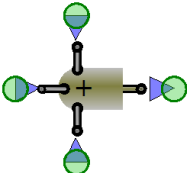
The outputs provide a number of aids to evaluating the fractionation. For example:

- 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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

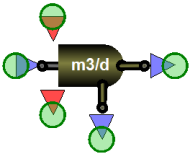
Derived State Variables

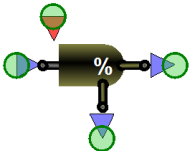
None

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

Last Updated: 12/06/2024

Instances

All

Description

It splits the incoming flow into two flows:

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

$$(Q_{out,1}^* > Q_{in}): Q_{out,1} = Q_{in}$$

$$(Q_{out,1}^* \leq Q_{in}): Q_{out,1} = Q_{out,1}^*$$

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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
<i>f Out 01</i>	<i>in 2</i>	<i>Desired portion of flow to outflow #1</i>	<i>1</i>	---
<i>f Out 02</i>	<i>in 2</i>	<i>Desired portion of flow to outflow #1</i>	<i>1</i>	---
Out 01	out 1	Outflow #01	---	g/d
Out 02	out 2	Outflow #02	---	g/d

SplitRel02s

Last Updated: 12/06/2024

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

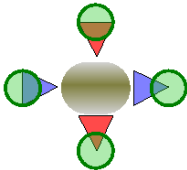
Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
<i>f_Out_01</i>	<i>in_2</i>	<i>Desired portion of flow to outflow #1</i>	1	---
<i>f_Out_02</i>	<i>in_2</i>	<i>Desired portion of flow to outflow #2</i>	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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

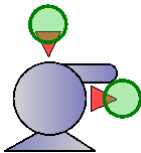
Derived State Variables

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

Last Updated: 12/06/2024

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	m ³ /d
TSS	in_2	TSS concentration in the pumped liquid	3,000	g/m ³
EnergyCons	out_2	Energy consumption since start of simulation	---	kWh
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m ³
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m ³ /d

CF_Q_Throttle

Last Updated: 12/06/2024

Instances

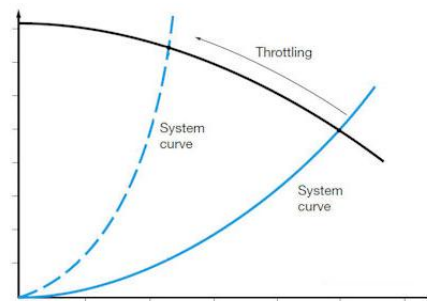
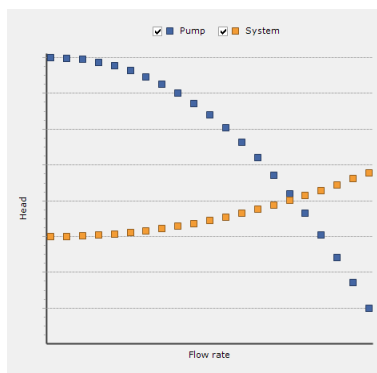
All

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.:

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

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

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

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_H2O	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

Last Updated: 12/06/2024

Instances

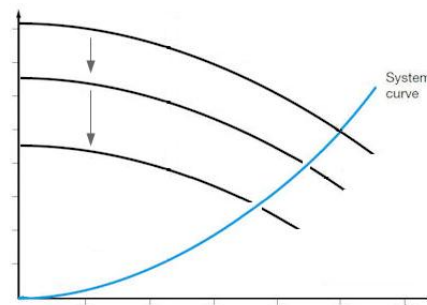
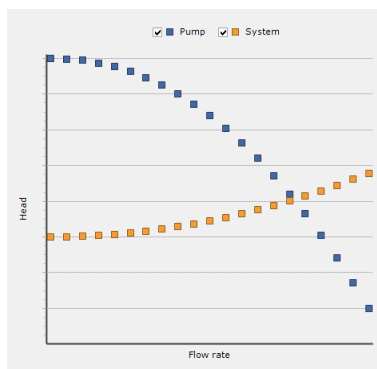
All

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.:

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

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

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

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 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	m ³ /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_H2O	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	m ³ /d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m ³ /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*s
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	m ³ /d
Q_MinVFD_Duty	Minimum flow rate for VFD pumps operating at N=Nmin	m ³ /d
Q_Max	Maximum flow rate in the specified system	m ³ /d
Q_Min	Minimum flow rate in the specified system	m ³ /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	m ³ /d
TSS	in_2	TSS concentration in the pumped liquid	3,000	g/m ³
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/m ³
PowerCons	out_2	Actual power consumption	---	kWh/d
N	out_2	Actual / nominal relative pump speed	---	---
Q_Out	out_2	Actual flow rate	---	m ³ /d

CF_HQ_VFD

Last Updated: 12/06/2024

Instances

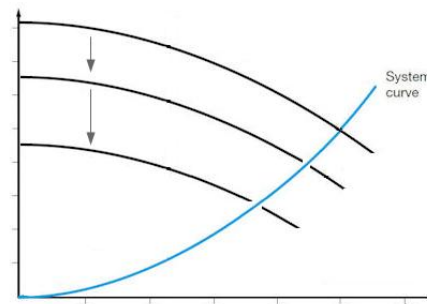
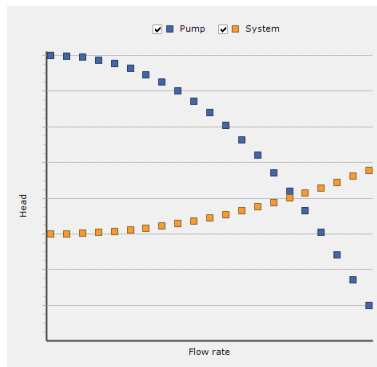
All

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	m ³ /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	m ³ /d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m ³ /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	m ³ /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	m ³ /d
TSS	in 2	TSS concentration in the pumped liquid	3,000	g/m ³
EnergyCons	out 2	Energy consumption since start of simulation	---	kWh
EnergySpec	out 2	Specific energy consumption from start	---	kWh/m ³
PowerCons	out 2	Actual power consumption	---	kWh/d
N	out 2	Actual / nominal relative pump speed	---	---
Q_Out	out 2	Actual flow rate	---	m ³ /d

CF_HN_VFD

Last Updated: 12/06/2024

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 :

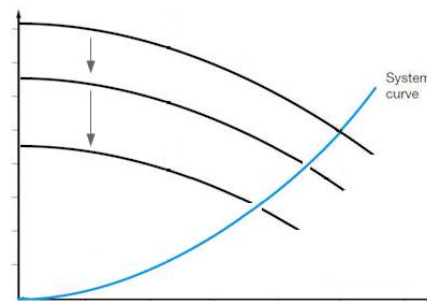
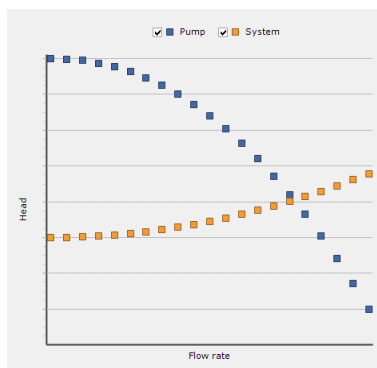
$$H_1 = N^2 A - B N^{2-C} Q_1^C$$

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	m ³ /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	m ³ /d
Q_3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m ³ /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	m ³ /d
TSS	in 2	TSS concentration in the pumped liquid	3,000	g/m ³
EnergyCons	out 2	Energy consumption since start of simulation	---	kWh
EnergySpec	out 2	Specific energy consumption from start	---	kWh/m ³
PowerCons	out 2	Actual power consumption	---	kWh/d
N	out 2	Actual / nominal relative pump speed	---	---
Q_Out	out 2	Actual flow rate	---	m ³ /d

CF_N_VFD

Last Updated: 12/06/2024

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:

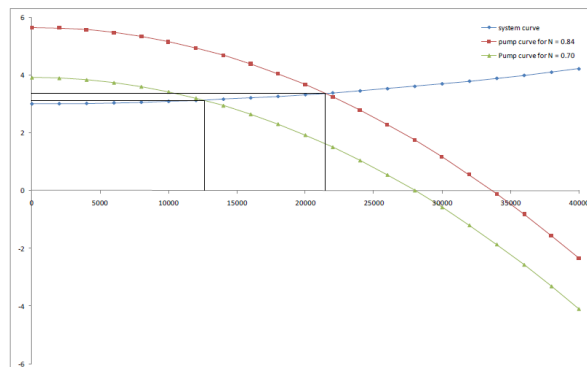
$$H_1 = N^2 A - B N^{2-C} Q_1^C$$

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 unknowns, H and Q , but it cannot be solved analytically. Therefore H_{system} and H_{pump} 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.

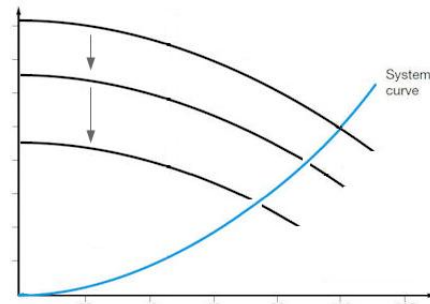
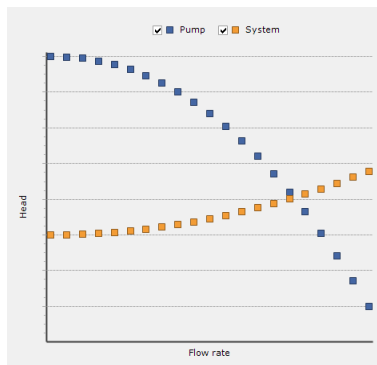


Discretized system curve and pump curve for two different values of the relative pump speed, N .

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	m ³ /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 H2O	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	m ³ /d
Q 3	Point (flow rate) on the pump curve (if unknown: -1)	-1	m ³ /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

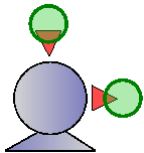
Derived State Variables

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	m ³ /d
TSS	in_2	TSS concentration in the pumped liquid	3,000	g/m ³
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/m ³
PowerCons	out_2	Actual power consumption	---	kWh/d
N	out_2	Actual / nominal relative pump speed	---	---
Q_Out	out_2	Actual flow rate	---	m ³ /d

BLOWERS

	Palette Group	Blowers and Pumps
	Category	Blowers
	Icon Name	blower

CF_Q_VFD

Last Updated: 12/06/2024

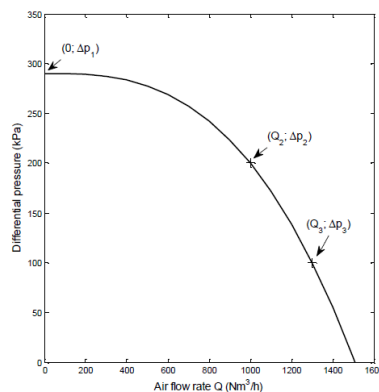
Instances

All

Description

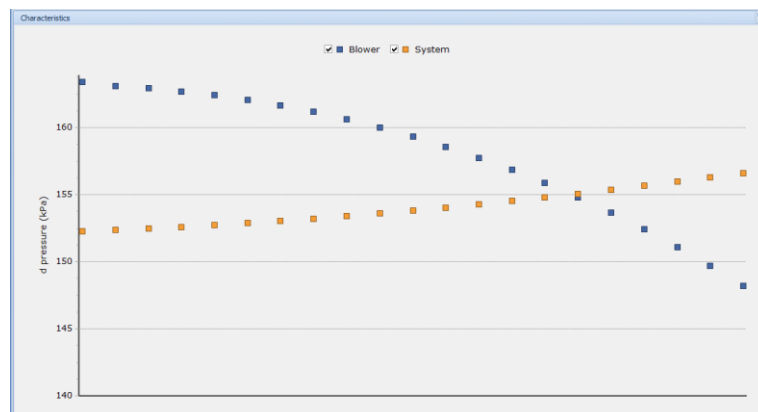
The model calculates the power consumption of a centrifugal (CF) blower controlled with Variable Frequency Drive (VFD). The calculation is based on the air flow rate, Q .

The differential pressure vs. flow rate for a centrifugal blower follows a power-law based on combinations between flow and pressure, (Q_1, dp_1) (Q_2, dp_2) (Q_3, dp_3) :



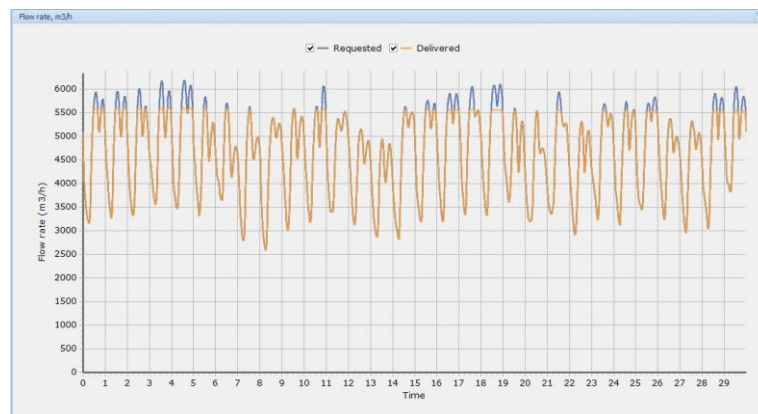
Blower curve following a power law based on three flow-pressure combinations, (Q, dp)

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.



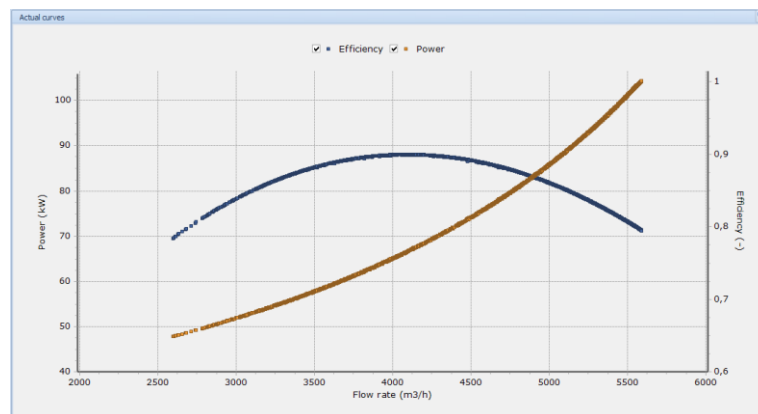
Differential pressure of the blower and the system.

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 unknown: -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

Last Updated: 12/06/2024

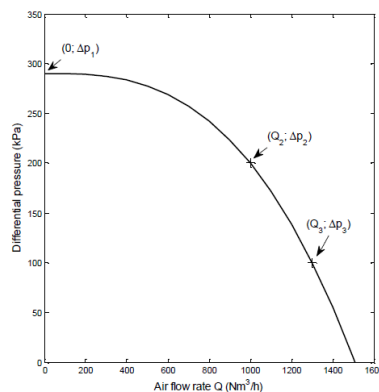
Instances

All

Description

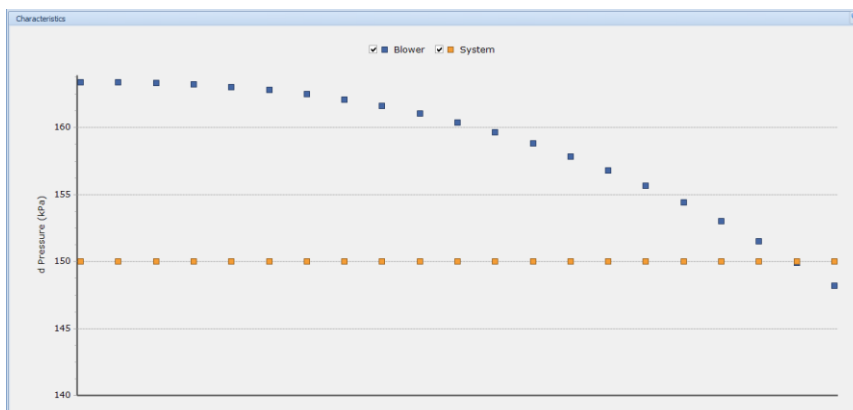
The model calculates the power consumption of a centrifugal (CF) blower controlled with Variable Frequency Drive (VFD). The calculation is based on air flow rate, Q , and pressure.

The differential pressure vs. flow rate for a centrifugal blower follows a power-law based on combinations between flow and pressure, (Q_1, dp_1) (Q_2, dp_2) (Q_3, dp_3) :



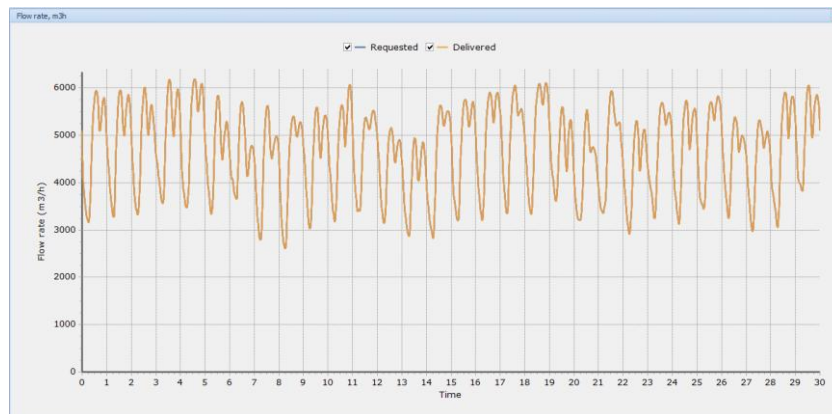
Blower curve following a power law based on three flow-pressure combinations, (Q, dp)

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.



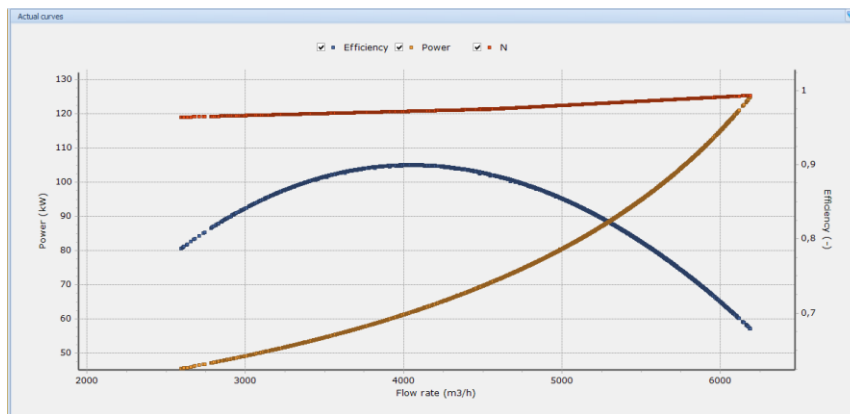
Differential pressure of the blower and the system.

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 unknown: -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

Last Updated: 12/06/2024

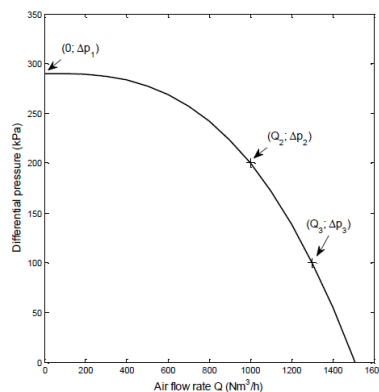
Instances

All

Description

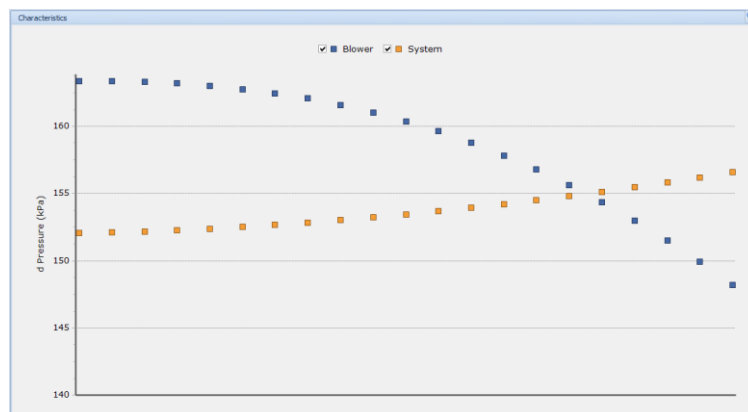
The model calculates the power consumption of a centrifugal (CF) blower controlled with variable Inlet Guide Vane (IGV). The calculation is based on the air flow rate, Q .

The differential pressure vs. flow rate for a centrifugal blower follows a power-law based on combinations between flow and pressure, (Q_1, dp_1) (Q_2, dp_2) (Q_3, dp_3):



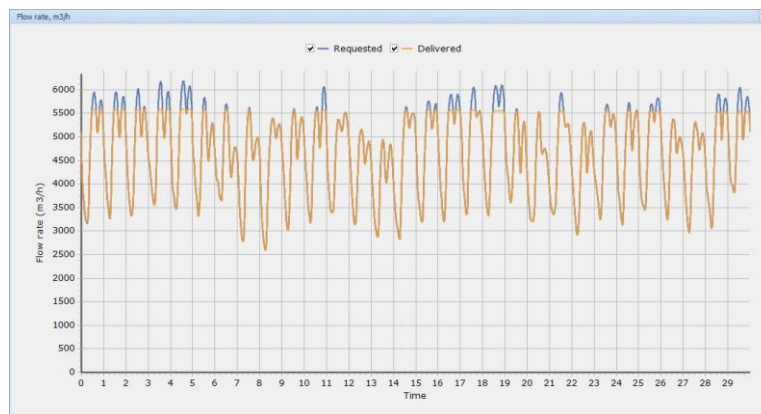
Blower curve following a power law based on three flow-pressure combinations, (Q, dp)

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.



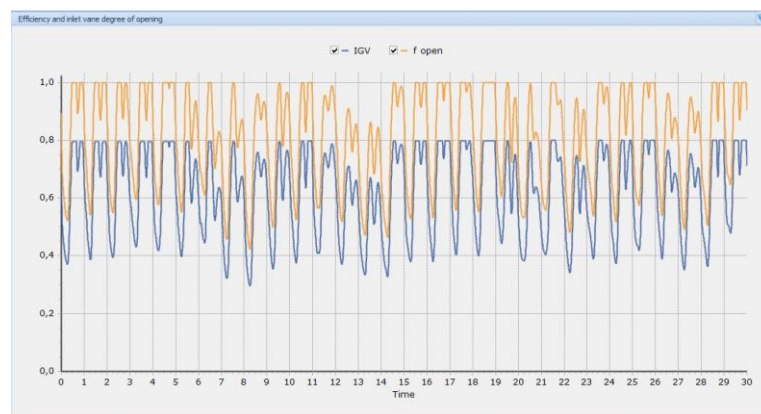
Differential pressure of the blower and the system.

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 unknown: -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
Q₁	Shutoff flow rate corresponding to dp1	0	m ³ /d
Q₂	Design flow rate corresponding to dp2	2000	m ³ /d
Q₃	Flow rate on the blower curve at dp3 (if unknown: -1.0)	-1	m ³ /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	m ³ /d
Q_Max	Maximum flow rate given the system curve	m ³ /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	m ³ /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/m ³
PowerCons	out 2	Actual power consumption	---	kWh/d
Q_{Out}	out 2	Actual flow rate	---	m ³ /d
P_{Out}	out 2	Absolute output pressure	---	Pa
dP_{Out}	out 2	Differential output pressure	---	Pa

PD_Q_VFD

Last Updated: 12/06/2024

Instances

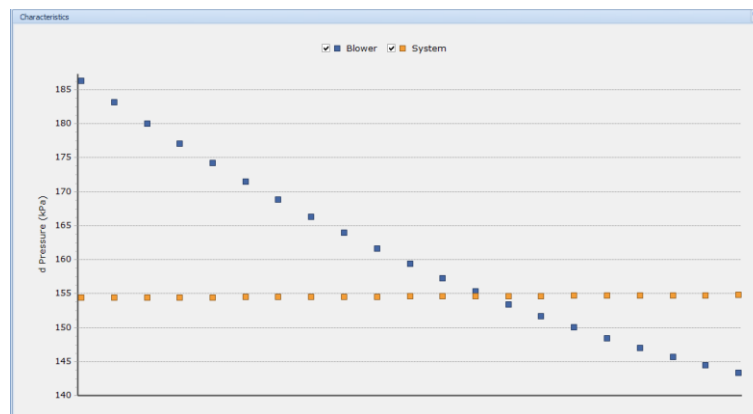
All

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 .

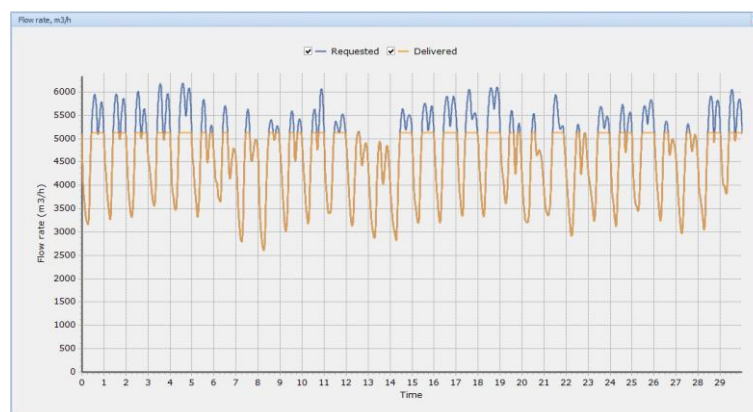
The efficiency of a PD blower takes the friction power loss at actual operating conditions into account.

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

Name	Description	Value	Units
Pipe_Leq	Equivalent pipe length of elements causing minor losses	75	m
A_Diff	Total surface area of diffuser's membrane	70	m ²
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/(m ³ /h/m ²)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m ³ /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 unknown: -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	m ³ /d
Q ₂	Design flow rate corresponding to dp2	2000	m ³ /d
Q ₃	Flow rate on the blower curve at dp3 (>Q ₂) (if unknown: -1.0)	-1	m ³ /d

State Variables

Name	Description	Units
Q ₀	Flow rate at full speed and P _{out} =P _{in} (extrapolated value)	m ³ /d
P_Duty	Operating pressure at max flow rate Q _{NoCtrl}	Pa
P_System_Duty	Actual operating pressure at Q _{In} (via system curve)	Pa
Q_Duty	Maximum flow rate	m ³ /d
Q_Max	Maximum flow rate given the system curve	m ³ /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	m ³ /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/m ³
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m ³ /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

Last Updated: 12/06/2024

Instances

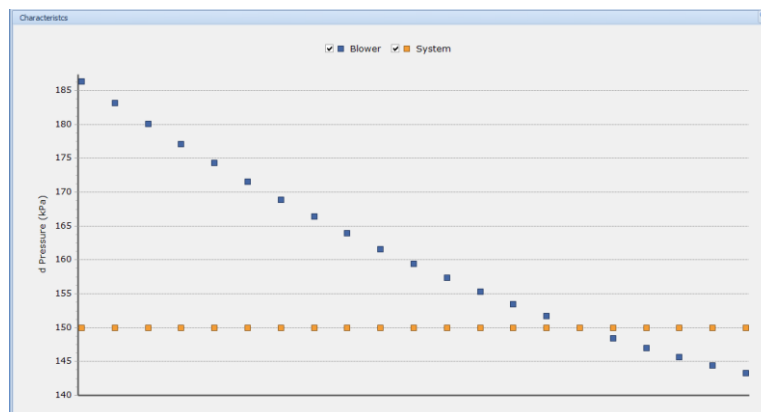
All

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.

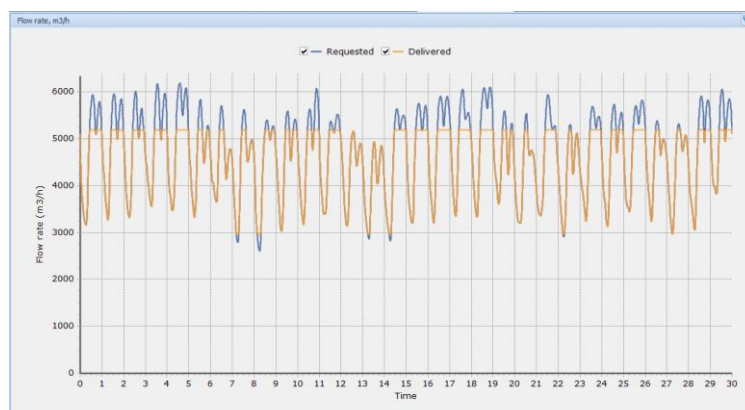
The efficiency of a PD blower takes the friction power loss at actual operating conditions into account.

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	---

Name	Description	Value	Units
dPower_Friction	Friction power losses (rel to max power consumption)	0.05	---
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 unknown: -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

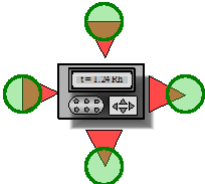
Derived State Variables

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

Last Updated: 12/06/2024

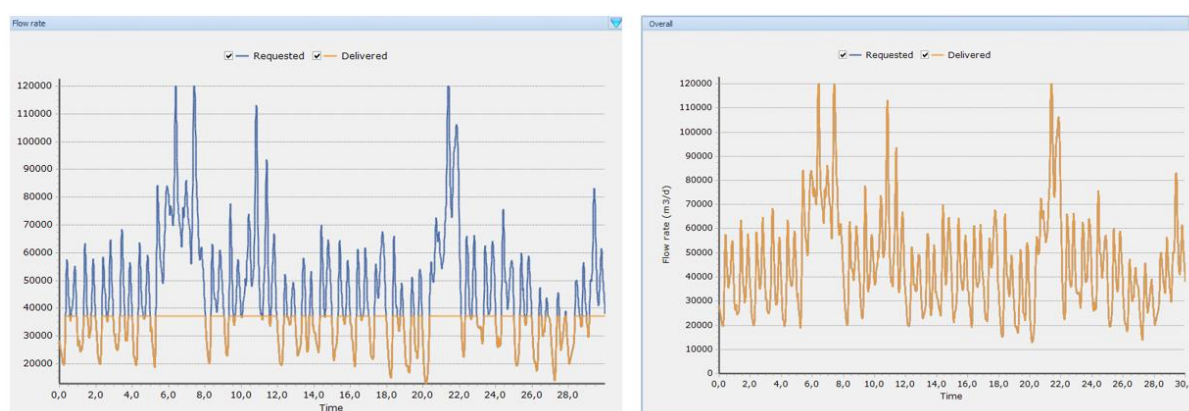
Instances

All

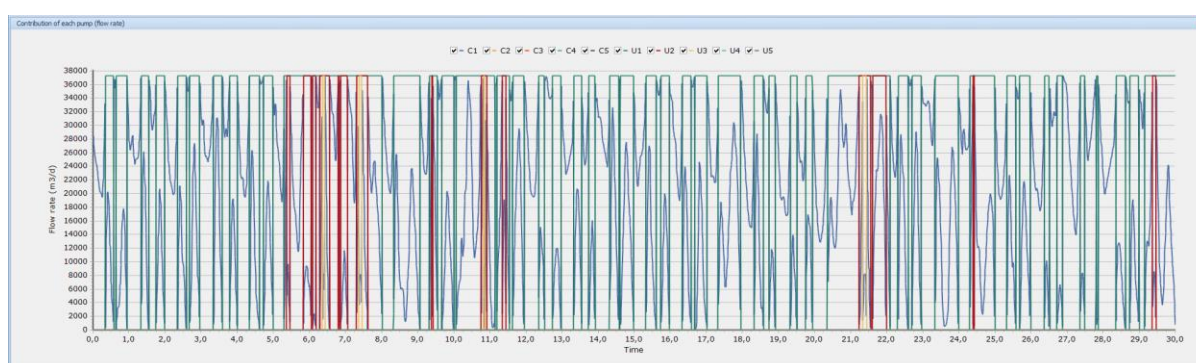
Description

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	---

Name	Description	Value	Units
Is_PU04	Unregulated pump #4 present (1) or not (0)	1	---
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/m ³
PowerCons	out 2	Actual power consumption	---	kWh/d
Q_Out	out 2	Actual flow rate	---	m ³ /d

Separate10_CFQVFD

Last Updated: 12/06/2024

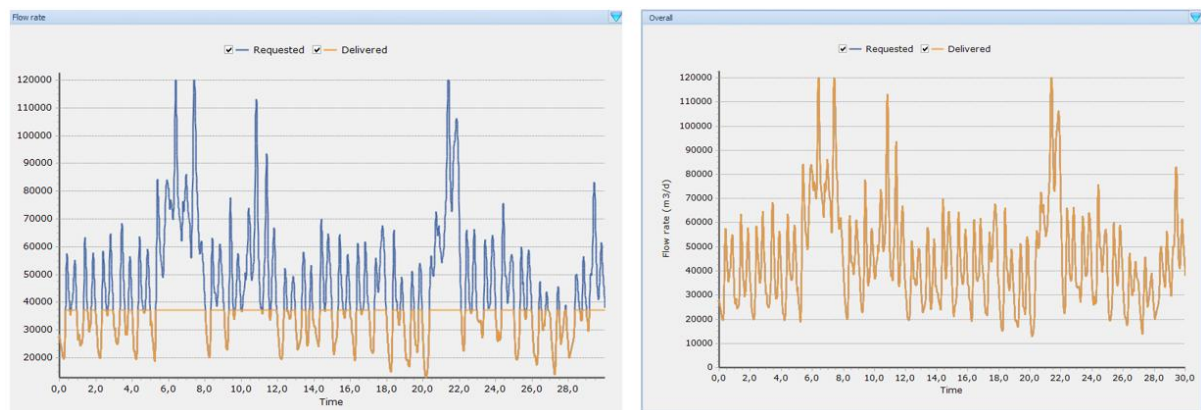
Instances

All

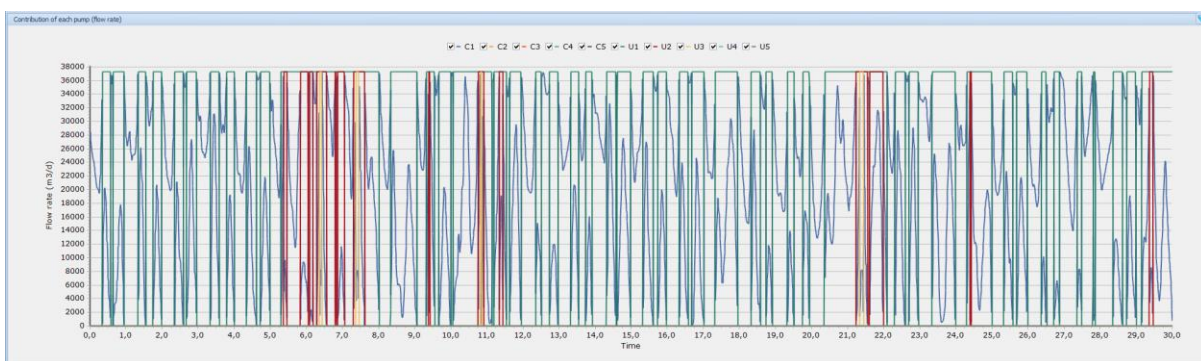
Description

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	---

Name	Description	Value	Units
Is_PU04	Unregulated pump #4 present (1) or not (0)	1	---
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/m ³
PowerCons	out 2	Actual power consumption	---	kWh/d
Q_Out	out 2	Actual flow rate	---	m ³ /d

Common10_CFHQVFD

Last Updated: 12/06/2024

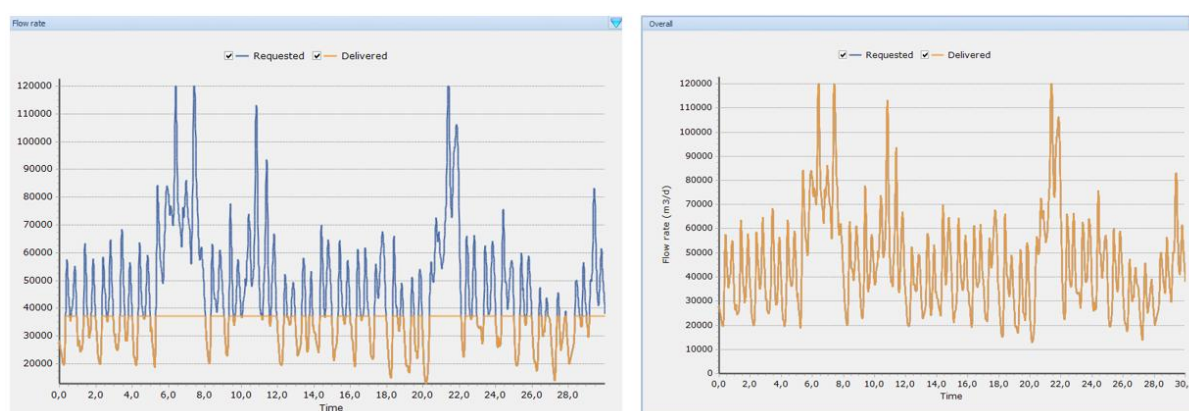
Instances

All

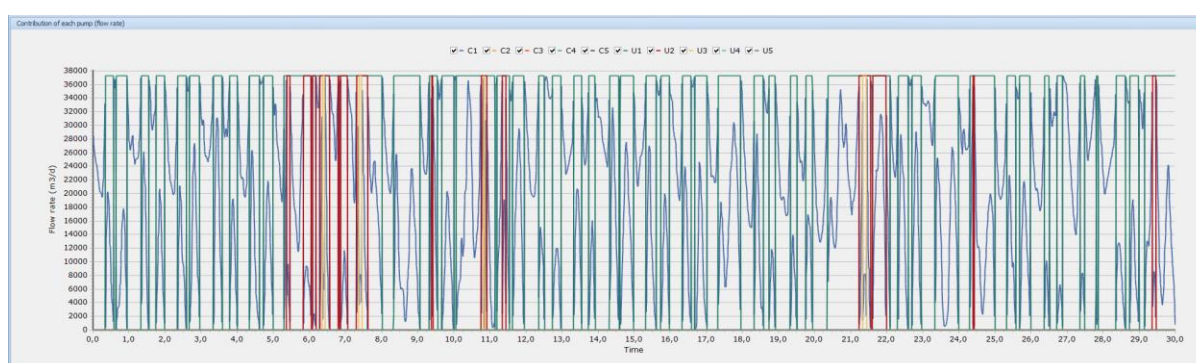
Description

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	---

Name	Description	Value	Units
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_H2O	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	m ³ /d
PC01_Qmin	Minimum flow rate attainable by PC #1	m ³ /d
PC02_Qmax	Maximum flow rate attainable by PC #2	m ³ /d
PC02_Qmin	Minimum flow rate attainable by PC #2	m ³ /d
PC03_Qmax	Maximum flow rate attainable by PC #3	m ³ /d
PC03_Qmin	Minimum flow rate attainable by PC #3	m ³ /d
PC04_Qmax	Maximum flow rate attainable by PC #4	m ³ /d
PC04_Qmin	Minimum flow rate attainable by PC #4	m ³ /d
PC05_Qmax	Maximum flow rate attainable by PC #5	m ³ /d
PC05_Qmin	Minimum flow rate attainable by PC #5	m ³ /d
PU01_Qmax	Maximum flow rate attainable by PU #1	m ³ /d
PU02_Qmax	Maximum flow rate attainable by PU #2	m ³ /d
PU03_Qmax	Maximum flow rate attainable by PU #3	m ³ /d
PU04_Qmax	Maximum flow rate attainable by PU #4	m ³ /d
PU05_Qmax	Maximum flow rate attainable by PU #5	m ³ /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

Name	Class Name
PU01	CF HQ VFD
PU02	CF HQ VFD
PU03	CF HQ VFD
PU04	CF HQ VFD
PU05	CF HQ VFD

Interface Variables

Name	Terminal	Description	Value	Units
<i>H_e</i>	<i>in_2</i>	<i>Elevation head to be overcome</i>	<i>0</i>	<i>m</i>
<i>Q_{Op}</i>	<i>in_2</i>	<i>Desired operating flow rate</i>	<i>20,000</i>	<i>m³/d</i>
<i>TSS</i>	<i>in_2</i>	<i>TSS concentration in the pumped liquid</i>	<i>3,000</i>	<i>g/m³</i>
<i>dH_{Ext}</i>	<i>in_2</i>	<i>Head loss due to external factors (optional)</i>	<i>0</i>	<i>m</i>
EnergySpec	<i>out_2</i>	Specific energy consumption from start	---	kWh/m ³
PowerCons	<i>out_2</i>	Actual power consumption	---	kWh/d
Q_{Out}	<i>out_2</i>	Actual flow rate	---	m ³ /d

Common10_CFHNVFD

Last Updated: 12/06/2024

Instances

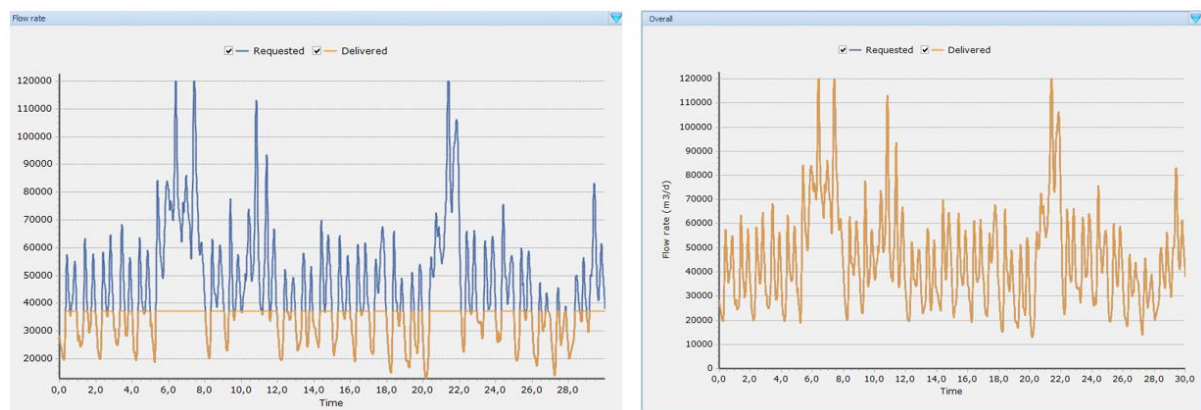
All

Description

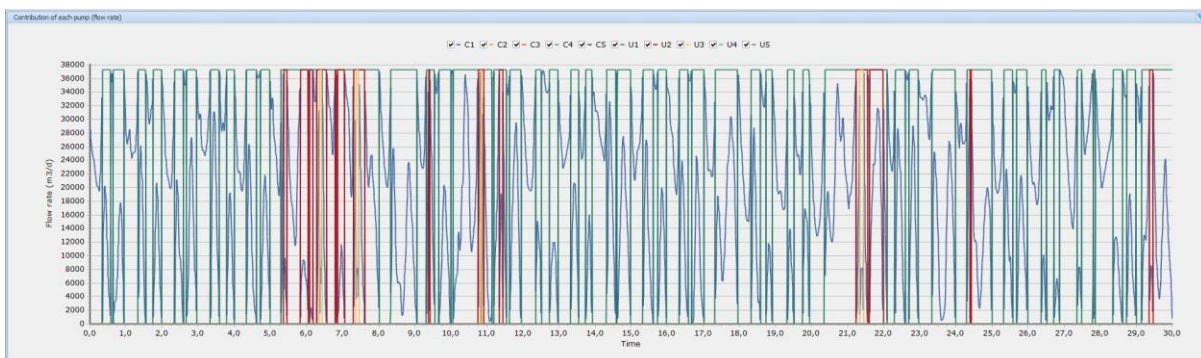
Description

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	---

Name	Description	Value	Units
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	---
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_H2O	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

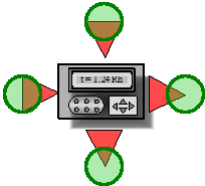
Name	Class Name
PC01	CF HN VFD
PC02	CF HN VFD
PC03	CF HN VFD
PC04	CF HN VFD
PC05	CF HN VFD
PU01	CF HN VFD
PU02	CF HN VFD
PU03	CF HN VFD
PU04	CF HN VFD
PU05	CF HN VFD

Interface Variables

Name	Terminal	Description	Value	Units
H_e	in 2	Elevation head to be overcome	0	m

Name	Terminal	Description	Value	Units
PC01_Nop	in_2	<i>Desired relative speed of controllable pump #1</i>	0.6	---
PC02_Nop	in_2	<i>Desired relative speed of controllable pump #2</i>	0.6	---
PC03_Nop	in_2	<i>Desired relative speed of controllable pump #3</i>	0.6	---
PC04_Nop	in_2	<i>Desired relative speed of controllable pump #4</i>	0.6	---
PC05_Nop	in_2	<i>Desired relative speed of controllable pump #5</i>	0.6	---
Q_Op	in_2	<i>Desired operating flow rate</i>	20,000	m ³ /d
TSS	in_2	<i>TSS concentration in the pumped liquid</i>	3,000	g/m ³
dH_Ext	in_2	<i>Head loss due to external factors (optional)</i>	0	m
EnergySpec	out_2	Specific energy consumption from start	---	kWh/m ³
PowerCons	out_2	Actual power consumption	---	kWh/d
Q_Out	out_2	Actual flow rate	---	m ³ /d

BLOWER CONTROLLERS

	Palette Group	Blowers and Pumps
	Category	Blowers
	Icon Name	controller_blower

Common10_CFHQVFD

Last Updated: 12/06/2024

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	m ²
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/(m ³ /h/m ²)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m ³ /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	m ³ /d
BC01_Qmin	Minimum flow rate attainable by BC #1	m ³ /d
BC02_Qmax	Maximum flow rate attainable by BC #2	m ³ /d
BC02_Qmin	Minimum flow rate attainable by BC #2	m ³ /d
BC03_Qmax	Maximum flow rate attainable by BC #3	m ³ /d
BC03_Qmin	Minimum flow rate attainable by BC #3	m ³ /d
BC04_Qmax	Maximum flow rate attainable by BC #4	m ³ /d
BC04_Qmin	Minimum flow rate attainable by BC #4	m ³ /d

Name	Description	Units
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-point	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_PDHSVFD

Last Updated: 12/06/2024

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	m ²
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/(m ³ /h/m ²)
H_sl	Altitude above sea level	0	m
Kv	Valve flow factor to quantify friction loss	300,000	m ³ /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	m ³ /d
BC01_Qmin	Minimum flow rate attainable by BC #1	m ³ /d
BC02_Qmax	Maximum flow rate attainable by BC #2	m ³ /d
BC02_Qmin	Minimum flow rate attainable by BC #2	m ³ /d
BC03_Qmax	Maximum flow rate attainable by BC #3	m ³ /d
BC03_Qmin	Minimum flow rate attainable by BC #3	m ³ /d

Name	Description	Units
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
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

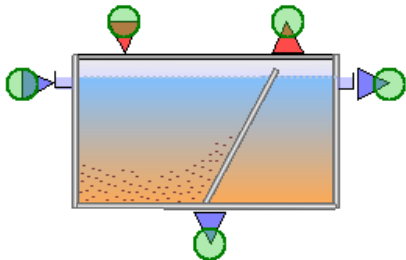
Sub-models

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

Last Updated: 12/06/2024

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_{out} and Q_{under} 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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
r_COD	Reduction in COD concentration	---
r_TSS	Reduction in TSS concentration	---

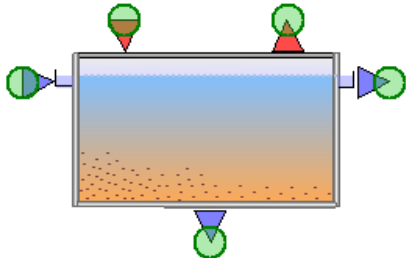
Derived State Variables

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	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
Q_Under	in_2	<i>Desired sludge flow</i>	50	m ³ /d
P_Pump	out_3	Pumping power	---	kWh/d

GRIT REMOVAL

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

Grit_Ideal

Last Updated: 12/06/2024

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_{out} and Q_{under} 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:

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

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

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

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

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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
r_COD	Reduction in COD concentration	---
r_TSS	Reduction in TSS concentration	---

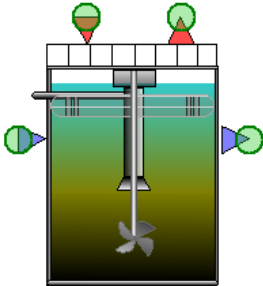
Derived State Variables

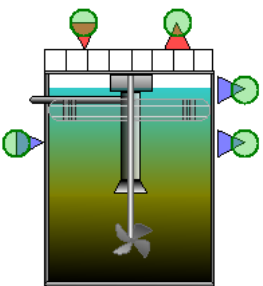
None

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/m ³
Q_Under	in 2	Desired sludge flow	50	m ³ /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

Last Updated: 12/06/2024

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	m ³

State Variables

Name	Description	Units
C	Concentration of the state components (vector)	g/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /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	---	m ³
E_Mix_sp	in_2	Mixing energy per unit volume	0.005	kW/m ³

Tanks_Buffer.VolumeVariable

Last Updated: 12/06/2024

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	<i>Mixing energy per unit volume</i>	0.005	kW/m3

Tanks_Buffer.VolumePumped

Last Updated: 12/06/2024

Instances

All

Description

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

$$V < V_{min}: Q_{out} = 0$$

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

$$V < V_{max}: Q_{out} = Q_p$$

$$V \geq V_{max}: Q_{out} = Q_p$$

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	---	m ³
Q01_Pump	in_2	<i>Desired effluent flow rate (pump #1)</i>	100	m ³
E_Mix_sp	in_2	<i>Mixing energy per unit volume</i>	0.005	kW/m ³
E_Pump_sp	in_2	<i>Pumping energy per unit volume</i>	0.04	kWh/m ³

Tanks_Buffer.VolumePumped02

Last Updated: 12/06/2024

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):

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

and possible overflow:

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

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 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

Name	Description	Units
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Over	Overflow flow rate	m ³ /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	---	m ³
Q01_Pump	in 2	<i>Desired effluent flow rate (pump #1)</i>	100	m ³
Q02_Pump	in 2	<i>Desired effluent flow rate (pump #2)</i>	100	m ³
E_Mix_sp	in 2	<i>Mixing energy per unit volume</i>	0.005	kW/m ³
E_Pump_sp	in 2	<i>Pumping energy per unit volume</i>	0.04	kWh/m ³

Tanks_Buffer.StormTankBw

Last Updated: 12/06/2024

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.

$$V < V_{min}: Q_{out} = 0$$

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

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	<i>Pump flow rate</i>	100	m3
Qbk	in_2	<i>Background flow rate</i>	100	m3
Qlim	in_2	<i>Maximum total flow rate</i>	100	m3
E_Mix_sp	in_2	<i>Mixing energy per unit volume</i>	0.005	kW/m3

Tanks_Buffer.StormTank

Last Updated: 12/06/2024

Instances

All

Description

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

$$V < V_{min}: Q_{out} = 0$$

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

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/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Over	Overflow flow rate	m ³ /d
DT	Detention time	d
SOR	Surface Overflow Rate	m/d
vh	Horizontal velocity	m/d
r_TSS	Expected TSS removal efficiency	-

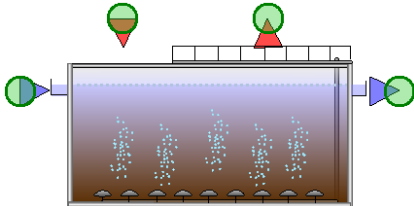
Derived State Variables

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	---	m ³
Q01_Pump	in 2	<i>Desired effluent flow rate (pump #1)</i>	<i>100</i>	<i>m³</i>
E_Mix_sp	in 2	<i>Mixing energy per unit volume</i>	<i>0.005</i>	<i>kW/m³</i>
E_Pump_sp	in 2	<i>Pumping energy per unit volume</i>	<i>0.04</i>	<i>kWh/m³</i>

ACTIVATED SLUDGE TANKS

	Palette Group	Biological Treatment
	Category	Tanks_AS, TanksMulti_AS
	Icon Name	tank_activated_sludge

VolumeConstant

Last Updated: 12/06/2024

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	m ³
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/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /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/m ³ /d

VolumePumped

Last Updated: 12/06/2024

Instances

All

Description

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

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

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/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /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/m ³ /d

VolumeVariable

Last Updated: 12/06/2024

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/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /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/m ³ /d

VolumeConstant02

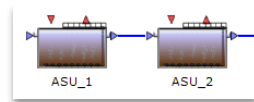
Last Updated: 12/06/2024

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

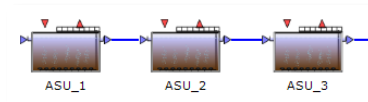
Last Updated: 12/06/2024

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

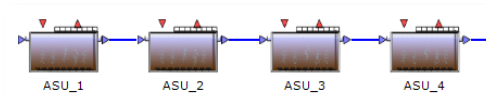
Last Updated: 12/06/2024

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

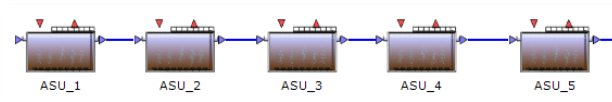
Last Updated: 12/06/2024

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

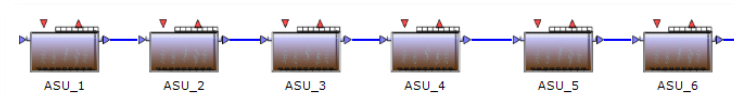
Last Updated: 12/06/2024

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

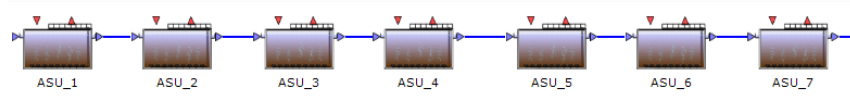
Last Updated: 12/06/2024

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

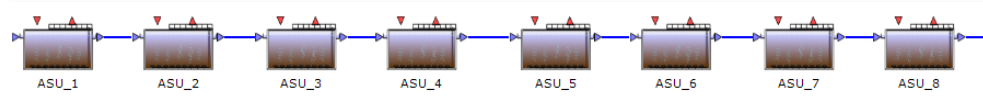
Last Updated: 12/06/2024

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

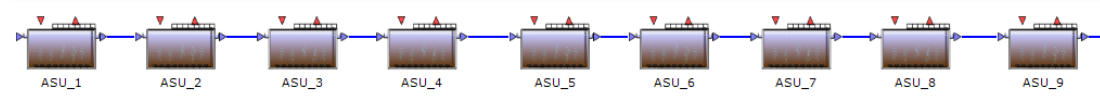
Last Updated: 12/06/2024

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

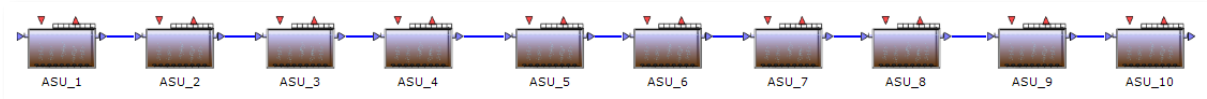
Last Updated: 12/06/2024

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

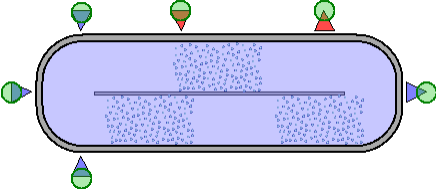
Derived State Variables

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/m ³ /d

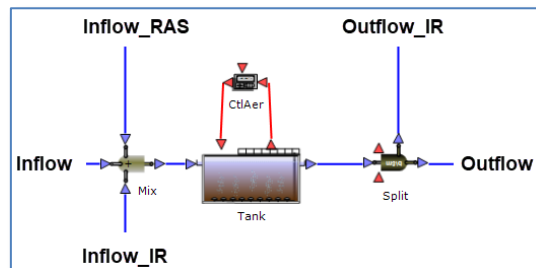
OXIDATION DITCH

	Palette Group	Biological Treatment
	Category	OxidationDitch
	Icon Name	oxidation_ditch

Sector

Last Updated: 12/06/2024

*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	m ³ /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

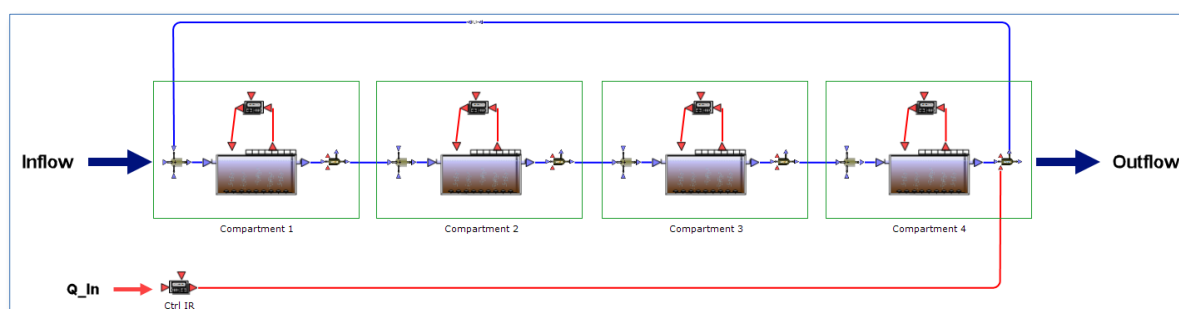
Inflow_RAS	---	Inflow for activated sludge recycle	---	g/d
------------	-----	-------------------------------------	-----	-----

Ditch04

Last Updated: 12/06/2024

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	m ³ /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

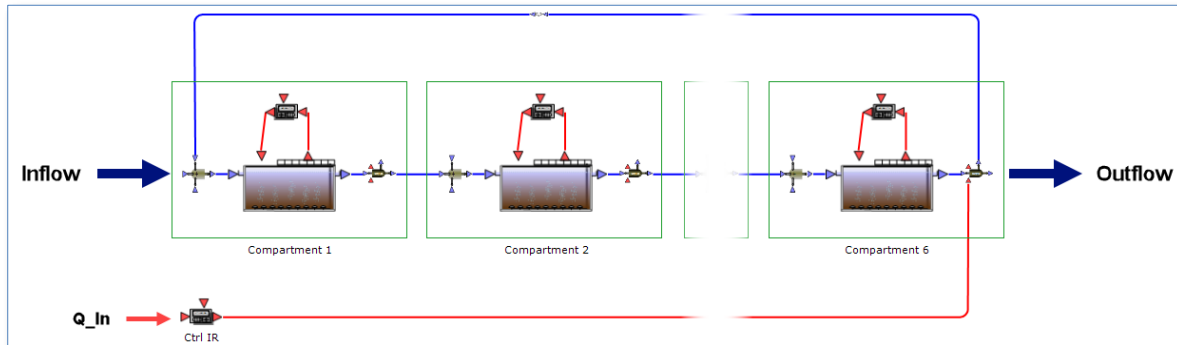
Name	Terminal	Description	Value	Units
Inflow	in_1	Inflow	---	g/d
Outflow	out_1	Outflow	---	g/d
Inflow_IR	in_4	Inflow for internal recycle	---	g/d
Inflow_RAS	in_3	Inflow for activated sludge recycle	---	g/d
P_Aer	out_2	Power consumption for aeration	---	kWh/d
P_Mix	out_2	Power consumption for mixing	---	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	<i>DO set-point for compartment no.1 .. 4</i>	2	g/m3
KP_01 .. 04	in_2	<i>Factor of proportionality</i>	25	---
kLa_Max_01 .. 04	in_2	<i>Maximum kLa for compartment no.1 .. 4</i>	1000	1/d
R	in_2	<i>Internal (virtual) recirculation rate</i>	50	---
Temp	in_2	<i>Temperature</i>	15.0	°C
E_OTR	in_2	<i>Oxygen Transfer Rate per unit energy</i>	1800.0	g/kWh
E_Mix_sp	in_2	<i>Mixing energy per unit volume</i>	0.005	kWh/m3/d

Ditch06

Last Updated: 12/06/2024

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	m ³ /d
v_H	Horizontal velocity	m/s

Derived State Variables

None

Sub-models

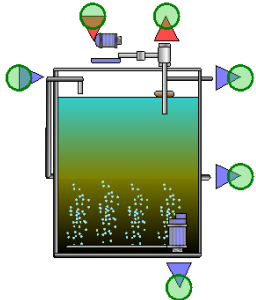
Name	Class Name
Comp_01 .. 06	Sector

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

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d

Name	Description	Units
Q_Out	Effluent flow rate	m ³ /d
Q_Under	Sludge withdrawal flow rate	m ³ /d
Q_Over	By-pass flow rate	m ³ /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	m ³ /d
Q_Waste	in_2	Desired waste flow	240.0	m ³ /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/m ³
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/m ³ /d

SBR_PS_R02

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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	<i>in 2</i>	<i>Mixing energy per unit volume</i>	<i>0.005</i>	<i>kWh/m3/d</i>
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SBR_PS_R08

Last Updated: 12/06/2024

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	m ²
V_Min	Minimum volume of the tank	1.0	m ³
V_Max	Maximum volume of the tank	2000.0	m ³
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
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	<i>in 2</i>	<i>Energy per unit flow rate</i>	<i>0.04</i>	<i>kWh/m3</i>
E_OTR	<i>in 2</i>	<i>Oxygen Transfer Rate per unit energy</i>	<i>1800.0</i>	<i>g/kWh</i>
E_Mix_sp	<i>in 2</i>	<i>Mixing energy per unit volume</i>	<i>0.005</i>	<i>kWh/m3/d</i>

SBR_A

Last Updated: 22/06/2026

Instances

All

Description

This model describes a sequencing batch reactor with five phases plus an optional launch phase, similar to the SBR_PS_R01, ..., SBR_PS_R10 models. Settling is represented by a point settler model and desludging occurs during the idle phase. Differences between SBR_A and the previous SBR models include:

- the reaction phase consists of a single nitrification phase which can vary in length depending on when a specified ammonia threshold is achieved.
- the effluent flow stops when the volume drops to a specified minimum V_{Draw} during the withdrawal phase
- each phase is assigned an ID number which can be used in control logic

The operation of each phase is summarised below

	(Launch*)	Filling	Reaction (Nitrification)	Settling	Withdrawal	Idle
<i>phaseid</i>	0	1	2	3	4	5
<i>Q_{bypass}</i>	0	0	Q_{in}	Q_{in}	Q_{in}	Q_{in}
<i>Q_{out}</i>	If $V > V_{max}$ then Q_{in} else 0 **		0	0	For $V > V_{draw}$ Q_{draw} else 0	0
<i>Q_{under}</i>	0	0	0	0	0	Q_{waste} for $V > V_{Min}$
Duration	T_{Launch}	T1	For $t_{2min} < t_{phase} < t_{2min}$ go to phase 3 if $NH_4 < NH_{4threshold}$	T3	T4	T5
<i>Kla</i>	Kla_{Launch}	Kla_{Fill}	Kla_{N01}	0	0	0
<i>IS_{React}</i>	1	1	1	0	0	0

* Once at beginning of simulation only

** this replaces the weir equation in the SBR_PS_R01, ..., SBR_PS_R10 models to avoid excessive volume increases.

Parameters

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

Group: Dimension

Name	Description	Value	Units
V_Ini	Initial level in the tank (liquid volume)	100	m3
V_Max	Highest level in the tank (liquid volume)	2000	m3
V_Min	Lowest level in the tank (liquid volume)	1	m3

Group: Energy

Name	Description	Value	Units
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, Concentrations, Masses, Measurement and some operating data are derived from the underlying, instance-specific, conversion model. State variables specific to the variable phase SBR model are:

Group:

Name	Description	Units
Help_EMix	Instantaneous mixing energy	kWh/d

Group: Operation

Name	Description	Units
Help_Q_Under	Sludge flow rate	m3/d
Q_Bypass	By-pass flow rate	m3/d
Q_Under	Sludge flow rate	m3/d
Help_Q_Draw	Desired withdraw flow rate	m3/d
Q_Out_Calc	Calculated effluent flow rate	m3/d

Interface Variables

Inflow, Outflow (out_1 = Effluent flow) and some sensor variables are derived from the underlying, instance-specific, conversion model. Interface variables specific to variable phase SBRs and SBR_A are:

Group: By-pass

Name	Terminal	Description	Value	Units
Outflow2	out_3	By-pass		g/d

Group: Energy

Name	Terminal	Description	Value	Units
E_Mix_sp	in_2	Energy requirement for mixing per unit volume	0.005	kW/m3
E_OTR	in_2	Oxygen transfer per unit energy	1800	g/kWh
E_Pump_sp	in_2	Energy requirement for pumping per unit flow	0.04	kWh/m3
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

Group: Operation

Name	Terminal	Description	Value	Units
NH4_threshold	in_2	Ammonia target for nitrification phase	0.5	g/m3
kLa_N01	in_2	Oxygen transfer coefficient for nitrification phase no.1	50	
Q_Draw	in_2	Desired withdraw flow rate	24000	
Q_Waste	in_2	Desired waste flow rate during the idle phase	240	
V_Draw	in_2	Minimum volume for draw phase	3200	m3
kLa_Fill	in_2	Oxygen transfer coefficient for filling phase	0	
kLa_Launch	in_2	Oxygen transfer coefficient for launch phase	0	
Vol	out_2	Volume in reactor	2000	m3

Group: Operation - Timing

Name	Terminal	Description	Value	Units
T1	in_2	Length of filling phase	0.125	d
T3	in_2	Length of the settling phase	0.125	d
T4	in_2	Length of the draw phase	0.125	d
T5	in_2	Length of the idle phase	0.125	d
T_Launch	in_2	Time delay in a multi-SBR set-up	0	d
t_N_max	in_2	Maximum nitrification time	0.167	d
t_N_min	in_2	Minimum nitrification time	0.083	d
phaseid	out_2	Phase ID (0=lager, 1=fill, 2 = nitrif, 3=settle, 4=draw, 5=idle, 6=denitrify, 7=desludge)	0	---
phaseid_prev	out_2	Phase ID at previous time step	0	---
t_cycle	out_2	Elapsed time for current cycle	0	d
t_phase	out_2	Elapsed time for current phase	0	d
t_switch	out_2	Time of last phase switch	0	d

Group: Operation - Settling

Name	Terminal	Description	Value	Units
F_Th	in_2	Thickening factor of the suspended solids	2	---
f_ns	in_2	Fraction of non-settleable solids	0.005	---

Group: Waste

Name	Terminal	Description	Value	Units
Outflow3	out_4	Waste		g/d

SBR_B

Last Updated: 20/06/2026

Instances

All

Description

SBR_B

SBR_B is an extension of SBR_A with an added denitrification phase (phaseid = 6) which can vary in length depending on when a threshold nitrate value is achieved. The operation of SBR_B is summarised below

	(Launch)	Filling	Reaction (Denitrification)	Reaction (Nitrification)	Settling	Withdrawal	Idle
<i>phaseid</i>	0	1	6	2	3	4	5
<i>Q_{bypass}</i>	0	0	Q_{in}	Q_{in}	Q_{in}	Q_{in}	Q_{in}
<i>Q_{out}</i>	If $V > V_{max}$ then Q_{in} else		0	0	0	For $V > V_{Draw}$ Q_{draw} else 0	0
<i>Q_{under}</i>	0	0	0	0	0	0	Q_{waste} for $V > V_{Min}$
Duration	T_{Launch}	T1	For $t_{6min} < t_{phase} < t_{6min}$ go to phase 2 if $NO_3 < NO_{3threshold}$	For $t_{2min} < t_{phase} < t_{2min}$ go to phase 3 if $NH_4 < NH_{4threshold}$	T3	T4	T5
<i>Kla</i>	Kla_{Launch}	Kla_{Fill}	0	Kla_{N01}	0	0	0
<i>IS_{React}</i>	1	1	1	1	0	0	0

Parameters

Parameters for SBR_B are the same as SBR_A.

State Variables

Parameters for SBR_B are the same as SBR_A.

Interface Variables

Inflow, Outflow (out_1 = Effluent flow) and some sensor variables are derived from the underlying, instance-specific, conversion model. The By-pass, Energy, Operation – Settling and Operation - Waste group interface variables are the same as for SBR_A. The Operation and Operation – Timing interface variables for SBR_B are:

Group: Operation

Name	Terminal	Description	Value	Units
NH4_threshold	in_2	Ammonia target for nitrification phase	0.5	g/m3
NO3_threshold	in_2	Nitrate target for denitrification phase	5	g/m3
kLa_N01	in_2	Oxygen transfer coefficient for nitrification phase no.1	50	1/d
t_N_max	in_2	Maximum nitrification time	0.167	d
t_N_min	in_2	Minimum nitrification time	0.083	d
t_D_max	in_2	Maximum denitrification time	0.167	d
t_D_min	in_2	Minimum denitrification time	0.083	d
Q_Draw	in_2	Desired withdraw flow rate	24000	m3/d
Q_Waste	in_2	Desired waste flow rate during the idle phase	240	m3/d
V_Draw	in_2	Minimum volume for draw phase	3200	m3
kLa_Fill	in_2	Oxygen transfer coefficient for filling phase	0	1/d
kLa_Launch	in_2	Oxygen transfer coefficient for launch phase	0	1/d
Vol	out_2	Volume in reactor	2000	m3

Group: Operation - Timing

Name	Terminal	Description	Value	Units
T1	in_2	Length of filling phase	0.125	d
T3	in_2	Length of the settling phase	0.125	d
T4	in_2	Length of the draw phase	0.125	d
T5	in_2	Length of the idle phase	0.125	d
T_Launch	in_2	Time delay in a multi-SBR set-up	0	d
phaseid	out_2	Phase ID (0=lager, 1=fill, 2 = nitrif, 3=settle, 4=draw, 5=idle, 6=denitrify, 7=desludge)	0	---
phaseid_prev	out_2	Phase ID at previous time step	0	---
t_cycle	out_2	Elapsed time for current cycle	0	d
t_phase	out_2	Elapsed time for current phase	0	d
t_switch	out_2	Time of last phase switch	0	d

SBR_C

Last Updated: 20/06/2026

Instances

All

Description

SBR_C

SBR_C is an extension of SBR_A where the duration of the launch, fill and withdrawal phases depend on the volume of liquor in the reactor.

- The launch phase and fill phases end early if $V \geq V_{Max}$
- the withdrawal phase ends early if $V \leq V_{Draw}$.

The desludge phase is also separated from the idle phase making them easier to control individually.

	(Launch*)	Filling	Reaction (Nitrification)	Settling	Withdrawal	Desludge	Idle
<i>phaseid</i>	0	1	2	3	4	7	5
<i>Q_{bypass}</i>	0	0	Q_{in}	Q_{in}	Q_{in}	Q_{in}	Q_{in}
<i>Q_{out}</i>	If $V > V_{Max}$ then Q_{in} else 0		0	0	Q_{draw}	0	0
<i>Q_{under}</i>	0	0	0	0	0	Q_{waste} for $V > V_{Min}$	0
Duration	For $t_{phase} < T_{Launch}$ go to phase 2 if $V \geq V_{Max}$	For $t_{phase} < t_{1max}$ go to phase 2 if $V \geq V_{Max}$	For $t_{2min} < t_{phase} < t_{2max}$ end phase if $NH_4 < NH_{4threshold}$	T3	For $t_{phase} < t_{4max}$ go to phase 5 if $V \leq V_{Draw}$	T7	T5
<i>Kla</i>	Kla_{Launch}	Kla_{Fill}	Kla_{NO1}	0	0	0	0
<i>IS_{React}</i>	1	1	1	0	0	0	0

Parameters

Parameters for SBR_C are the same as SBR_A.

State Variables

Parameters for SBR_C are the same as SBR_A.

Interface Variables

Inflow, Outflow (out_1 = Effluent flow) and some sensor variables are derived from the underlying, instance-specific, conversion model. The By-pass, Energy, Operation – Settling and Operation - Waste group interface variables are the same as for SBR_A. The Operation and Operation – Timing interface variables for SBR_C are:

Group: Operation

Name	Terminal	Description	Value	Units
NH4_threshold	in_2	Ammonia target for nitrification phase	0.5	g/m3
kLa_N01	in_2	Oxygen transfer coefficient for nitrification phase no.1	50	1/d
Q_Draw	in_2	Desired withdraw flow rate	24000	m3/d
Q_Waste	in_2	Desired waste flow rate during the idle phase	240	m3/d
V_Draw	in_2	Minimum volume for draw phase	3200	m3
kLa_Fill	in_2	Oxygen transfer coefficient for filling phase	0	1/d
kLa_Launch	in_2	Oxygen transfer coefficient for launch phase	0	1/d
Vol	out_2	Volume in reactor	2000	m3

Group: Operation - Timing

Name	Terminal	Description	Value	Units
t1_max	in_2	Maximum length of filling phase	0.125	d
T3	in_2	Length of the settling phase	0.125	d
t4_max	in_2	Maximum length of the draw phase	0.125	d
T5	in_2	Length of the idle phase	0.125	d
T7	in_2	Desludge time independent of idle phase	0.125	d
T_Launch	in_2	Time delay in a multi-SBR set-up	0	d
t_N_max	in_2	Maximum nitrification time	0.167	d
t_N_min	in_2	Minimum nitrification time	0.083	d
phaseid	out_2	Phase ID (0=lager, 1=fill, 2 = nitrif, 3=settle, 4=draw, 5=idle, 6=denitrify, 7=desludge)	0	---
phaseid_prev	out_2	Phase ID at previous time step	0	---
t_cycle	out_2	Elapsed time for current cycle	0	d
t_phase	out_2	Elapsed time for current phase	0	d
t_switch	out_2	Time of last phase switch	0	d

SBR_D

Last Updated: 20/06/2026

Instances

All

Description

SBR_D

SBR_D is an extension of SBR_C with an added denitrification phase (phaseid = 6) which can vary in length depending on when a threshold nitrate value is achieved, similar to SBR_B. The operation of SBR_D is summarised below

	(Launch*)	Filling	Reaction (Denitrification)	Reaction (Nitrification)	Settling	Withdrawal	Desludge	Idle
<i>phaseid</i>	0	1	6	2	3	4	7	5
<i>Q_{bypass}</i>	0	0	<i>Q_{in}</i>	<i>Q_{in}</i>	<i>Q_{in}</i>	<i>Q_{in}</i>	<i>Q_{in}</i>	<i>Q_{in}</i>
<i>Q_{out}</i>	If $V > V_{Max}$ then <i>Q_{in}</i> else 0		0	0	0	<i>Q_{draw}</i>	0	0
<i>Q_{under}</i>	0	0	0	0	0	0	<i>Q_{waste}</i> for $V > V_{Min}$	0
Duration	For $t_{phase} < T_{Launch}$ go to phase 2 if $V \geq V_{Max}$	For $t_{phase} < t_{1max}$ go to phase 2 if $V \geq V_{Max}$	For $t_{6min} < t_{phase} < t_{6min}$ go to phase 2 if $NO_3 < NO_{3threshold}$	For $t_{2min} < t_{phase} < t_{2max}$ end phase if $NH_4 < NH_{4threshold}$	T3	For $t_{phase} < t_{4max}$ go to phase 5 if $V \leq V_{Draw}$	T7	T5
<i>Kla</i>	<i>Kla_{Launch}</i>	<i>Kla_{Fill}</i>	0	<i>Kla_{N01}</i>	0	0	0	0
<i>IS_{React}</i>	1	1	1	1	0	0	0	0

Group: Operation

Name	Terminal	Description	Value	Units
NH4_threshold	in_2	Ammonia target for nitrification phase	0.5	g/m3
NO3_threshold	in_2	Nitrate target for denitrification phase	5	g/m3
kLa_N01	in_2	Oxygen transfer coefficient for nitrification phase no.1	50	1/d
Q_Draw	in_2	Desired withdraw flow rate	24000	m3/d
Q_Waste	in_2	Desired waste flow rate during the idle phase	240	m3/d
V_Draw	in_2	Minimum volume for draw phase	3200	m3
kLa_Fill	in_2	Oxygen transfer coefficient for filling phase	0	1/d
kLa_Launch	in_2	Oxygen transfer coefficient for launch phase	0	1/d
Vol	out_2	Volume in reactor	2000	m3

Group: Operation - Timing

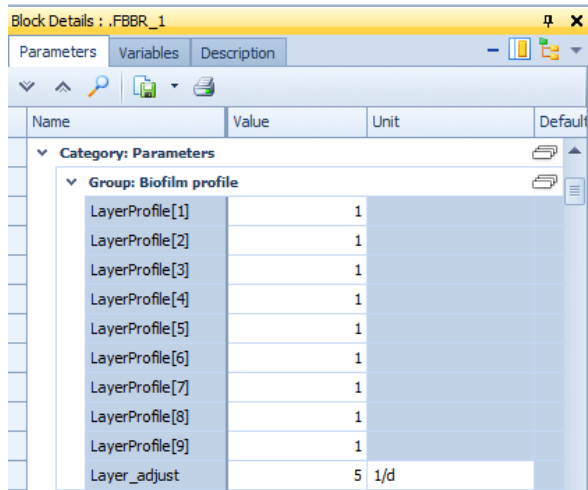
Name	Terminal	Description	Value	Units
t1_max	in_2	Maximum length of filling phase	0.125	d
T3	in_2	Length of the settling phase	0.125	d
t4_max	in_2	Maximum length of the draw phase	0.125	d
T5	in_2	Length of the idle phase	0.125	d
T7	in_2	Desludge time independent of idle phase	0.125	d
T_Launch	in_2	Time delay in a multi-SBR set-up	0	d
t_D_max	in_2	Maximum denitrification time	0.167	d
t_D_min	in_2	Minimum denitrification time	0.083	d
t_N_max	in_2	Maximum nitrification time	0.167	d
t_N_min	in_2	Minimum nitrification time	0.083	d
phaseid	out_2	Phase ID (0=lager, 1=fill, 2 = nitrif, 3=settle, 4=draw, 5=idle, 6=denitrify, 7=desludge)	0	---
phaseid_prev	out_2	Phase ID at previous time step	0	---
t_cycle	out_2	Elapsed time for current cycle	0	d
t_phase	out_2	Elapsed time for current phase	0	d
t_switch	out_2	Time of last phase switch	0	d

BIOFILM MODELS

Last Updated: 26/03/2025

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.

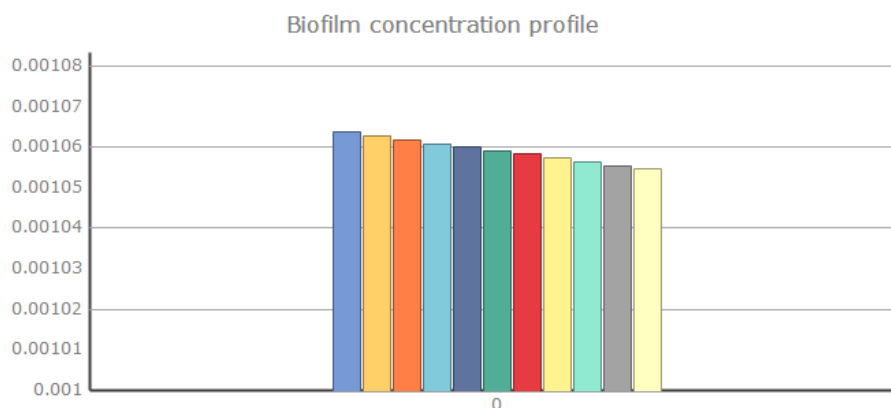
The layers do not have any physical significance – they are a numerical device to represent the continuous variation of conditions through the biofilm. Since the number of layers is fixed, the layer thicknesses grow as the biofilm grows. The model has a mechanism to maintain the relative thicknesses 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.

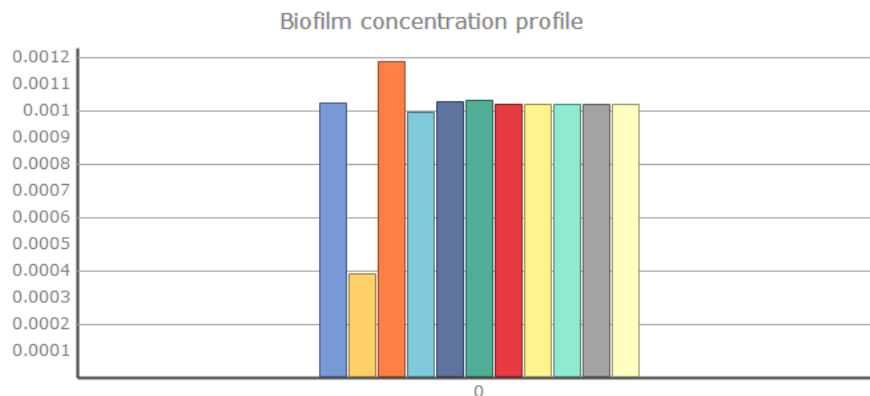


Name	Value	Unit	Default
Category: Parameters			
Group: Biofilm profile			
LayerProfile[1]	1		
LayerProfile[2]	1		
LayerProfile[3]	1		
LayerProfile[4]	1		
LayerProfile[5]	1		
LayerProfile[6]	1		
LayerProfile[7]	1		
LayerProfile[8]	1		
LayerProfile[9]	1		
Layer_adjust	5	1/d	

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.





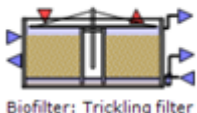
This instability causes the solution to run extremely slowly as the solver tries to track the oscillations. The problem can be partly mitigated by setting very tight tolerances on the solver accuracy. The problem is most acute at the start of a new model when the standard WEST procedure of initializing 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

Last Updated: 26/03/2025

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

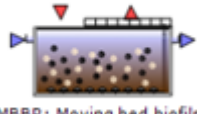
None

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/m ³
OUR_{bf}	out 2	Oxygen Uptake Rate in the biofilm	---	g/m ³ /d
OUR_{bk}	out 2	Oxygen Uptake Rate in the bulk	---	g/m ³ /d
OUR_{tot}	out 2	Total Oxygen Uptake Rate	---	g/m ³ /d
Temp	in 2	Temperature	15	°C
kLa	in 2	Oxygen transfer coefficient	0	1/d

MBBR

 MBBR: Moving bed biofilm	Palette Group	Biological Treatment
	Category	Tanks_Filters
	Icon Name	mbbr

Last Updated: 26/03/2025

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/m ³
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/m ³
M_Biofilm	Mass of the state components in each layer (matrix)	g/m ³
d	Thickness of the biofilm	m
d_layer	Thickness of each layer (vector)	m
V_bf	Volume of the biofilm	m ³
V_layer	Volume of each layer (vector)	m ³
C_Bulk	Concentration of the state components in the bulk (vector)	g/m ³
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /d

Derived State Variables

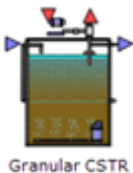
None

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/m ³
OUR_{bf}	out 2	Oxygen Uptake Rate in the biofilm	---	g/m ³ /d
OUR_{bk}	out 2	Oxygen Uptake Rate in the bulk	---	g/m ³ /d
OUR_{tot}	out 2	Total Oxygen Uptake Rate	---	g/m ³ /d
Temp	in 2	Temperature	15	°C
kLa	in 2	Oxygen transfer coefficient	0	1/d

GranuleCSTR

 Granular CSTR	Palette Group	Biological Treatment
	Category	Tanks_Filters
	Icon Name	cstr_gr

Last Updated: 26/03/2025

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

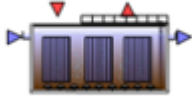
None

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/m ³
OUR_bf	out 2	Oxygen Uptake Rate in the biofilm	---	g/m ³ /d
OUR_bk	out 2	Oxygen Uptake Rate in the bulk	---	g/m ³ /d
OUR_tot	out 2	Total Oxygen Uptake Rate	---	g/m ³ /d
Temp	in 2	Temperature	15	°C
kLa	in 2	Oxygen transfer coefficient	0	1/d

MABR

 MABR: Membrane aerated biofilm	Palette Group	Biological Treatment
	Category	Tanks_Filters
	Icon Name	mabr

Last Updated: 26/03/2025

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

Name	Description	Units
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

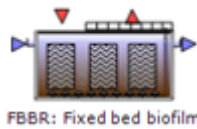
None

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
Kla_membrane	in 2	<i>Oxygen transfer coefficient for the membrane</i>	1,000	1/d
Q_air	in 2	<i>Air flow rate under standard conditions</i>	100,000	m3/d
Temp	in 2	<i>Temperature</i>	15	°C
kLa	in 2	<i>Oxygen transfer coefficient</i>	0	1/d

FBBR

	Palette Group	Biological Treatment
	Category	Tanks_Filters
	Icon Name	fbbr

Last Updated: 26/03/2025

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

Name	Description	Units
Q_Out	Effluent flow rate	m ³ /d

Derived State Variables

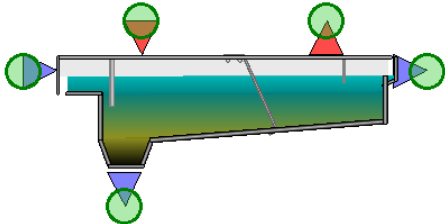
None

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/m ³
OUR_bf	out_2	Oxygen Uptake Rate in the biofilm	---	g/m ³ /d
OUR_bk	out_2	Oxygen Uptake Rate in the bulk	---	g/m ³ /d
OUR_tot	out_2	Total Oxygen Uptake Rate	---	g/m ³ /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

Last Updated: 12/06/2024

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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
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	<i>Fraction of non-settleable solids</i>	0.6	---
E_Pump_sp	in_2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
Q_Under	in_2	<i>Desired sludge flow</i>	50	m ³ /d
P_Pump	out_3	Pumping power	---	kWh/d

OtterpohlFreund

Last Updated: 12/06/2024

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	m ³
C	Concentration vector	g/m ³

Derived State Variables

Name	Description	Units
M	Mass vector	g
Q_m	Mean influent flow rate	m ³ /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
<i>f_{PS}</i>	in 2	<i>Primary sludge- to influent flow rate ratio</i>	0.007	-
<i>E_{Pump_sp}</i>	in 2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
P_{Pump}	out 3	Pumping power	---	kWh/d
V_{Tank}	out 3	Volume of the tank	---	m ³

Takacs_SVI

Last Updated: 12/06/2024

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.

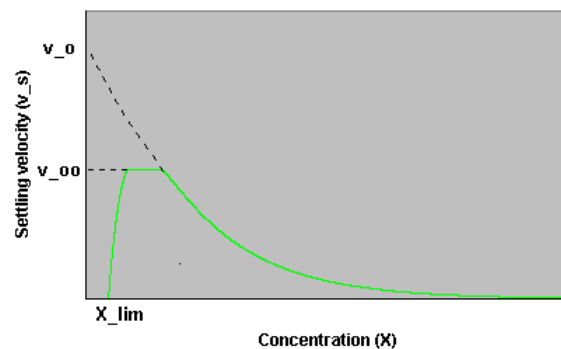
$$(X < X_{Min}): v_s = 0$$

$$(X \geq X_{Min}): v_s = v_0 \cdot e^{-r_H \cdot X_j} - v_0 \cdot e^{-r_P \cdot X_j}$$

$$X_{Min} = f_{ns} \cdot \frac{X_{in}}{Q_{in}}$$

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:

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

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	m ²
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m ³
X_Lim	Minimal concentration in sludge blanket	900	g/m ³
r_P	Low concentration settling parameter	0.0007	m ³ /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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m ³
r_H	Hindered settling parameter	m ³ /g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m ³

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	<i>Desired underflow rate</i>	50.0	m ³ /d
E_Pump_sp	in_2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
SVI	in_2	<i>Sludge Volume Index</i>	100	mL/g
f_ns	in_2	<i>Non-settleable fraction of suspended solids</i>	0.0024	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m ³
y_HS	out_3	Height of the sludge blanket	---	m

Lamellae_Takacs

Last Updated: 12/06/2024

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	m ²
L_n	Number of lamellae	10	---
L_S	Specific area of the lamellae	100	m ²
L_Theta	Inclination of the pack	45	deg
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m ³
X_Lim	Minimal concentration in sludge blanket	900	g/m ³
r_P	Low concentration settling parameter	0.0007	m ³ /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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m ³
r_H	Hindered settling parameter	m ³ /g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m ³

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
<i>Q_Under</i>	in_2	<i>Desired underflow rate</i>	50.0	<i>m³/d</i>
<i>E_Pump_sp</i>	in_2	<i>Energy per unit flow rate</i>	0.04	<i>kWh/m³</i>
<i>SVI</i>	in_2	<i>Sludge Volume Index</i>	100	<i>mL/g</i>
<i>f_ns</i>	in_2	<i>Non-settleable fraction of suspended solids</i>	0.0024	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m ³
y_HS	out_3	Height of the sludge blanket	---	m

BSM2

Last Updated: 12/06/2024

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_{out} 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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
DS	Dry solids content of the sludge	%
f_thick	Thickening factor	---

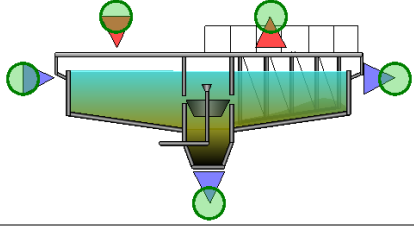
Derived State Variables

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	<i>Desired solids content in the underflow</i>	0.28	---
P_Pump	out_3	Pumping power	---	kWh/d

SECONDARY CLARIFIERS

	Palette Group	Separation
	Category	Settlers_SST
	Icon Name	clarifier_secondary

Point

Last Updated: 12/06/2024

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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
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	<i>Fraction of non-settleable solids</i>	0.005	---
E_Pump_sp	in_2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
Q_Under	in_2	<i>Desired sludge flow</i>	50	m ³ /d
P_Pump	out_3	Pumping power	---	kWh/d

Takacs_SVI

Last Updated: 12/06/2024

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.

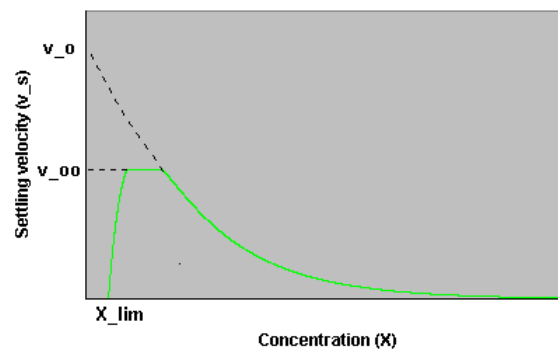
$$(X < X_{Min}): v_s = 0$$

$$(X \geq X_{Min}): v_s = v_0 \cdot e^{-r_H \cdot X_j} - v_0 \cdot e^{-r_P \cdot X_j}$$

$$X_{Min} = f_{ns} \cdot X_{in}$$

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:

$$P_{\text{pump}} = E_{\text{pump},s} \cdot Q_{\text{out}2}$$

where:

- $E_{\text{pump},s}$ indicates the pumping energy per unit flow rate (kWh/m³)
- $Q_{\text{out}2}$ 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	m ²
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m ³
X_Lim	Minimal concentration in sludge blanket	900	g/m ³
r_P	Low concentration settling parameter	0.0007	m ³ /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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m ³
r_H	Hindered settling parameter	m ³ /g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m ³

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	<i>Desired underflow rate</i>	50.0	m ³ /d
E_Pump_sp	in_2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
SVI	in_2	<i>Sludge Volume Index</i>	100	mL/g
f_ns	in_2	<i>Non-settleable fraction of suspended solids</i>	0.00228	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m ³
y_HS	out_3	Height of the sludge blanket	---	m

BurgerDiehl30

Last Updated: 12/06/2024

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 homogeneously 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: J_{up}), and downwards below the feed layer (and driven by the extraction of the sludge from the bottom of the settler: 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:

$$(C_i \leq C_{i+1}): J_G = \min_{C_i \leq C \leq C_{i+1}} \{v_S(C) \cdot C\}$$

$$(C \geq C_{crit}): J_G = \max_{C_i \geq C \geq C_{i+1}} \{v_S(C) \cdot C\}$$

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:

$$(0 \leq C < C_{crit}): d_{comp} = 0$$

$$(C \geq C_{crit}): d_{comp} = \frac{Comp_{ON} \cdot Rho_s \cdot \alpha \cdot v_S(C)}{g \cdot (Rho_s - Rho_f)}$$

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.

$$(|z| < b_{mix} \cdot Q_{in}): d_{disp} = Disp_{ON} \cdot \frac{a_{mix}}{A} \cdot Q_{in} \cdot \cos^2 \left(\frac{\pi \cdot z}{2 \cdot b_{mix} \cdot Q_{in}} \right)$$

$$(|z| \geq b_{mix} \cdot Q_{in}): d_{disp} = 0$$

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:**

$$\Delta t \leq 1 / \left[\frac{1}{\Delta z} \left(\max_{0 < t < T} \frac{Q_{In}(t)}{A} + \max_{0 \leq C < C_{max}} J'_G(C) \right) + \frac{2}{(\Delta z)^2} \left(\max_{0 \leq C < C_{max}} d_{comp}(C) + \max_{0 < t < T} d_{disp}(z, Q_{In}(t)) \right) \right]$$

Energy consumption for pumping is estimated as follows:

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

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	m ²
H	Height of the clarifier	3	m
v0	Maximum theoretical settling velocity	474	m/d
r_V	Settling parameter	0.000576	m ³ /g
X_Lim	Minimum concentration in the sludge blanket	900	g/m ³
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/m ²

* only ASM1

State Variables

Name	Description	Units
Q_In	Influent flow rate	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
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/m ³

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	m ³ /d
E_Pump_sp	in_2	Energy per unit flow rate	0.04	kWh/m ³
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m ³
TSS	out_3	Total Suspended Solids concentration	---	g/m ³

y_HS	out 3	Height of the sludge blanket	---	m
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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

Last Updated: 12/06/2024

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	m ²
L_n	Number of lamellae	10	---
L_S	Specific area of the lamellae	100	m ²
L_Theta	Inclination of the pack	45	deg
H	Height of the clarifier	4	m
X_T	Threshold suspended solids concentration	3,000	g/m ³
X_Lim	Minimal concentration in sludge blanket	900	g/m ³
r_P	Low concentration settling parameter	0.0007	m ³ /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	m ³ /d
Q_Out	Effluent flow rate	m ³ /d
Q_Out2	Effluent (under) flow rate	m ³ /d
X_In	Solids (TSS) concentration in the inflow	g/m ³
X_Out	Solids (TSS) concentration in the outflow	g/m ³
X_Under	Solids (TSS) concentration in the underflow	g/m ³
DS	Dry solids content of the sludge	%
H_S	Height of the sludge blanket	m
X_Min	Non-settleable sludge concentration	g/m ³
r_H	Hindered settling parameter	m ³ /g

Derived State Variables

Name	Description	Units
X_Layer	Solids concentration in each layer (vector)	g/m ³

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
<i>Q_Under</i>	in_2	<i>Desired underflow rate</i>	50.0	<i>m³/d</i>
<i>E_Pump_sp</i>	in_2	<i>Energy per unit flow rate</i>	0.04	<i>kWh/m³</i>
<i>SVI</i>	in_2	<i>Sludge Volume Index</i>	100	<i>mL/g</i>
<i>f_ns</i>	in_2	<i>Non-settleable fraction of suspended solids</i>	0.0024	---
P_Pump	out_3	Pumping power	---	kWh/d
V_Clarifier	out_3	Volume of the tank	---	m ³
y_HS	out_3	Height of the sludge blanket	---	m

Point_wVolumePre

Last Updated: 12/06/2024

Instances

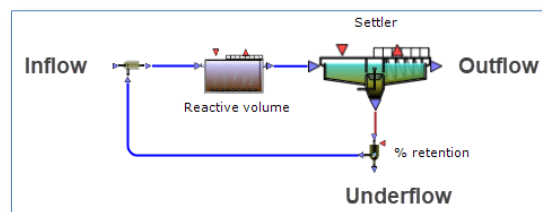
All

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

Name	Terminal	Description	Value	Units
<i>kLa</i>	<i>in_2</i>	<i>Oxygen transfer coefficient</i>	<i>1.0</i>	<i>1/d</i>
<i>f_ns</i>	<i>in_2</i>	<i>Fraction of non-settleable solids</i>	<i>0.00228</i>	<i>---</i>
<i>f_rec</i>	<i>in_2</i>	<i>Fraction of internal recirculation</i>	<i>0.1</i>	<i>---</i>
<i>E_Pump_sp</i>	<i>in_2</i>	<i>Energy per unit flow rate</i>	<i>0.04</i>	<i>kWh/m3</i>
<i>Q_Under</i>	<i>in_2</i>	<i>Desired sludge flow</i>	<i>50</i>	<i>m3/d</i>
<i>P_Pump</i>	<i>out_3</i>	<i>Pumping power</i>	<i>---</i>	<i>kWh/d</i>

Point_wVolumePost

Last Updated: 12/06/2024

Instances

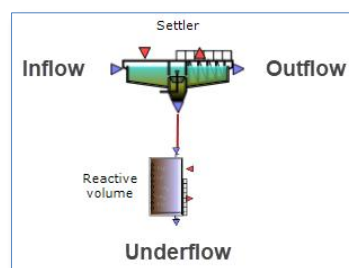
All

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
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TakacsSVI_wVolumePre

Last Updated: 12/06/2024

Instances

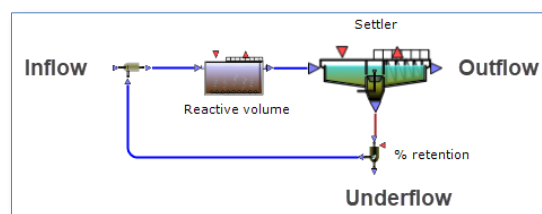
All

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

Name	Terminal	Description	Value	Units
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	---
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/m ³
Q_Under	in_2	Desired sludge flow	50	m ³ /d
P_Pump	out_3	Pumping power	---	kWh/d

TakacsSVI_wVolumePost

Last Updated: 12/06/2024

Instances

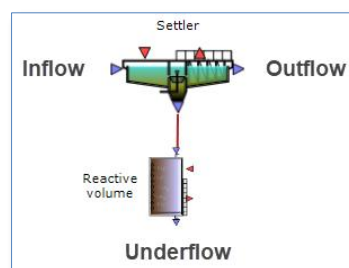
All

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

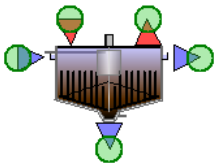
Name	Class Name
ReactiveVolume	Tanks_AS.VolumeConstant
Settler	Settlers_SST.Takacs_SVI

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	---

Name	Terminal	Description	Value	Units
<i>SVI</i>	<i>in_2</i>	<i>Sludge Volume Index</i>	<i>100</i>	<i>mL/g</i>
<i>E_Pump_sp</i>	<i>in_2</i>	<i>Energy per unit flow rate</i>	<i>0.04</i>	<i>kWh/m3</i>
<i>Q_Under</i>	<i>in_2</i>	<i>Desired sludge flow</i>	<i>50</i>	<i>m3/d</i>
P_Pump	out_3	Pumping power	---	kWh/d

THICKENERS

	Palette Group	Separation
	Category	Tanks_Dewater
	Icon Name	thickener

Tanks_Dewater.ThickenerDS

Last Updated: 12/06/2024

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/m ³

State Variables

Name	Description	Units
Q_In	Raw sludge influent flow	m ³ /d
Q_Out	Flow rate of the clarified water	m ³ /d
Q_Out2	Flow rate of the thickened sludge	m ³ /d
Q_Sludge_Actual	Flow rate of the thickened sludge	m ³ /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
DS	in_2	<i>Dry Solids content</i>	5	---
Q_Sludge	in_2	<i>Desired flow rate of thickened sludge</i>	10	m ³ /d
E_Pump_sp	in_2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
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/m ³
X_Out	out_2	Solids (TSS) concentration in the clarified water	---	g/m ³
X_Sludge	out_2	Solids (TSS) concentration in the thickened sludge	---	g/m ³

Tanks_Dewater.ThickenerEfficiency

Last Updated: 12/06/2024

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/m ³

State Variables

Name	Description	Units
Q_In	Raw sludge influent flow	m ³ /d
Q_Out	Flow rate of the clarified water	m ³ /d
Q_Out2	Flow rate of the thickened sludge	m ³ /d
Q_Sludge_Actual	Flow rate of the thickened sludge	m ³ /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
<i>e_X</i>	in_2	<i>Desired solids separation efficiency</i>	0.96	-
<i>Q_Sludge</i>	in_2	<i>Desired flow rate of thickened sludge</i>	10	m ³ /d
<i>E_Pump_sp</i>	in_2	<i>Energy per unit flow rate</i>	0.04	kWh/m ³
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/m ³
X_Out	out_2	Solids (TSS) concentration in the clarified water	---	g/m ³
X_Sludge	out_2	Solids (TSS) concentration in the thickened sludge	---	g/m ³

Tanks_Dewater.ThickenerEfficiency2

Last Updated: 12/06/2024

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/m ³

State Variables

Name	Description	Units
Q_In	Raw sludge influent flow	m ³ /d
Q_Out	Flow rate of the clarified water	m ³ /d
Q_Out2	Flow rate of the thickened sludge	m ³ /d
Q_Sludge_Actual	Flow rate of the thickened sludge	m ³ /d
DrySolids	Dry solids content of the sludge	%

Derived State Variables

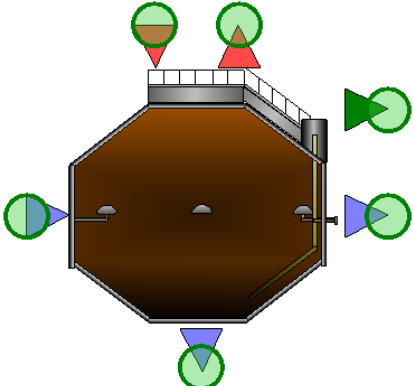
None

Interface Variables

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

Name	Terminal	Description	Value	Units
Outflow	out_1	Clarified water (component vector)	---	g/d
Outflow2	out_3	Thickened sludge (component vector)	---	g/d
<i>e_X</i>	in_2	<i>Desired solids separation efficiency</i>	0.96	-
<i>q_under</i>	in_2	<i>Thickened to raw sludge flow ratio</i>	0.5	-
<i>E_Pump_sp</i>	in_2	<i>Energy per unit flow rate</i>	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

ANAEROBIC DIGESTERS

	Palette Group	Sludge Treatment
	Category	Tanks_AD
	Icon Name	anaerobic_digester

ASM2 – ADM1 transformers

Last Updated: 26/06/2026

The activated sludge model categories ASM2dMod, ASM2dModNDHA, ASM2dISS, ASM2dModMP and ASM2dModPFAS use sets of components that are very similar, but the components for anaerobic models in the ADM1 category are quite different. Where a model layout includes both aerobic and anaerobic unit models, transformers are required to convert stream compositions from one set of components to the other. The differences in the components mean that some information is lost in the transformation. The main issue is the difference in microorganism components: aerobic microorganisms are not represented in ADM1 and anaerobic organisms are not represented in the ASM2d variants because they are assumed to die off out of their favorable environments.

Each ASM2d category has two alternative sets of transformers to and from ADM1 (**TinADM1**, **ToutADM1** and **TinADM1_b**, **ToutADM1_b**). **TinADM1** and **ToutADM1** are legacy models retained for backward compatibility. The older transformers involve a double transformation ASM2d – ASM1 – ADM1 and so lose even more compositional information. The loss is minimized in **TinADM1_b** and **ToutADM1_b** because they cut out the intermediate ASM1 step. There are corresponding anaerobic digester unit models **VolConstADM1mod** and **VolConstADM1mod_b** that have the relevant transformers bundled into them so that they interface with ASM2d streams.

TinADM1_b

The transformation from ASM2 components to ADM1 components is achieved in 4 steps.

1. ASM2 biomass components are converted to X_S (biodegradable particulate) and X_I (unbiodegradable particulate). This releases S_NH (ammonia) and S_PO (phosphate) which also changes S_ALK (alkalinity). All X_PHA (internal storage product) is allocated to S_A (acetate) and X_PP (polyphosphate) to S_PO
2. Any S_O (oxygen) and S_NO (nitrate) is used up oxidising organics, in the order S_A, S_F, X_S. NO is assumed to be reduced to N₂ gas, which disappears as it is not represented in ADM1
3. The resulting organics (S_A, S_F, S_I, X_S, X_I) are allocated to corresponding ADM1 components (S_ac, S_aa, S_su, S_Inert, X_pr, X_li, X_ch, X_Inert). Biodegradable N is allocated to S_aa, X_c and X_pr to maintain the soluble and particulate proportions.
4. The ADM1 components involved in pH calculation are estimated from S_ALK (alkalinity).

ADM1 does not cater for organically bound P, only dissolved phosphate (S_PO). To allow the P balance to be maintained, the total P in the ASM2d influent is recorded in the interface variable Total_P_In that can be linked to the corresponding output transformer. (This link is automatic in the **VolConstADM1mod_b digester model**)

ToutADM1_b

The transformation from ADM1 components to ASM2d components is achieved in 3 steps.

1. ADM1 biomass components are converted to X_S (biodegradable particulate). This releases S_NH (ammonia).
2. Soluble biodegradable ADM1 components are allocated to ASM2 S_F and S_A. ASM2d has less degrees of freedom than ADM1 to represent the N fractionation, so any imbalances are allocated to S_NH (ammonia) to maintain the overall N balance. Soluble unbiodegradable COD is allocated to S_I. A similar process is used to allocate particulate components.
3. S_ALK (alkalinity) is estimate from the ADM1 components involved in the calculation of pH.

ADM1 does not cater for organically bound P, only dissolved phosphate (S_PO). To allow the P balance to be maintained, the total P in the ASM2dMod influent is obtained in the interface variable Total_P_In that can be obtained through a link to the corresponding input transformer interface variable. (This link is automatic in the **VolConstADM1mod_b digester model**)

Parameters

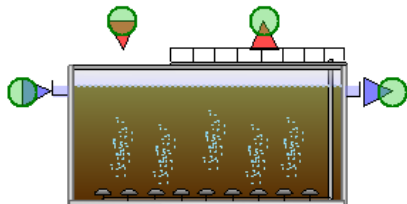
The transformers use the same parameters as found in ASM2 and ADM1 to represent component properties. In particular, those for the N content of organic components must be aligned for the N fractionation to work properly. This is automatically enforced in the coupled VolConstADM1mod_b model. However, the same values should also be used for all model in a project layout to avoid mass balance inconsistencies.

▼ Group: ASM2dMod composition				
i_N_BM	...	0.07	Nitrogen content of biomass X_H, X_PAO, X_AUT	gN/gCOD
i_N_S_F	...	0.03	Nitrogen content of soluble substrate S_F	gN/gCOD
i_N_S_I	...	0.01	Nitrogen content of inert soluble COD S_I	gN/gCOD
i_N_X_I	...	0.02	Nitrogen content of inert particulate COD X_I	gN/gCOD
i_N_X_S	...	0.04	Nitrogen content of particulate substrate X_S	gN/gCOD
i_P_BM	...	0.02	Phosphorus content of biomass X_H, X_PAO, X_AUT	gP/gCOD
i_P_S_F	...	0.01	Phosphorus content of soluble substrate S_F	gP/gCOD
i_P_S_I	...	0	Phosphorus content of inert soluble COD S_I	gP/gCOD
i_P_X_I	...	0.01	Phosphorus content of inert particulate COD X_I	gP/gCOD
i_P_X_S	...	0.01	Phosphorus content of particulate substrate X_S	gP/gCOD
▼ Group: Conversion factors				
F_TSS_COD	...	0.75	Fraction TSS/COD	
▼ Group: Stoichiometry				
i_TSS_X_I	...	0.75	TSS to X_I ratio	g/gCOD
i_TSS_X_S	...	0.75	TSS to X_S ratio	g/gCOD
▼ Group: ADM1 composition				
N_SI	...	0.00428571428571429	Nitrogen content of soluble inert COD	mol/gCOD
N_XI	...	0.00428571428571429	Nitrogen content of particulate inert COD	mol/gCOD
N_Xc	...	0.00268571428571429	Nitrogen content of particulate degradable COD	mol/gCOD
N_aa	...	0.007	Nitrogen content of amino acids	mol/gCOD
N_biom	...	0.00571428571428571	Nitrogen content of biomass	mol/gCOD
▼ Group: Conversion				
i_COD_VSS	...	1.42	VSS to COD conversion	gCOD/gVS
▼ Group: Stoichiometry				
f_S_I	...	0	Fraction of inert COD in particulate substrate	
f_X_I	...	0.1	Fraction of inert COD generated in biomass lysis	

Continuity checks (variables)

▼ Group: Balance			
COD_BP_In	...		Incoming Biodegradable Particulate COD
COD_BP_Out	...		Outgoing Biodegradable Particulate COD
COD_BS_In	...		Incoming Biodegradable Soluble COD
COD_BS_Out	...		Outgoing Biodegradable Soluble COD
COD_In	...		Incoming COD
COD_Out	...		Outgoing COD
COD_P_In	...		Incoming Particulate COD
COD_P_Out	...		Outgoing Particulate COD
COD_S_In	...		Incoming Soluble COD
COD_S_Out	...		Outgoing Soluble COD
N_In	...		Incoming nitrogen
N_Out	...		Outgoing nitrogen
S_Chk	...		$S_{balance} = S_{In} - S_{Out}$
S_In	...		Incoming S
S_Out	...		Outgoing S

AEROBIC DIGESTERS

	Palette Group	Sludge Treatment
	Category	Tanks_AerDig
	Icon Name	aerobic_digester

Tanks_AerDig.VolumeConstant

Last Updated: 12/06/2024

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	m ³
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/m ³
V	Volume of the tank	m ³
Q_In	Influent flow rate	m ³ /d

Name	Description	Units
Q_Out	Effluent flow rate	m ³ /d
Kla_Actual	Oxygen Transfer Coefficient	1/d
Temp_Actual	Temperature	°C

Derived State Variables

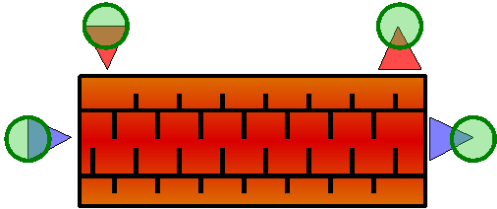
Name	Description	Units
M	Mass of the state components (vector)	---

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
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/m ³ /d

SLUDGE DRYING

	Palette Group	Sludge Treatment
	Category	ASM1, ASM2dISS, ASM2dMod
	Icon Name	sludge_dryer

SludgeDrying_Ideal

Last Updated: 12/06/2024

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:

$$P = h \cdot A \cdot (T_{heat} + T_{sludge})$$

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	---

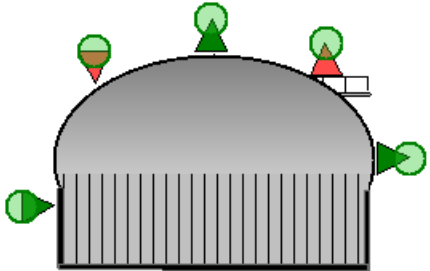
Derived State Variables

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

Last Updated: 12/06/2024

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

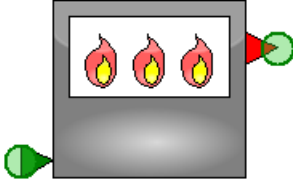
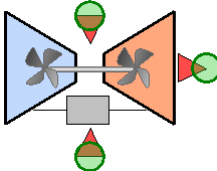
Name	Description	Units
------	-------------	-------

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)	---	---
<i>Q_Flare</i>	in_2	<i>Overflow</i>	9600	m3/d
<i>Q_Util</i>	in_2	<i>Effluent flow</i>	3240	m3/d
<i>Temp</i>	in_2	<i>Temperature</i>	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

Last Updated: 12/06/2024

Instances

All

Description

This is a simple model to describe a gas boiler for thermal power generation.

$$P_{GasTh} = \eta_{th} * Q_{CH_4} * \frac{16.0}{64.0} * F_{CH_4}$$

where:

- P_{GasTh} is the generated thermal power [kWh/d]
- η_{th} is the efficiency of the motor
- Q_{CH_4} 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_{CH_4} 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

Last Updated: 12/06/2024

Instances

All

Description

This is a simple model for a biogas engine that generates electrical power:

$$P_{GasEl} = \eta_{el} \cdot Q_{CH_4} \cdot \frac{16.0}{64.0} \cdot F_{CH_4}$$

where:

- P_{GasEl} is the generated electrical power [kWh/d]
- η_{el} is the efficiency of the motor
- Q_{CH_4} 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_{CH_4} 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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

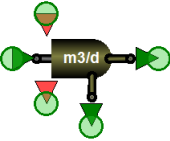
Derived State Variables

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 CO ₂	---	kg/d

SplitAbs02

	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

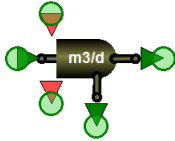
Derived State Variables

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
<i>Q Out 01</i>	<i>in 2</i>	<i>Desired flow rate no.1</i>	<i>10</i>	<i>m3/d</i>

SplitAbs02_bypass

	Palette Group	Sludge treatment
	Category	Biogas
	Icon Name	split_flow_02_gas

Last Updated: 12/06/2024

Instances

All

Description

It splits the incoming gas flow into two flows:

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

$$Q_{out,1} = \text{if } (Q_{in} < Q_{out,2,max}) \text{ then } Q_{out,1}^* \text{ else } Q_{in} - Q_{out,2,max}$$

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

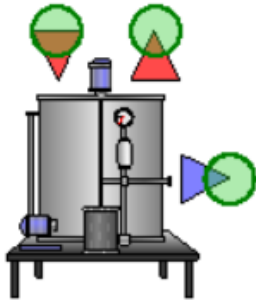
Derived State Variables

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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_SF	Nitrogen content of soluble substrate S_F	0.03	---
i_P_SF	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

Name	Terminal	Description	Value	Units
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_Methanol

Last Updated: 12/06/2024

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_SF	Nitrogen content of soluble substrate S_F	0.03	---
i_P_SF	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

Name	Terminal	Description	Value	Units
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_Alum

Last Updated: 12/06/2024

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of alum:

$$M_{MEOH} = Q_{dose} \cdot C_{dose} \cdot P_{eq} \cdot \frac{MW_{ref}}{MW}$$

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_{ref} and MW indicate the molecular weight of iron hydroxide ($Fe(OH)_3$, 106.85 g/mol) and that of alum (342 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

Last Updated: 12/06/2024

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of iron hydroxide:

$$M_{MEOH} = Q_{dose} \cdot C_{dose} \cdot P_{eq} \cdot \frac{MW_{ref}}{MW}$$

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_{ref} and MW indicate the molecular weight of iron hydroxide ($Fe(OH)_3$, 106.85 g/mol) and that of iron hydroxide

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

Last Updated: 12/06/2024

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of iron chloride:

$$M_{MEOH} = Q_{dose} \cdot (S \cdot \rho) \cdot P_{eq} \cdot \frac{MW_{ref}}{MW}$$

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_{ref} and MW indicate the molecular weight of iron hydroxide ($Fe(OH)_3$, 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

Dose_Fe2SO43

Last Updated: 07/07/2025

Instances

ASM2dMod, ASM2dISS

Description

The model describes the addition of a precipitant agent, in the form of iron III sulphate, $\text{Fe}_2(\text{SO}_4)_3$:

$$M_{\text{MEOH}} = Q_{\text{dose}} \cdot (S \cdot \rho) \cdot P_{\text{eq}} \cdot \frac{MW_{\text{ref}}}{MW}$$

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_{ref} and MW indicate the molecular weight of iron hydroxide ($\text{Fe}(\text{OH})_3$, 106.85 g/mol) and that of iron III sulphate (399.8 g/mol)

The power required for pumping is estimated as follows:

$$P_{\text{pump}} = \frac{F \cdot Q_{\text{dose}}}{24} \cdot 10^3$$

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/m ³
P_eq	Molar equivalence to phosphorous	0	---
Rho	Specific weight of the solution	1,500	kg/m ³
Strength	Strength of the solution (%w/w)	40	%

State Variables

Name	Description	Units
Q_Out	Effluent flow rate	m ³ /d

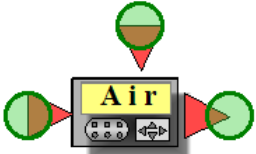
Derived State Variables

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	---	m ³ /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	m ³ /d

AERATION

	Palette Group	Aeration
	Category	Aerators
	Icon name	aerator

Ideal

Last Updated: 12/06/2024

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 :

$$kLa = \frac{m}{(C_S - C_0) \cdot V}$$

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

Last Updated: 12/06/2024

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	m ³
AE	Aeration efficiency	0.8	kgO ₂ /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/m ³
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	m ³ /d

IdealMulti2

Last Updated: 12/06/2024

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	m ³
AE	Aeration efficiency	0.8	kgO ₂ /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/m ³
Kla_01 ... Kla_10	out_1	Computed kLa for tank no. 1 to 10	---	1/d
T_air	in_2	Air temperature	15	°C

Name	Terminal	Description	Value	Units
<i>T_{water}</i>	<i>in 2</i>	<i>Water temperature</i>	<i>15</i>	<i>°C</i>
<i>Q_{air}</i>	<i>in 2</i>	<i>Total air flow rate</i>	<i>35,000</i>	<i>m³/d</i>
<i>f_{air_01} ... f_{air_10}</i>	<i>in 2</i>	<i>Fraction of total air flow to tank no. 1 to 10</i>	<i>0,1</i>	<i>---</i>

Surface

Last Updated: 12/06/2024

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	m ³
AE	Aeration efficiency	0.8	kgO ₂ /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/m ³
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

Last Updated: 12/06/2024

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 (m²) 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/m ³
Rho_{sludge}	Sludge density	1,000,000	g/m ³
Vol_{tank}	Volume of the aeration tank	1,000	m ³
A_{sp}	Specific area of the diffusers	2	m ²
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/m ³
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/m ³ /d
Q_{O2}	Oxygen mass load in air flow	kg/h
Qn	Normalised air flow	---
Qsp	Specific air flow (through each diffuser)	m ³ /d
SOTR	Standard Oxygen Transfer Rate	g/d
O2_{sat}	Oxygen saturation (temperature-water-dependent)	g/m ³
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/m ³
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

Name	Terminal	Description	Value	Units
P_Out	in 2	Pressure at delivery	80,000	Pa
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	m ³ /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

Last Updated: 12/06/2024

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:

$$\text{Krampe and Krauth (2003): } \alpha_0 = e^{-0.08788 \cdot MLSS}$$

$$\text{Baquero-Rodriguez et al. (2018): } \alpha_1 = \frac{0.507}{0.507 - 0.104} \cdot (e^{-0.104 \cdot MLSS} - e^{-0.507 \cdot MLSS})$$

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/m ³
Rho_sludge	Sludge density	1,000,000	g/m ³
Vol_tank	Volume of the aeration tank	1,000	m ³
A_sp	Specific area of the diffusers	2	m ²
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/m ³
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	CO ₂ 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/m ³ /d
Qsp	Specific air flow (through each diffuser)	m ³ /d
SOTR	Standard Oxygen Transfer Rate	g/d
O2_sat	Oxygen saturation (temperature-water-dependent)	g/m ³
P_vapour	Vapour pressure	Pa
Alpha	Empirical factor	---
AlphaF	Alpha-F factor (account for fouling of diffusers)	---
O2_rsats_ave	Average oxygen saturation for fine bubble aeration	g/m ³
M_CO2	CO ₂ production	g/d

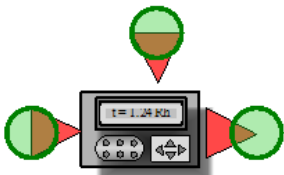
Derived State Variables

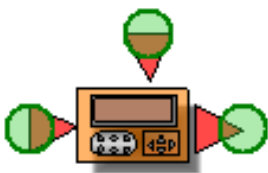
Name	Description	Units
E_CO2	CO ₂ emission	g

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	m ³ /d
MLSS	in 2	MLSS concentration in the tank	4,000	g/m ³
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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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	<i>Set-point values for the controlled variables</i>	2	---
K1-5_P	in 2	<i>Factors of proportionality</i>	25	---
u1-5_0	in 2	<i>No error actions</i>	50	---
u1-5_Min	in 2	<i>Minimum control actions</i>	0	---
u1-5_Max	in 2	<i>Maximum control actions</i>	1000.0	---

Controllers.PID_Saturation

Last Updated: 12/06/2024

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	<i>Set-point value for controlled variable</i>	2	---
K1_P	in_2	<i>Factor of proportionality</i>	25	---
T1_I	in_2	<i>Integral time</i>	0.1	d
T1_D	in_2	<i>Derivative time</i>	0.1	d
u1_0	in_2	<i>No error action</i>	50	---
u1_Min	in_2	<i>Minimum control action</i>	0	---
u1_Max	in_2	<i>Maximum control action</i>	1000.0	---

Controllers.PID_SaturationAW

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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	---	---
RI	in_2	Ratio between output and measured value	1	---

ControllersOp.OnOff11

Last Updated: 12/06/2024

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	---	---
<i>in01_Max</i>	in_2	Upper limit for the measured value no.1	0	---
<i>in01_Min</i>	in_2	Lower limit for the measured value no.1	0	---
<i>out01_Max</i>	in_2	Output when measured value > in01_Max	0	---
<i>out01_Min</i>	in_2	Output when measured value < in01_Min	0	---
<i>mode</i>	in_2	On (1), off (0)	1	---
<i>out_01_fb</i>	in_2	Fall-back for output no.1	0	---

ControllersOp.PI11

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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	---

Name	Terminal	Description	Value	Units
u01_Min	<i>in 2</i>	<i>Output when measured value < in01_Min</i>	<i>0</i>	<i>---</i>
u01_Max	<i>in 2</i>	<i>Output when measured value > in01_Max</i>	<i>0.0</i>	<i>---</i>
mode	<i>in 2</i>	<i>On (1), off (0)</i>	<i>1</i>	<i>---</i>
out_01_fb	<i>in 2</i>	<i>Fall-back for output no.1</i>	<i>0</i>	<i>---</i>

ControllersOp.PID_SRT

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

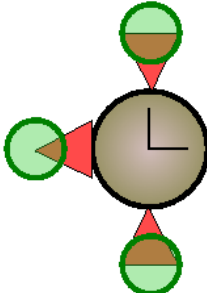
Derived State Variables

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

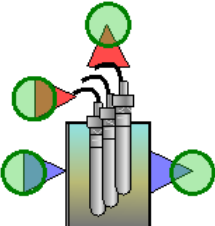
Derived State Variables

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

Last Updated: 12/06/2024

Instances

ASM1

Description

This is an in-line sensor that measures the following quantities:

Quantity	Units	Expression
Q	m ³ /d	Q_{In}
DO	g/m ³	S_O
COD	g/m ³	$S_S + S_I + X_S + X_I + X_{BA} + X_{BH} + X_P$
BOD	g/m ³	$S_S + X_S + (1 - f_P) \cdot (X_{BA} + X_{BH})$
NH	g/m ³	S_{NH}
NO	g/m ³	S_{NO}
TKN	g/m ³	$S_{NH} + S_{ND} + i_{NSI} \cdot S_I + i_{XB} \cdot (X_{BA} + X_{BH}) + i_{XP} \cdot (X_P + X_I)$
TN	g/m ³	$S_{NO} + TKN$
TSS	g/m ³	$F_{TSS,COD} \cdot TSS$
VSS	g/m ³	$(X_S + X_I + X_{BA} + X_{BH} + X_P) / i_{COD,VSS}$

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	m ³ /d
Q Out	Flow rate	m ³ /d
C	Concentration vector	g/m ³

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	---	m ³ /d
DO	out 2	Dissolved oxygen	---	g/m ³
BOD	out 2	BOD	---	g/m ³
COD	out 2	COD	---	g/m ³
NH	out 2	Ammonia	---	g/m ³

Name	Terminal	Description	Value	Units
NO	out_2	Nitrate + nitrite	---	g/m3
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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

Instances

ASM2dISS

Description

This is an in-line sensor that measures the following quantities:

Quantity	Units	Expression
Q	m ³ /d	Q_{In}
DO	g/m ³	S_O
COD	g/m ³	$S_{VFA} + S_F + S_U + XC_B + X_U + \sum X_{BM,i} + X_{PAO,Stor}$
BOD	g/m ³	$F_{BOD5,BOD20} \cdot \left(S_{VFA} + S_F + F_{BOD,COD,X} \cdot \left(XC_B + \sum X_{BM,i} + X_{PAO,Stor} \right) \right)$
NH	g/m ³	S_{NHx}
NO	g/m ³	$NO_2 + NO_3$
NO2	g/m ³	S_{NO2}
NO3	g/m ³	S_{NO3}
OrgN	g/m ³	$i_{NSU} \cdot S_U + i_{NSF} \cdot S_F + i_{NXU} \cdot X_U + i_{NXCB} \cdot XC_B + i_{NXBM} \cdot \sum X_{BM,i}$
TKN	g/m ³	$Org_N + S_{NHx}$
TN	g/m ³	$Org_N + S_{NHx} + S_{NO3} + S_{NO2} + S_{NO} + S_{N2O}$
OrgP	g/m ³	$i_{PSU} \cdot S_U + i_{PSF} \cdot S_F + i_{PXU} \cdot X_U + i_{PXC_B} \cdot XC_B + i_{PXBM} \cdot \sum X_{BM,i}$
PO	g/m ³	S_{PO}
TP	g/m ³	$Org_P + S_{PO} + X_{PAO,PP} + 0.205 \cdot X_{MEP}$
SO4	g/m ³	S_{SO}
TSS	g/m ³	$VSS + ISS$
VSS	g/m ³	$\sum X_{BM,i} / i_{COD,VSS,BM_i} + (XC_B + X_U + X_{PAO,Stor}) / i_{COD,VSS}$
ISS	g/m ³	$X_{MEOH} + X_{MEP} + i_{ISS,PP} \cdot X_{PAO,PP} + X_{U,Ig} + X_{Ash}$
X_Ash	g/m ³	$i_{ISS,BM} \cdot (X_{OHO} + X_{AOB} + X_{NOB} + X_{ANA} + X_{PAO})$

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	m ³ /d
Q_Out	Flow rate	m ³ /d
C	Concentration vector	g/m ³
Org_N	Organic nitrogen	g/m ³
Org_P	Organic phosphorous	g/m ³
X_Ash	Ash content of biomass	g/m ³
X_ISS	Inorganic suspended solids	g/m ³
X_VSS	Volatile suspended solids	g/m ³

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	---	m ³ /d
DO	out 2	Dissolved oxygen	---	g/m ³
BOD	out 2	BOD	---	g/m ³
COD	out 2	COD	---	g/m ³
NH	out 2	Ammonia	---	g/m ³
NO	out 2	Nitrate + nitrite	---	g/m ³
NO2	out 2	Nitrite	---	g/m ³
NO3	out 2	Nitrate	---	g/m ³
TKN	out 2	TKN	---	g/m ³
TN	out 2	Total nitrogen	---	g/m ³
PO	out 2	Orto-phosphate	---	g/m ³
TP	out 2	Total phosphorous	---	g/m ³
SO4	out 2	Sulphate	---	g/m ³
TSS	out 2	Total suspended solids	---	g/m ³
TSSc	out 2	Calculated total suspended solids	---	g/m ³
VSS	out 2	Volatile suspended solids	---	g/m ³
ISS	out 2	Inorganic suspended solids	---	g/m ³
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

Name	Terminal	Description	Value	Units
L_ISS	out 2	ISS load	---	g/d
P_Pump	out 2	Pumping power	---	kWh/d
IsPumped	in 2	<i>Flow is pumped (1) or not (0)</i>	0	---
E_Pump_sp	in 2	<i>Pumping energy per unit flow</i>	0.04	kWh/m ³

ASM2dISS.MultiSampler_kVol

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

Instances

ASM2dMod

Description

This is an in-line sensor that measures the following quantities:

Quantity	Units	Expression
Q	m ³ /d	Q_{In}
DO	g/m ³	S_O
COD	g/m ³	$S_A + S_F + S_I + X_S + X_I + X_H + X_{AUT} + X_{PAO} + X_{PHA}$
BOD	g/m ³	$F_{BOD,COD} \cdot (S_A + S_F + X_S + X_{PHA} + (1 - f_{X,I}) \cdot (X_H + X_{AUT} + X_{PAO}))$
NH	g/m ³	S_{NH}
NO	g/m ³	S_{NO}
OrgN	g/m ³	$i_{NSI} \cdot S_I + i_{NSF} \cdot S_F + i_{NXI} \cdot X_I + i_{NXS} \cdot X_S + i_{NBM} \cdot \sum X_{BM,i}$
TKN	g/m ³	$Org_N + S_{NH}$
TN	g/m ³	$Org_N + S_{NH} + S_{NO}$
OrgP	g/m ³	$i_{PSI} \cdot S_I + i_{PSF} \cdot S_F + i_{PXI} \cdot X_I + i_{PXS} \cdot X_S + i_{PBM} \cdot \sum X_{BM,i}$
PO	g/m ³	S_{PO}
TP	g/m ³	$Org_P + S_{PO} + X_{PAO,PP} + 0.205 \cdot X_{MEP}$
TSS	g/m ³	X_{TSS}
TSSc	g/m ³	$i_{TSS,XS} \cdot X_S + i_{TSS,XI} \cdot X_I + i_{TSS,BM} \cdot \sum X_{BM,i} + 3.25 \cdot X_{PP} + 0.6 \cdot X_{PHA} + X_{MEOH} + X_{MEP}$
VSS	g/m ³	$(X_S + X_I + X_H + X_{AUT} + X_{PAO}) / i_{COD,VSS}$

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	m ³ /d
Q_Out	Flow rate	m ³ /d
C	Concentration vector	g/m ³

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	---	m ³ /d
DO	out_2	Dissolved oxygen	---	g/m ³
BOD	out_2	BOD	---	g/m ³
COD	out_2	COD	---	g/m ³
NH	out_2	Ammonia	---	g/m ³
NO	out_2	Nitrate + nitrite	---	g/m ³
TKN	out_2	TKN	---	g/m ³
TN	out_2	Total nitrogen	---	g/m ³
PO	out_2	Orto-phosphate	---	g/m ³
TP	out_2	Total phosphorous	---	g/m ³
TSS	out_2	Total suspended solids	---	g/m ³
TSSc	out_2	Calculated total suspended solids	---	g/m ³
VSS	out_2	Volatile suspended solids	---	g/m ³
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/m ³

ASM2dMod.MultiSampler_kVol

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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*	$FSA + MW_N \cdot (i_{N,SU} \cdot S_U + i_{N,SF} \cdot S_F + i_{N,XUInf} \cdot X_{U,Inf} + i_{N,XBOrg} \cdot X_{B,Org} + i_{N,XOHO} \cdot (X_{OHO} + X_{PAO} + X_{AD} + X_{AC} + X_{AM} + X_{XM} + X_{ANO}) + i_{N,XUOrg} \cdot X_{U,Org} + i_{N,XBInf} \cdot X_{B,Inf} + i_{N,XStr,NH4} \cdot X_{Str,NH4})$
TKN_filt*	$FSA + MW_N \cdot (i_{N,SU} \cdot S_U + i_{N,SF} \cdot S_F)$
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**	$TP_o + TP_u + MW_P \cdot (i_{P,SPO4} \cdot S_{PO4} + i_{P,XStr,NH4} \cdot X_{Str,NH4} + i_{P,XStr,K} \cdot X_{Str,K} + i_{P,XACP} \cdot X_{ACP} + i_{P,XPAO,PP} \cdot X_{PAO,PP})$
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 PO ₄ 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	m ³ /d
Q_Out	Flow rate	m ³ /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

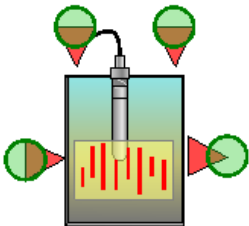
None

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 CaCO ₃	---	g/m ³
TotalAlkalinity	out_2	Total alkalinity as CaCO ₃	---	g/m ³
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

Last Updated: 12/06/2024

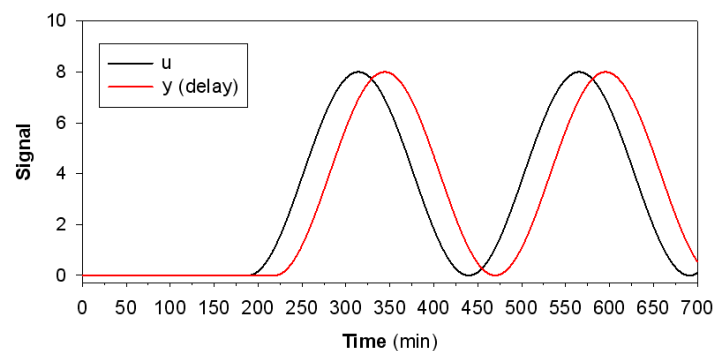
Instances

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.

$$y(t) = u \cdot (t - t_{\text{delay}})$$



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

Last Updated: 12/06/2024

Instances

All

Description

The model adds a random noise to the input signal.

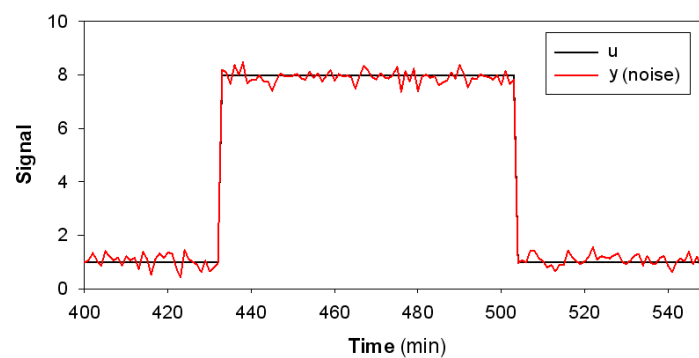
The noise is generated by randomly sampling from a normal distribution $N(0,1)$.

The model is described by the following equation and illustrated in the figure below.

$$y(t) = u(t) + \text{noise}(t) \cdot \text{NoiseLevel} \cdot y_{\max}$$

where:

- $\text{noise}(t)$ is the random noise
- $\text{NoiseLevel} \cdot y_{\max}$ 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

Last Updated: 12/06/2024

Instances

All

Description

The model adds a random noise to the input signal.

The noise is obtained from an input file

$$y(t) = u(t) + \text{noise}(t) \cdot \text{NoiseLevel} \cdot y_{\max}$$

where:

- $\text{noise}(t)$ is the random noise
- $\text{NoiseLevel} \cdot y_{\max}$ 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

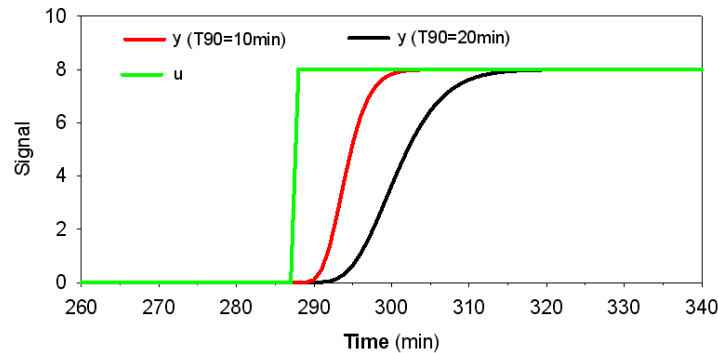
Last Updated: 12/06/2024

Instances

All

Description

The model describes the dynamic behaviour of a signal that is subjected to input dynamics (cf. figure).



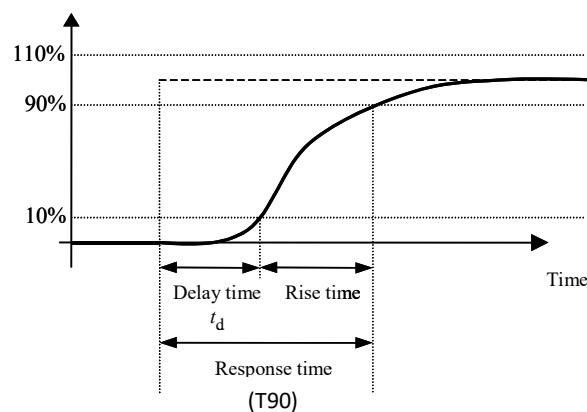
The dynamic behaviour of the response time is modelled through a series of Laplace transfer functions (i.e. creating an n -th order linear system composed of n first order differential equations) as in the following equation:

$$G_S(s) = \frac{y(s)}{u(s)} = \left(\frac{1}{1 + \text{Tau} \cdot s} \right)^n$$

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

Last Updated: 12/06/2024

Instances

All

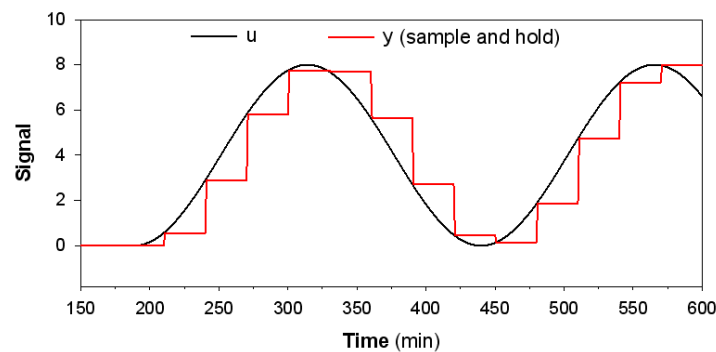
Description

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.

$$y(t) = u(t_{sample})$$

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

Last Updated: 12/06/2024

Instances

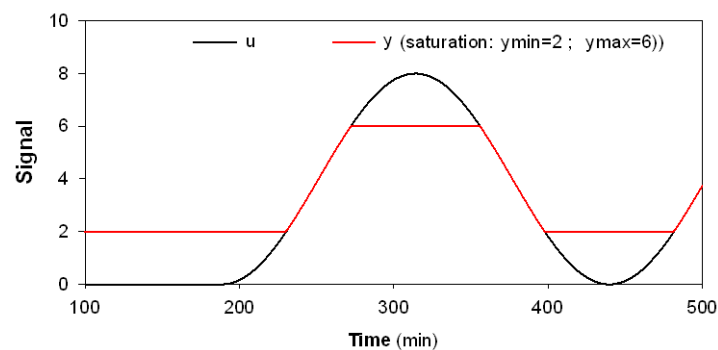
All

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.

$$y(t) = \begin{cases} y_{max}, & u(t) > y_{max} \\ u(t), & y_{min} \leq u(t) \leq y_{max} \\ y_{min}, & u(t) < y_{min} \end{cases}$$



Parameters

Name	Description	Value	Units
y Min	Minimum level for the signal	0	---
y Max	Maximum level for the signal	10	---

State Variables

None

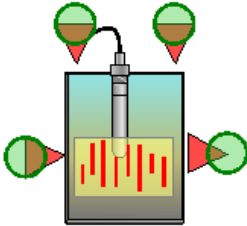
Derived State Variables

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

Last Updated: 12/06/2024

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/m ³
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/m ³
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/m ³

kTime

Last Updated: 12/06/2024

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/m ³
N_Bottle	Accumulated nr of aliquots collected over the sampling period	0	---
V_Bottle	Volume of composite sample	2	m ³
V_Sample	Volume of each aliquot; must be <= V_bottle	1	m ³
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/m ³
C_M_Comp	Measured concentration in the composite sample before full bottle	g/m ³
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

Last Updated: 12/06/2024

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

Name	Description	Value	Units
t_stop	Stop time for sampling	1	d
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

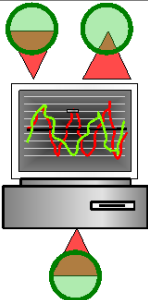
Derived State Variables

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	<i>Cost of analysis per sample</i>	<i>50</i>	<i>Euro</i>

PROCESS CALCULATORS

	Palette Group	Sensors
	Category	Calculators
	Icon Name	process_calculator

AS_SRT

Last Updated: 22/06/2026

Instances

All

Description

This block computes the Sludge Retention Time (SRT) – also referred to as sludge age or Mean Cell Residence Time (MCRT) – for an activated sludge system. It accepts solids concentrations and volumes from up to 30 biological reactor compartments, together with the flow rates and solids concentrations of up to two waste sludge streams and the plant effluent.

Two SRT's are computed:

- The instantaneous SRT, SRT_i
- The SRT averaged over a given time window, SRT_{avg}

Instantaneous SRT

$$SRT_i = \frac{TSS_{tanks}}{TSS_{flux}} = \frac{\sum V_i \cdot TSS_i}{Q_{out} \cdot TSS_{out} + Q_{WAS} \cdot TSS_{WAS}}$$

where:

- V_i and TSS_i denote the volume and solids concentration in the i-th process tank ($i = 1 \sim 30$)
- Q_{out} and Q_{WAS} denote the flow rate (m³/d) of the treated effluent and of the excess sludge respectively
- TSS_{out} and TSS_{WAS} denote the solids concentration (g/m³) in the treated effluent and in the excess sludge respectively

SRT_i can be numerically unstable when the WAS flow rate is regulated by an external controller, as rapid variations in Q_{WAS} produce large swings in the denominator.

Average SRT

$$SRT_{ave} = \frac{Mean(TSS_{tanks})}{Mean(TSS_{flux})}$$

This formulation – ratio of means rather than mean of a ratio, is the correct approach when instantaneous values are subject to high-frequency disturbances (e.g., pulsed WAS withdrawal, dynamic influent loading), as it prevents transient peaks in TSS_Flux from artificially depressing the reported average SRT.

Parameters

None

State Variables

Name	Description	Units
Avg flux	Average flux	g/d
Avg mass	Average mass in tanks	g
M_WAS	Sludge production	g/d

Derived State Variables

None

Interface Variables

Name	Terminal	Description	Value	Units
Q_Out	in_1	Effluent flow rate	---	m ³ /d
TSS_Out	in_1	Sludge concentration in the effluent	---	g/m ³
TSS_01 .. 30	in_1	TSS concentration in tank 01, 02, .. 30	---	g/m ³
V_01 .. 30	in_1	Volume of tank 01, 02, .. 30	---	m ³
Q_Waste1, 2	in_1	Flow of waste sludge no.1, 2	---	m ³ /d
TSS_Waste1, 2	in_1	Solids in waste sludge no.1, 2	---	g/m ³
SRTavg	out_1	Sludge age, averaged over T_Window	---	d
SRTi	out_1	Instantaneous sludge age	---	d
T_Window	in_2	Period to compute moving average	1.0	d

COST CALCULATORS

	Palette Group	Sensors
	Category	Cost
	Icon Name	cost

Operation_Simple

Last Updated: 12/06/2024

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

$$C_{aer} = \int (f_{aer} \cdot P_{aer,tot})$$

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

$$C_{mix} = \int (f_{mix} \cdot P_{mix,tot})$$

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

$$C_{pump} = \int (f_{pump} \cdot P_{pump,tot})$$

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

$$C_{heat,sludge} = \int (f_{heat} \cdot P_{heat,sludge})$$

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

$$C_{heat,loss} = \int (f_{heat} \cdot P_{heat,loss})$$

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

$$C_{sludge} = \int (f_{sludge} \cdot (TSS_{P1} \cdot Q_{P1} + TSS_{P2} \cdot Q_{P2}))$$

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	m ³
V_COD_dt	Amount of external carbon added over the set period	m ³
V_MEOH	Total amount of hydroxide added (or equiv. for P-precipitation)	m ³
V_MEOH_dt	Amount of hydroxide added (or equiv.) over the set period	m ³
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

Last Updated: 12/06/2024

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

$$CO2_{elec} = (P_{aer,tot} + P_{pump,tot} + P_{mix,tot}) \cdot f_{elec}$$

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

$$CO2_{chem} = L_{COD} \cdot f_{COD} + L_{MeOH} \cdot f_{MeOH} + CO2_{COD,DN}$$

$$CO2_{COD,DN} = (1 - Y_H) \cdot L_{COD} \cdot f_{COD} + L_{COD} \cdot EF_{CH_4} \cdot GWP_{CH_4}$$

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_{CH_4} is the mass of methane produced per load of incoming COD (kg CH₄/kg COD)
- GWP_{CH_4} denotes the Global Warming Potential of methane (kg CO₂eq/kg CH₄)

Process emissions of carbon dioxide

$$CO2_{CO_2,process} = (1 - Y_H) \cdot Q_{in} \cdot (BOD_{in} - BOD_{out}) \cdot EF_{CO_2}$$

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_{CO_2} 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

$$CO2_{sludge,soil} = S_{soil} \cdot C_{TN,sludge} \cdot (EF_{N2O,soil} \cdot GWP_{N2O} - CO2_{eq,synthN})$$

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

$$CO2_{sludge,comb} = S_{comb} \cdot C_{TN,sludge} \cdot (EF_{N2O,comb} \cdot GWP_{N2O} - E_{sludge} \cdot (e_{el} \cdot f_{el} + e_{th} \cdot f_{th}))$$

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 CH ₄)	13.9	---
Gas2El	Electricity utilisation from methane combustion	0.4	dUnit/dUnit
Gas2Th	Heat utilisation from methane combustion	0.5	dUnit/dUnit
EF_CH4	Mass of CH ₄ produced per load of incoming COD (kg N ₂ O-N / kg COD)	0.0075	dUnit/dUnit
EF_N2O	Mass of N ₂ O produced per load of incoming N (kgN ₂ O-N/kgN)	0.00084	dUnit/dUnit
GWP_CH4	Global warming potential of CH ₄	34	---
GWP_N2O	Global warming potential of N ₂ O	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 CO ₂ 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

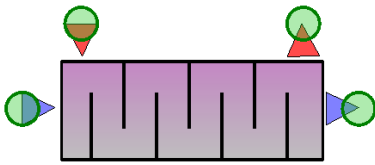
None

Interface Variables

Name	Terminal	Description	Value	Units
SI_TN01	in_1	Total N concentration in sludge flux #1	---	g/m3
SI_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

Last Updated: 12/06/2024

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	<i>E-coli count in the influent (from unit upstream)</i>	-1	---
rho_EColi_WWTP	in_2	<i>E-coli removal in the WWTP</i>	0.95	---

ChlorineInv

Last Updated: 12/06/2024

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
<i>EColi_In</i>	<i>in 2</i>	<i>E-coli count in the influent (from unit upstream)</i>	<i>-1</i>	---
<i>EColi_Out</i>	<i>in 2</i>	<i>Desired E-coli count in the effluent</i>	<i>240</i>	---
<i>rho_EColi_WWTP</i>	<i>in 2</i>	<i>E-coli removal in the WWTP</i>	<i>0.95</i>	---

PAA_02

Last Updated: 12/06/2024

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: $D_{PAA} = \frac{C_{PAA} - OD}{k} \cdot (1 - e^{-k \cdot HRT})$

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:

$$EColi_{Out} = 10^{In_{EColi} + dLog}$$

$$dLog = \log\left(\frac{N}{N_0}\right) = -k1 \cdot D_{PAA}^n \cdot \frac{1}{1 + e^{h - D_{PAA}}}$$

Parameters

Name	Description	Value	Units
F_TSS_COD*	Fraction TSS/COD	0.75	---
h	Empirical factor	6.335	---
k1	Empirical factor	1.851	---

Name	Description	Value	Units
n	Empirical factor	0.328	---
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	<i>E-coli count in the influent (from upstream)</i>	-1	---
rho_EColi_WWTP	in_2	<i>E-coli removal in the WWTP</i>	0.95	---
C_PAA	in_2	<i>Initial PAA concentration</i>	10	g/m3

UV

Last Updated: 12/06/2024

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	---

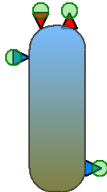
Derived State Variables

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	<i>E-coli count in the influent (from unit upstream)</i>	-1	---
rho_EColi_WWTP	in_2	<i>E-coli removal in the WWTP</i>	0.95	---
UV_I	in_2	<i>UV intensity</i>	0.2	mW/cm2

QUATERNARY TREATMENT

	Palette Group	Quaternary
	Category	Carbon Active
	Icon Name	GAC

GAC_01bed

Last Updated: 26/03/2025

Instances

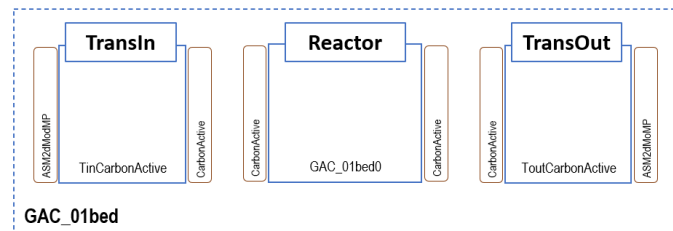
IUWS4

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

Last Updated: 26/03/2025

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	$k_{des} \cdot C_{XMP}$

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	$k_{des} \cdot C_{XDOC}$

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/m ³ /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/m ³
Inflow	in 1	Inflow	--	g/d
Outflow	out 1	Outflow	--	g/d
V_Tank	out 2	Volume of the tank	--	m ³

The sorption rate is calculated as follows:

- mode = 0, i.e., according to Freundlich isotherm

$$r_{sorption} = k_{des} \cdot K_{f_{MP}} \cdot \left(10^{-6 + \frac{3}{n_{MP}}} \right) \cdot \left(C_{S,MP}^{\frac{1}{n_{MP}}} \right) \cdot C_{ac}$$

- 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

Last Updated: 26/03/2025

Instances

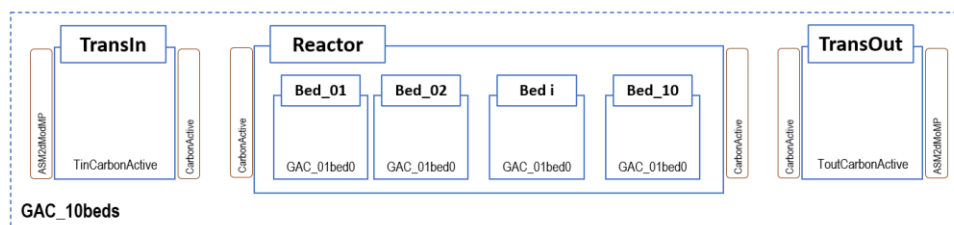
IUWS4

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

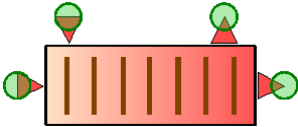
Derived State Variables

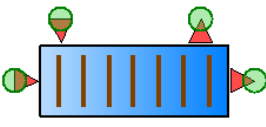
None

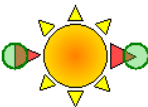
Interface Variables

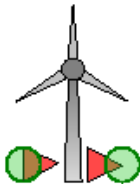
Name	Terminal	Description	Value	Units
Outflow	out 1	Outflow	---	m ³ /d
Inflow	in 1	Inflow	---	m ³ /d
Temp	in 2	<i>Temperature of the liquor</i>	<i>15</i>	<i>degC</i>

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

Last Updated: 12/06/2024

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):

$$\frac{dT_{\text{tank}}}{dt} = M_{\text{Feed}} \cdot C_p \cdot (T_{\text{Feed}} - T_{\text{Tank}}) + UA \cdot \frac{T_{\text{Gas}} - T_{\text{Tank}}}{M_{\text{Tank}} \cdot C_p}$$

where:

- M_{Feed} and M_{Tank} denote the feed flow rate [kg/d] and the total mass in the tank [kg]
- C_p 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]:

$$P_{\text{HeatSludge}} = c \cdot M_{\text{Feed}} \cdot C_p \cdot (T_{\text{Target}} - T_{\text{Feed}})$$

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

Last Updated: 12/06/2024

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):

$$\frac{dT_{\text{tank}}}{dt} = \frac{M_{\text{Feed}} \cdot Cp \cdot (T_{\text{Out}} - T_{\text{Tank}}) - P_{\text{HeatLoss}}}{M_{\text{Tank}} \cdot Cp}$$

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]:

$$P_{\text{HeatSludge}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot (T_{\text{Target}} - T_{\text{Feed}})$$

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:

$$P_{\text{biogas}} = P_{\text{GasTh}} + P_{\text{aux}}$$

$$P_{\text{lossdig}} = P_{\text{HeatLoss}}$$

$$P_{\text{sl}_{\text{dig}}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot T_{\text{op}}$$

$$P_{\text{sl}_{\text{heated}}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot T_{\text{Out}}$$

$$P_{\text{sl}_{\text{raw}}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot T_{\text{Feed}}$$

$$dP_{\text{dig}} = P_{\text{sl}_{\text{heated}}} - P_{\text{lossdig}} - P_{\text{sl}_{\text{dig}}}$$

$$dP_{\text{heater}} = P_{\text{sl}_{\text{raw}}} + P_{\text{biogas}} - P_{\text{sl}_{\text{heated}}}$$

$$dP_{\text{tot}} = P_{\text{sl}_{\text{raw}}} + P_{\text{biogas}} - P_{\text{lossdig}} - P_{\text{sl}_{\text{dig}}}$$

$$P_{\text{aux}} = \eta_{\text{aux}} \cdot Q_{\text{aux}} \cdot E_{\text{aux}_{\text{sp}}}$$

$$dt_{ml} = \frac{(T_{h2o_{in}} - T_{Out}) - (T_{h2o_{out}} - T_{Feed})}{\log\left(\frac{T_{h2o_{in}} - T_{Out}}{T_{h2o_{out}} - T_{Feed}}\right)}$$

$$P_{heat} = UA \cdot \frac{dt_{ml}}{3600}$$

$$T_{h2o_{out}} = T_{h2o_{in}} - \frac{P_{GasTh} + P_{aux}}{c \cdot Q_{h2o_{in}} \cdot \rho_{h2o} \cdot Cp_{h2o}}$$

Parameters

Name	Description	Value	Units
A	Area of heat exchanger	10	m ²
Cp	Heat capacity	2	kJ/kg/°C
Cp_h2o	Heat capacity of water	4.184	kJ/kg/°C
U	Heat transfer coefficient	100	W/m ² /°C
UA	Area x heat transfer coefficient	2,160,000	kJ/d/°C
V_Reactor	Volume of the tank receiving heated stream	1,000	m ³
rho_h2o	Density of water	1,000,000	g/m ³
rho_sludge	Sludge density	1,070,000	g/m ³
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	---	m ³ /d
Q_aux	in 1	Flow rate of auxiliary combustible	---	m ³ /d
Q_h2o_in	in_1	Flow rate of the hot water stream entering the heat exchanger	100	m ³ /d
T_Feed	in 1	Feed temperature	20	°C

Name	Terminal	Description	Value	Units
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	<i>Target temperature of the feed flow</i>	60	°C
E_aux_sp	in 2	<i>Volume-to-energy conversion factor of auxiliary combustible</i>	10.842	kWh/m ³
P_GasTh	in 2	<i>Available power for heating</i>	0	kWh/d
P_HeatLoss	in 2	<i>Heat loss in downstream process unit</i>	0	kWh/d

HeatExchanger.SludgeRecirc

Last Updated: 12/06/2024

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):

$$\frac{dT_{\text{tank}}}{dt} = \frac{M_{\text{Feed}} \cdot Cp \cdot (T_{\text{Out}} - T_{\text{Tank}}) - Q_{\text{Raw}} \cdot \rho_{\text{sludge}} \cdot Cp \cdot (T_{\text{Tank}} - T_{\text{Raw}}) - P_{\text{HeatLoss}}}{M_{\text{Tank}} \cdot Cp}$$

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]:

$$P_{\text{HeatSludge}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot (T_{\text{Target}} - T_{\text{Feed}})$$

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:

$$P_{\text{extra}} = P_{\text{GasTh}} + P_{\text{aux}} - P_{\text{biogas}}$$

$$P_{\text{lossdig}} = P_{\text{HeatLoss}}$$

$$P_{\text{sl}_{\text{dig}}} = c \cdot Q_{\text{Raw}} \cdot \rho_{\text{sludge}} \cdot Cp \cdot T_{\text{Op}}$$

$$P_{\text{sl}_{\text{heated}}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot T_{\text{Out}}$$

$$P_{\text{sl}_{\text{raw}}} = c \cdot Q_{\text{Raw}} \cdot \rho_{\text{sludge}} \cdot Cp \cdot T_{\text{Raw}}$$

$$P_{\text{sl}_{\text{recirc}}} = c \cdot M_{\text{Feed}} \cdot Cp \cdot T_{\text{Op}}$$

$$dP_{\text{dig}} = P_{\text{sl}_{\text{raw}}} + P_{\text{sl}_{\text{heated}}} - P_{\text{sl}_{\text{recirc}}} - P_{\text{lossdig}} - P_{\text{sl}_{\text{dig}}}$$

$$dP_{\text{heater}} = P_{\text{sl}_{\text{recirc}}} + P_{\text{biogas}} - P_{\text{sl}_{\text{heated}}}$$

$$dP_{\text{tot}} = P_{\text{sl}_{\text{raw}}} + P_{\text{biogas}} - P_{\text{lossdig}} - P_{\text{sl}_{\text{dig}}}$$

$$P_{aux} = \eta_{aux} \cdot Q_{aux} \cdot E_{aux_{sp}}$$

$$dt_{ml} = \frac{(T_{h2o_{in}} - T_{Out}) - (T_{h2o_{out}} - T_{Feed})}{\log\left(\frac{T_{h2o_{in}} - T_{Out}}{T_{h2o_{out}} - T_{Feed}}\right)}$$

$$P_{heat} = UA \cdot \frac{dt_{ml}}{3600}$$

$$T_{h2o_{out}} = T_{h2o_{in}} - \frac{P_{GasTh} + P_{aux}}{c \cdot Q_{h2o_{in}} \cdot \rho_{h2o} \cdot Cp_{h2o}}$$

Parameters

Name	Description	Value	Units
A	Area of heat exchanger	10	m ²
Cp	Heat capacity	2	kJ/kg/°C
Cp_h2o	Heat capacity of water	4.184	kJ/kg/°C
U	Heat transfer coefficient	100	W/m ² /°C
UA	Area x heat transfer coefficient	2,160,000	kJ/d/°C
V_Reactor	Volume of the tank receiving heated stream	1,000	m ³
rho_h2o	Density of water	1,000,000	g/m ³
rho_sludge	Sludge density	1,070,000	g/m ³
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	---	m ³ /d

Name	Terminal	Description	Value	Units
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
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	<i>Target temperature of the feed flow</i>	60	°C
E_aux_sp	in_2	<i>Volume-to-energy conversion factor of auxiliary combustible</i>	10.842	kWh/m3
P_GasTh	in_2	<i>Available power for heating</i>	0	kWh/d
P_HeatLoss	in_2	<i>Heat loss in downstream process unit</i>	0	kWh/d

HeatExchanger.Heat Pump

Last Updated: 12/06/2024

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 calculated 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:

- Q_{in} denotes the wastewater flow rate (m³/d),
- C_p is the heat capacity of water (kJ/kg/°C),
- $T_{w,in}$ and $T_{w,out}$ denote the temperature of the influent and of the effluent water flows, respectively (K),
- $T_{dh,in}$ and $T_{dh,out}$ denote the temperature of the district heating supply and reflux, respectively (K).
- ϵ_{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
C_p	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	---	m ³ /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

Last Updated: 12/06/2024

Instances

All

Description

The model estimates the daily energy output of a photovoltaic (PV) solar panel system, as:

$$P_{pv} = \frac{\epsilon_{pv} \cdot A_{pv} \cdot I_0 \cdot 24}{1000}$$

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 (m²).
- I_0 is the average solar irradiance (W/m²).

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

Last Updated: 12/06/2024

Instances

All

Description

The model estimates the daily energy output of a wind turbine, as:

$$P_{wind} = \frac{1}{2} \cdot \rho_{air} \cdot \frac{\pi \cdot D_{rotor}^2}{4} \cdot \frac{v_{wind}^3 \cdot \epsilon_{pv} \cdot 24}{1000}$$

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/m ³
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

Last Updated: 26/03/2025

There is no true effluent block in the WEST library, as it used to be the case in earlier versions.

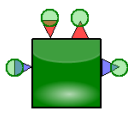
An influent block represents an entry point for a treatment plant model and allows for the generation of a dynamic influent file. More importantly, it establishes an interface (termed, fractionation model) between a set of conventional measurements and the set of “wwtp” state components.

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

Last Updated: 12/06/2024

Instances

All

Description

The model introduces a small differential delay:

$$\frac{d}{dt}F(t) = -\frac{1}{\tau} \cdot (F(t) - I(t))$$

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

Instances

All

Description

The model introduces a small differential delay:

$$\frac{d}{dt}x(t) = -\frac{1}{\tau} \cdot (x(t) - I(t))$$

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

Last Updated: 12/06/2024

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

Last Updated: 12/06/2024

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

