Tutorial

DYNAMIC SIMULATION SOFTWARE FOR BIOLOGICAL WASTEWATER TREATMENT MODELING

Activated Sludge Simulation Program

Asim 4.0

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1 AIM / IDEA

ASIM draws on a case study as an example to simulate a nitrification-enabled wastewater treatment plant (WWTP). It permits calculations and allows for a variety of optional expansions. This tutorial covers the most important aspects of ASIM and helps you to understand them. While working on the tutorial, you will create various files. All these files are saved in the folder “Tutorial” as well, but should not be used unless you are not able to proceed (Appendix B – Attached Data Files).

2 PLANT

Our fictitious WWTP serves a population equivalent of 10'000 and is originally designed for nitrification only (Figure 1).

Table 1 illustrates operating characteristics.

Table 1: Plant data and influent concentrations.

Average Influent	4000	$m^3\ d^{-1}$
Volume of Activated Sludge Tank	1500	m^3
Volume of Secondary Clarifier	2000	m^3
Return-sludge	4000	$m^3\ d^{-1}$
Sludge Age	9	d
Total Kjeldahl Nitrogen	34.6	$g\ m^{-3}$
NH_4-N-Concentration	25	$g\ m^{-3}$
COD_{tot}-Concentration	280	$g\ m^{-3}$
TSS-Concentration	210	$g\ m^{-3}$
Alkalinity	6	$mol\ m^{-3}$
Winter Temperature	10	°C

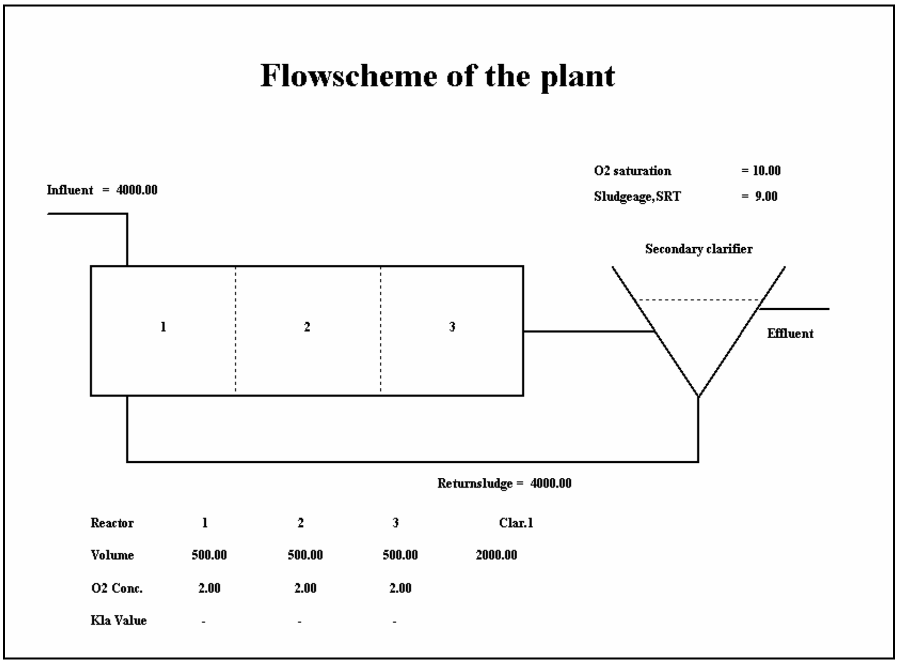


Figure 1: Flowscheme of the plant.

3 IMPLEMENTATION

In this chapter you will create a model plant and discover how the essential input masks work. The creation of a kinetic model is explained in the Appendix A – The Model File.

Start ASIM, create a new project (Figure 2) and choose a name for your new project folder (not “tutorial”, as this project already exists).

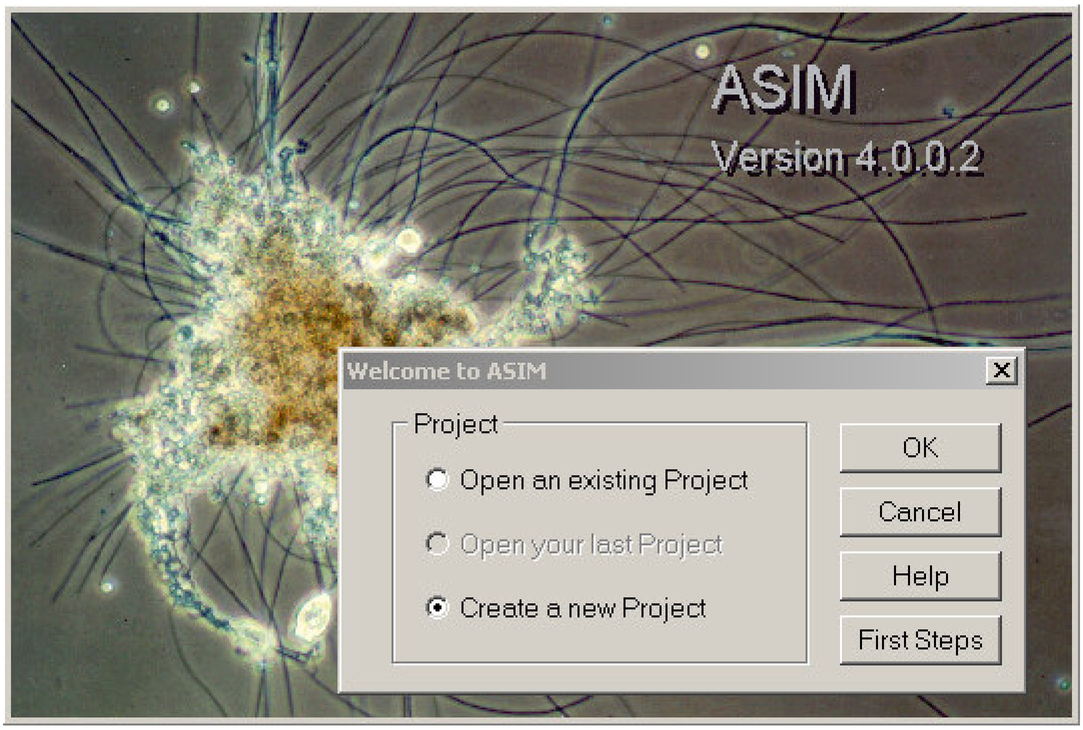


Figure 2: In ASIM you can continue working on any project. The last project is available as well.

ASIM uses different data files to manage different types of information. In the following you will create such files.

All files are saved in a project file directory, in the folder “User” (e.g. “C:\\Program Files\ASIM\User\Tutorial”).

If you want to continue working on an existing project, select “Open an existing project” and all the projects saved in the folder “User” become available.

3.1 MODEL FILE

A Model File contains a biokinetic model (e.g. the Activated Sludge Model), all kinetic and stoichiometric parameters, including temperature dependency, initial conditions for integration and the concentrations of the first influent.

In our present example we use an already existing model, the Activated Sludge Model No.3, calibrated for Swiss municipal wastewater. Load this model by selecting the file "Asm3_swiss.mod" from the menu bar "Model → Load ASIM Model". For details concerning this model and creating a new one, please consult literature (Koch, G. et al.) and Appendix B – Attached Data Files.

3.2 PLANT FILE

A Plant File includes the definition of the flow scheme, the concentrations of the first and the second influent and the valid control loops. The present state and current operating temperature of the plant are saved as well.

Create a Plant File using the parameters from Table 1 and the flow scheme from Figure 1.

From the menu "Plant definition → Define new Flowscheme → Activated Sludge Reactor" you reach the mask displayed in Figure 3.

3.2.1 DEFINITION

- The activated sludge reactor is modeled with three separate tanks in order to reproduce the hydraulic behaviour of the plant (consider results from tracer-experiments).
- The influent and return-sludge are fed into the first reactor.
- There is no internal recirculation.
- The sludge age amounts to 9 days.
- The secondary clarifier is represented with one reactor (in Asim the secondary clarifiers are ideally separating solids from the liquid. The solids retention time is 0).

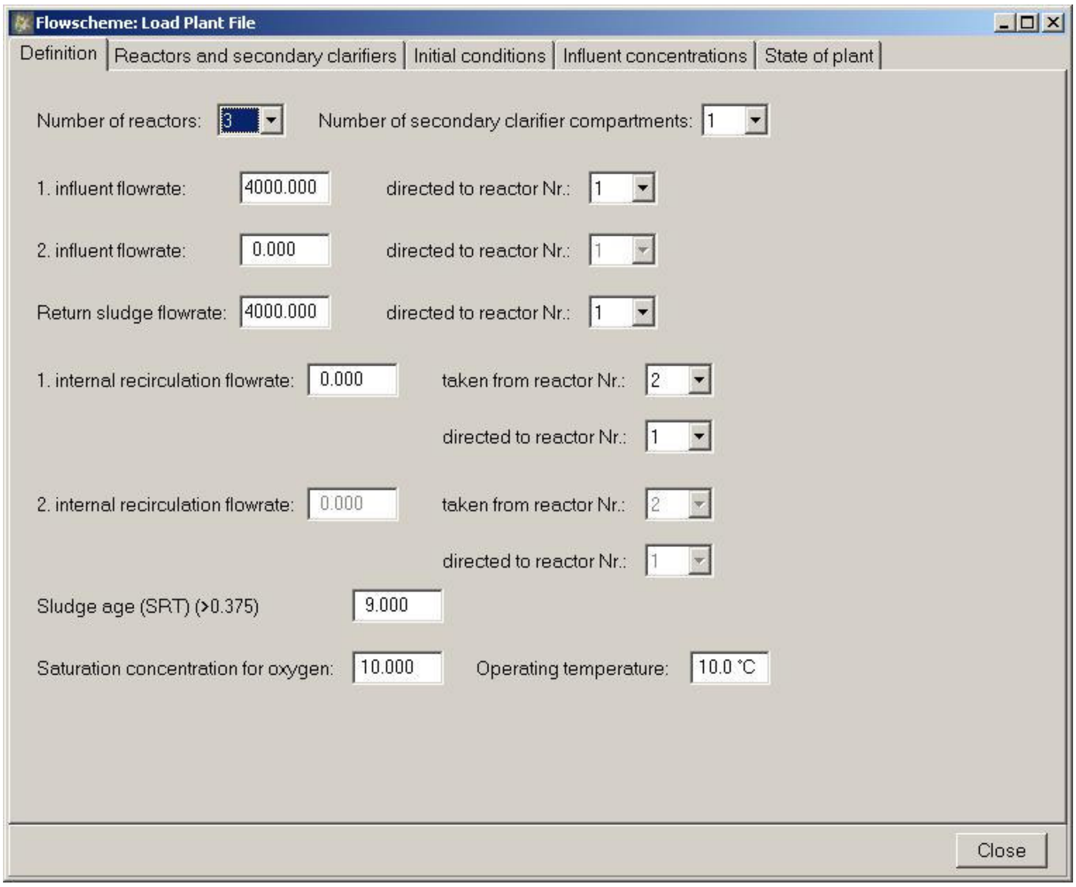


Figure 3: Plant definition with the configuration of reactors.

3.2.2 REACTORS AND SECONDARY CLARIFIERS

Now we turn to individual reactor volumes and aeration capacities:

- O_2-setpoint: Oxygen concentration is always kept at a certain level.
- k_La-value: Aeration capacity remains constant.

You have to choose between two types of aeration (in Chapter 8 we will introduce a third option, which is a control mechanism). O_2-setpoint remains at a constant level of 2 mg/l in all reactors.

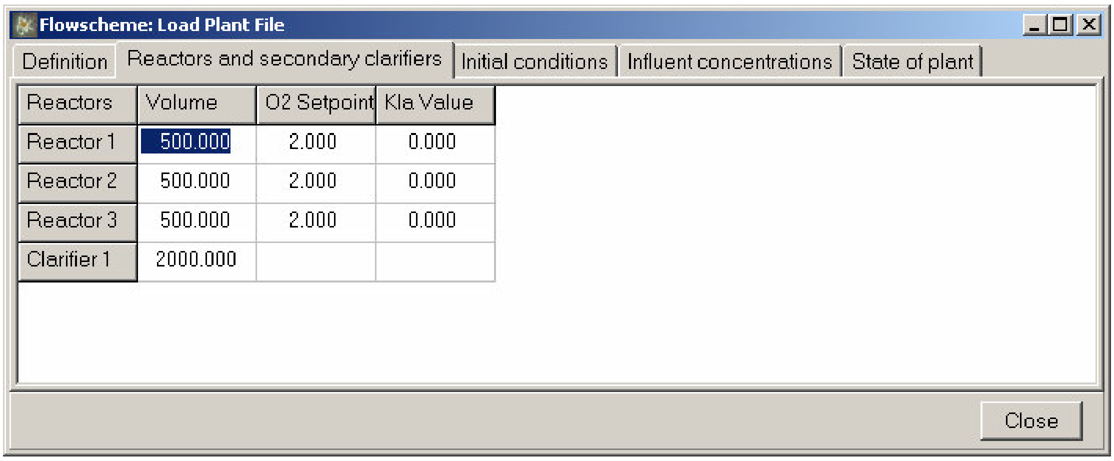


Figure 4: Plant definition with reactor volumes and aeration.

While providing your input, you can test it by using the graphic scheme shown on the background. To see the graphics afterwards, select “Graphic of Flowscheme” from the menu “Plant Definition”.

3.2.3 INFLUENT CONCENTRATIONS

In this register you fill in the concentrations of the first and the second influent. Table 2 illustrates how the COD_{tot}-concentration is divided into various COD-fractions. For an explanation of this table, we recommend literature relevant to ASM3. In most cases, the COD-fractionation results from calibration. Table 2 offers standard values. Enter the concentrations of the first influent according to Figure 5 and Table 1.

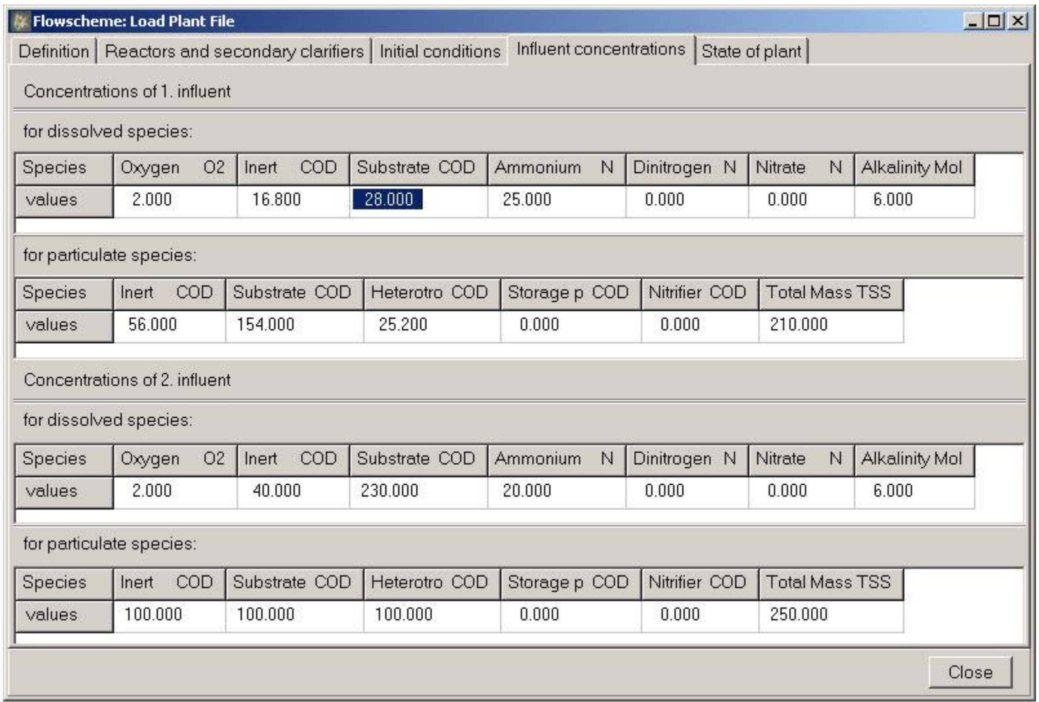


Figure 5: Plant definition with influent concentrations.

The second influent must be defined in register “Definition” before entering the data here. You will need this in Chapter 5.

Table 2: Standard Values for the Various Fractions of the Total COD in ASM3 (Koch et al., 2000)

	Dissolved		Particulate					
Fraction	Inert	Substrate	Inert	Substrate	Heterotroph	Storage p	Nitrifier	Total:
Share	6%	10%	20%	55%	9%	0%	0%	100%

3.2.4 INITIAL CONDITIONS AND STATE OF PLANT

There are two further registers involved in creating a Plant File: “Initial Conditions” and “State of plant”. The first one contains a set of initial conditions required for differential equations. Furthermore, they can be used to characterize the initial conditions of an experiment. The latter register includes a set of values in the influent, reactors and secondary clarifiers. You will notice that both registers involve the same parameters. This is deducible from the fact that – in order to enable further dynamic calculations directly – the values in “Initial Conditions” are overwritten with the new values from the register “State of plant“ subsequent to computations.

3.3 VARIATION FILE

A Variation File contains information that is necessary for dynamic simulations, such as changes in influent, excess sludge draw-off (DX), concentrations, etc. over a certain stretch of time. Only relative values are given (actual value / mean value over time), except for temperature, where absolute deviation is provided. The mean value over time is the value defined in the Plant File. This permits applying the same Variation File with different loads / in different situations.

Running dynamic simulations is not possible unless a Variation File is available.

Table 3 gives the diurnal variations of ammonium, COD and influent. In the following you will use these values to create a Variation File.

Table 3: Daily Variation of NH_4, COD and Influent

Time [h]	Ammonium [g m^{-3}]	COD_{tot} [g m^{-3}]	Q [m^3 d^{-1}]
0 – 2	20.70	73.7	2540
2 – 4	15.53	57.7	2284
4 – 6	10.35	145.3	2792
6 – 8	23.21	248.6	3048
8 – 10	46.74	345.3	4064
10 – 12	31.05	474.9	5080
12 – 14	26.71	467.6	6096
14 – 16	25.04	497.6	4824
16 – 18	23.21	408.2	4572
18 – 20	28.38	318.9	6096
20 – 22	25.88	211.9	3556
22 – 24	23.21	110.4	3035

Open a new Variation File by selecting “New Variation“ from the menu “Variation”.

3.3.1 OPTIONS

The first register requires individual cycle periods and their change intervals to be defined. As illustrated in Table 3, we are looking at a 24-hour-cycle with 2-hour resolution. For the time being there is no second influent.

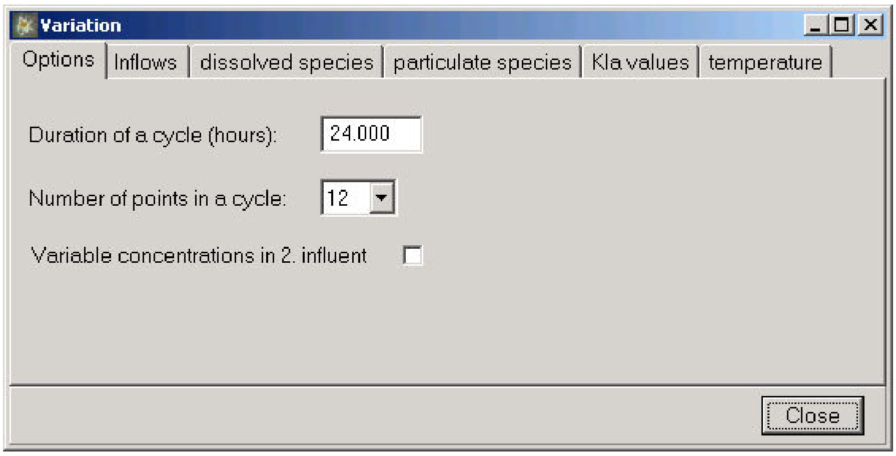
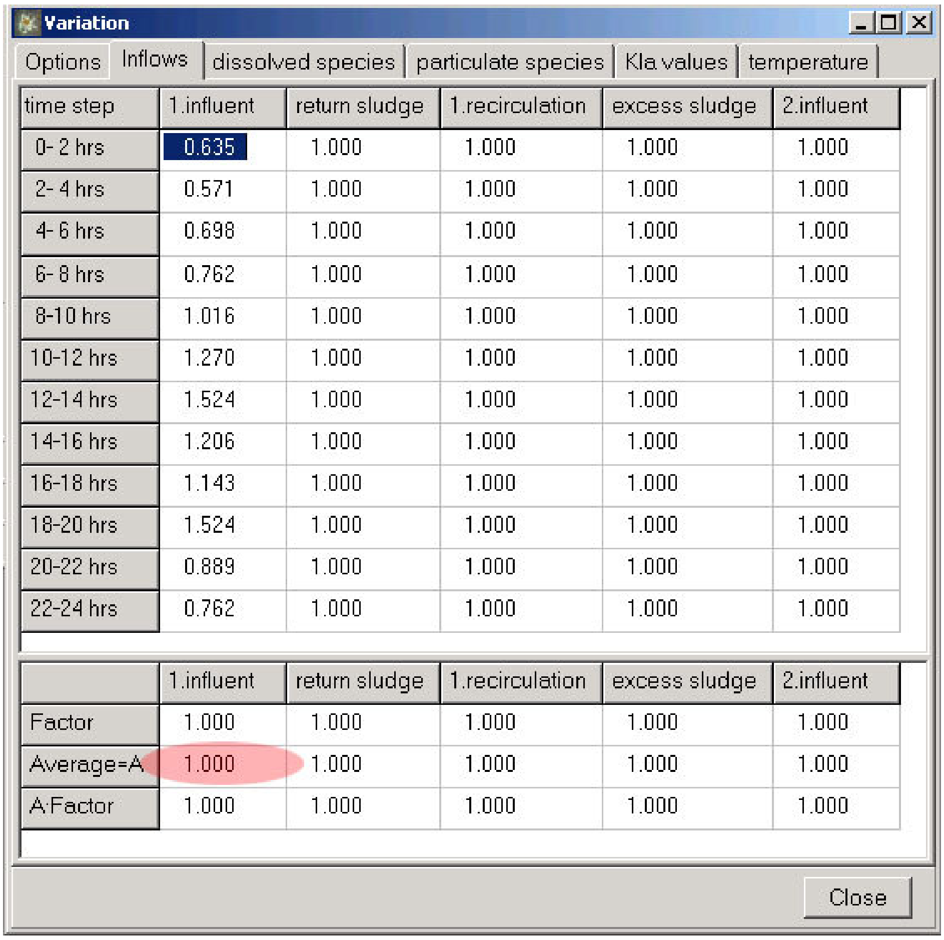


Figure 6: Variation definition.

3.3.2 INFLOWS

Please enter the data from Table 3 into the column “1.influent” in the register “Inflows”. You may use the absolute values from Table 3. If you set the mean value A “Average = A” underneath the first column to 1.000, ASIM will automatically substitute the absolute values with relative values. In our present example, the return and excess sludge are managed uninterrupted and kept constant for now.



time step	1.influent	return sludge	1.recirculation	excess sludge	2.influent
0- 2 hrs	0.635	1.000	1.000	1.000	1.000
2- 4 hrs	0.571	1.000	1.000	1.000	1.000
4- 6 hrs	0.698	1.000	1.000	1.000	1.000
6- 8 hrs	0.762	1.000	1.000	1.000	1.000
8-10 hrs	1.016	1.000	1.000	1.000	1.000
10-12 hrs	1.270	1.000	1.000	1.000	1.000
12-14 hrs	1.524	1.000	1.000	1.000	1.000
14-16 hrs	1.206	1.000	1.000	1.000	1.000
16-18 hrs	1.143	1.000	1.000	1.000	1.000
18-20 hrs	1.524	1.000	1.000	1.000	1.000
20-22 hrs	0.889	1.000	1.000	1.000	1.000
22-24 hrs	0.762	1.000	1.000	1.000	1.000

	1.influent	return sludge	1.recirculation	excess sludge	2.influent
Factor	1.000	1.000	1.000	1.000	1.000
Average=A	1.000	1.000	1.000	1.000	1.000
A·Factor	1.000	1.000	1.000	1.000	1.000

Figure 7: Influent variation and value standardization.

3.3.3 DISSOLVED / PARTICULATE SPECIES

Variation of ammonium concentration:

Input of the NH_4-concentrations is analogous to the influent variation discussed above. Enter the values from Table 3 into the column "Ammonium" in the register "dissolved species" and standardize the variation to 1.000 using the mean value A again.

COD-Variation:

Table 3 lists COD-values as COD_{tot}. For simplicity, we assume here that the various COD-fractions depend on identical variations. Enter the values from Table 3 into any COD-fraction column and standardize these to 1.000.

In order not to repeat this procedure for each COD-fraction individually, you can copy your data from one column to the others. Using your left mouse button, click on the title bar of your preferred column and select then the source to be copied from (Figure 8). Repeat this procedure with the particulate (inert, substrate, heterotrophic organisms) and the dissolved (inert, substrate) COD.

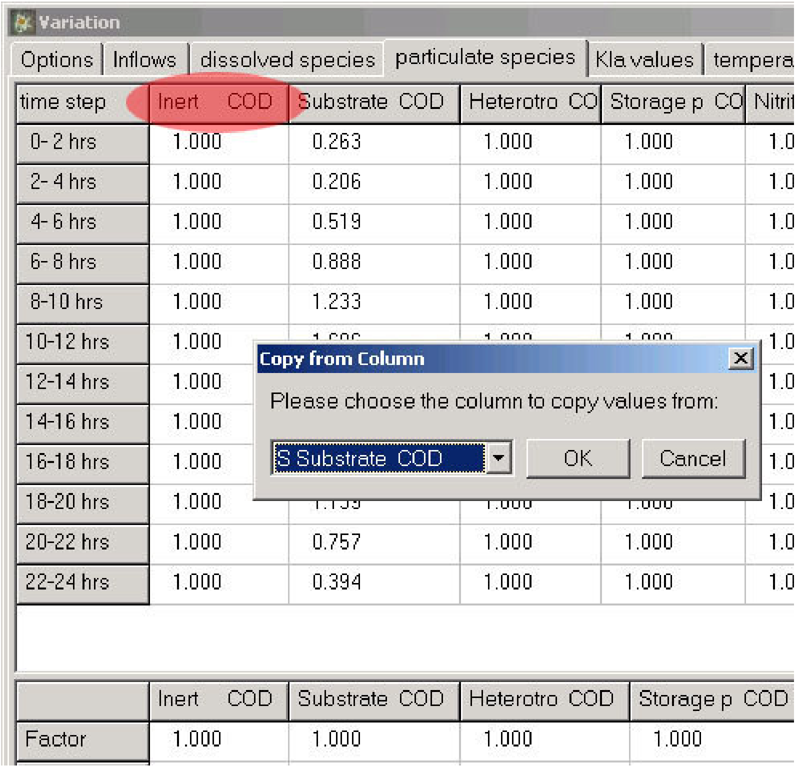


Figure 8: In order to copy the variation of readily degradable substrate (Substrate COD) to the fraction of inert COD, click on the highlighted area and select the readily degradable substrate from the pull down menu.

We assume that the variation of the total suspended solids (TSS) follows the influent variation: click on the title bar using your left mouse button again and copy the data from the influent variation. A further assumption concerns the independence of oxygen, nitrogen (N_2), nitrate and alkalinity; these are not influenced by any variation.

3.3.4 K_LA-VALUES

This register allows you to adjust the capacity of aeration in individual reactors. This may be of importance if you are aerating intermittently (not used in this tutorial). To do this, you must fill in the k_La -values column while providing input for oxygen conditions (Figure 4).

3.3.5 TEMPERATURE

Although temperature normally varies over time, we ignore it in this example. On the contrary to other parameters, the absolute deviation from the mean temperature is given here.

3.4 SAVING CHANGES

Should you change anything in a file while using ASIM, modifications are not automatically saved. So far your entries are saved merely in RAM. Your files are saved only in the following cases (providing that you want them to be):

- you load a new file
- you leave the program
- you choose the command “Save File(as)”

Save the Plant File you have created by selecting “Save Plant File as” from the menu “Plant Definition” (ignore the appearing alarm signal). Your plant is given the same name as the project folder by default, so name it “winter.pln”. Save your Variation File (“Variation”→ “Save Variation”).

This saving strategy enables various computations without overwriting the file created first.

You find the files introduced above also in the folder “Tutorial” (“tutorial_winter.pln“ and “tutorial.vrt”).

4 COMPUTATIONS

Different problems call for different computations. For a long-term run, main interest often concerns a steady state; for other aspects, data with temporary resolution is of importance. ASIM offers three computation methods: relaxation, integration and dynamic simulation. You can access all of them from the menu "Computations".

4.1 STEADY STATE

4.1.1 RELAXATION

Relaxation is a very fast routine that brings the system rapidly towards its steady state. However, you can never reach the steady state by relaxation, you can only approximate it. The steady state is subsequently completed by integration.

Relaxation requires entering three computation times. This follows from the different rates that oxygen, dissolved and particulate species require to reach their individual steady states. The proposed values are usually appropriate. The steady state is achieved by proceeding from relaxation to integration.

4.1.2 INTEGRATION

A system reaches its steady state through „Integration". After running an integration you can verify the state of your plant directly from „Show Results" in the register „State of plant" (will be opened by default).

Please keep in mind: computing steady states will substitute initial conditions with freshly computed values. Any subsequent computations are done on the basis of these new values. This can lead to detrimental results, especially in dynamic simulations, if you want to observe the development of a system from one operating stage to another.

Bring your plant to its steady state and compare the results with Table 4. (Deviations of up to 2 % are within the limits of the accuracy of ASIM.)

Table 4: The Plant in its Steady State in Winter (10°C)

		1. Influent	Reactor 1	Reactor 2	Reactor 3	Clarifier 1
	Flowrates / Volumes	4000	500	500	500	2000
dissolved	Oxygen O2	2	2	2	2	
	Inert COD	16.8	16.8	16.8	16.8	16.8
	Substrate COD	28	0.996	0.517	0.377	0.373
	Ammonium N	25	6.698	2.135	0.465	0.465
	Dinitrogen N	0	2.066	2.537	2.945	2.945
	Nitrate N	0	17.842	22.106	23.629	23.629
	Alkalinity Mol	6	3.419	2.789	2.561	2.561
particulate	Inert COD	56	1707.98	1710.60	1713.22	
	Substrate COD	154	93.212	68.55	50.247	
	Heterotro COD	25.2	1421.64	1427.69	1430.27	
	Storage p COD	0	29.891	25.885	20.916	
	Nitrifier COD	0	96.801	97.555	97.635	
	Total Mass TSS	210	3447.732	3434.914	3422.584	
	Oxygen consumption		844.887	640.297	412.200	

4.2 DYNAMIC COMPUTATIONS

In the previous section you brought your plant to its steady state and now – on the basis of this equilibrium – you are able to simulate dynamically one or more diurnal runs.

Select “Dynamic Simulation” from the menu “Computations“. In the appearing mask, enter the number of computation cycles to be simulated (e.g. 5). Optionally, you can illustrate all computed cycles as a chart series. Start your simulation and take a look at the results (you can access the results afterwards as well, by clicking the menu item “Results”).

Hydraulic fluctuations are shown in the beginning by default. From the menu “View Single Chart” you can switch to a parameter group of your choice (e.g. → “Dissolved Species → S Ammonium N of all Reactors”). Alternatively you can include or exclude individual curves.

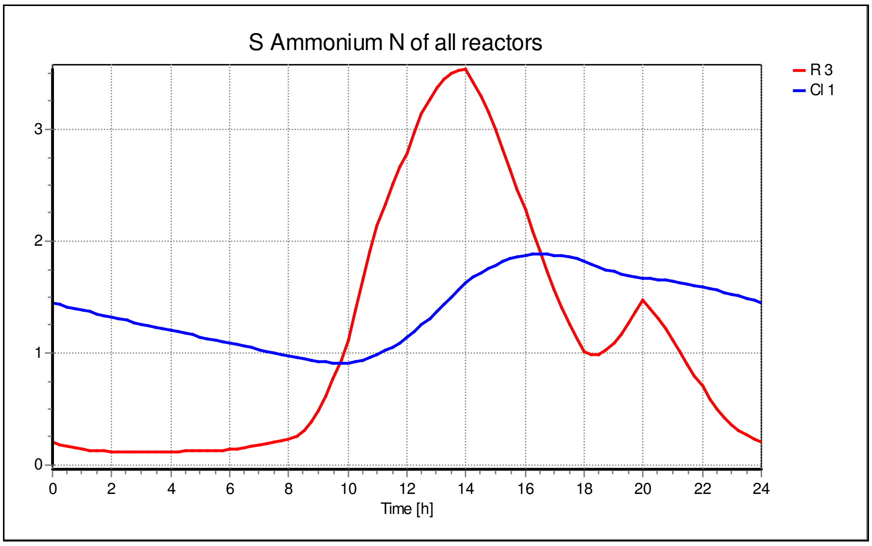


Figure 9: The ammonium concentration in the final reactor and secondary clarifier on the fifth day. As you can see, there is a considerable decrease in the reserves as opposed to the static computations. The reserves are approaching the limit value of 2 mg NH_4-N l^{-1}.

Using the right mouse button, you can edit and export the graphics or evaluate them statistically.

5 DIFFERENT SITUATIONS

How to simulate simply situations with different determining factors? This chapter offers examples of simulating a summer operating situation or situations with an increased total, COD- and nitrogen load. It furthermore explains how to deal with the consequences they bring.

5.1 SUMMER / WINTER

You can easily switch from an operating situation under winter conditions (10°C) to summer conditions by adjusting the operating temperature in your Plant File.

Run the same simulation again, but now with an operating temperature of 20°C. For this purpose, define a second Plant File with the necessary changes. Save the existing file first („Save Plant File"), then change the temperature and finally save the new file as „sommer.pln". You can also find the file „tutorial_sommer.pln" in the folder "Tutorial".

Table 5 and Figure 10 display the results as discussed in Chapter 4.

Table 5: Steady State under Summer Conditions (20°C)

	1.influent	Reactor 1	Reactor 2	Reactor 3	Clarifier 1
Flowrate/Volumes	4000	500	500	500	2000
Oxygen O2	2	2	2	2	
Inert COD	16.8	16.8	16.8	16.8	16.8
Substrate COD	28	0.814	0.388	0.252	0.25
Ammonium N	25	3.183	0.412	0.101	0.101
Dinitrogen N	0	2.358	2.885	3.316	3.316
Nitrate N	0	21.853	24.541	25.049	25.048
Alkalinity Mol	6	2.882	2.492	2.433	2.434
Inert COD	56	1818.735	1822.166	1825.583	
Substrate COD	154	69.326	45.126	29.204	
Heterotro COD	25.2	920.838	922.666	919.060	
Storage p COD	0	16.897	12.656	9.033	
Nitrifier COD	0	62.558	62.627	62.155	
Total Mass TSS	210	3022.125	3006.009	2990.787	
Oxygen consumption		1153.492	581.864	373.440	

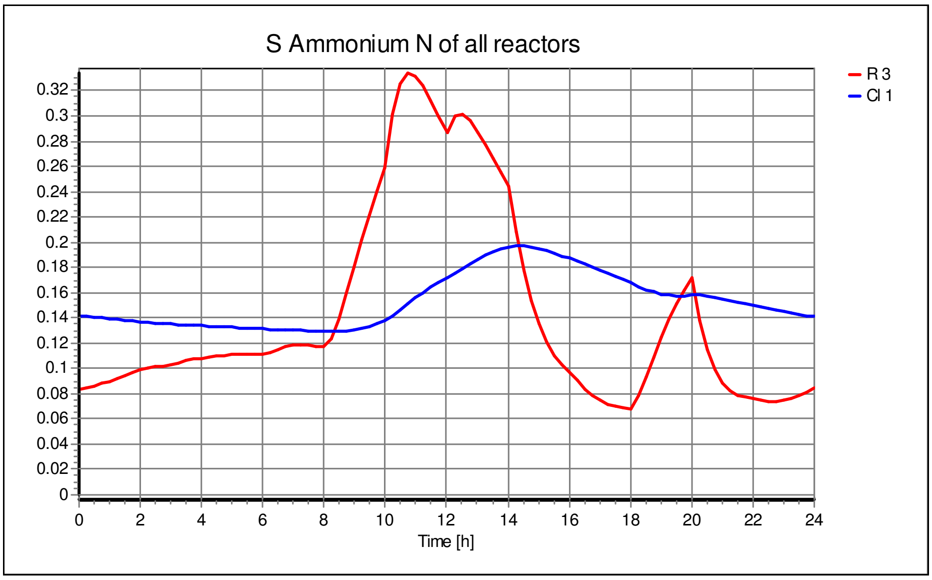


Figure 10: Variation of ammonium concentration in the effluent of a model plant in summer.

5.2 INCREASED LOAD

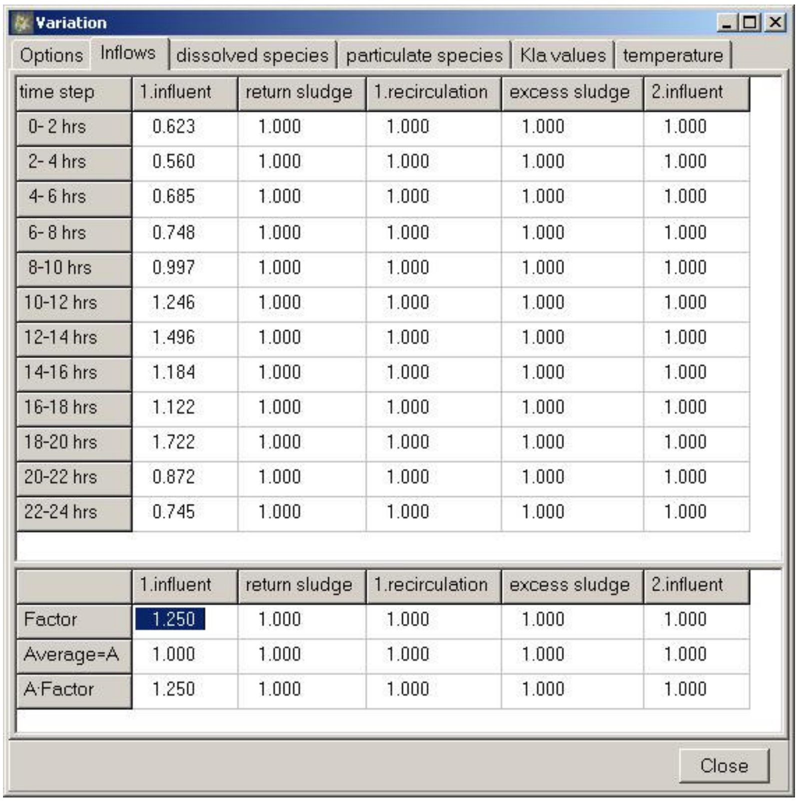
Simulating operating situations with a variety of load scenarios using a Variation File is straightforward. We are now going to simulate three different situations (Sections 5.2.1., 5.2.2. and 5.2.3.)

5.2.1 PERIOD WITH A TOTAL LOAD INCREASED BY 25 %

This situation applies approximately to a load that is not exceeded on 80 % of the operating days. Concentrate on the development of TSS over a range of several days.

Start from the winter operating state with its Plant, Variation and Model File from Section 4.2. To do this, select the file “winter.pln“ from “Plant Definition → Load Plant File”. (A dialog box may appear stating that the momentary plant is not available. Click “OK“).

- First, bring your plant to its steady state (the Plant File “winter.pln“ still includes the final values from your last (dynamic) simulation). Thus, you ensure that your plant is in its steady state before entering a new load situation.
- Then, edit the diurnal run of the influent in your Variation File (“Variation → Edit Variation”). Change the factor underneath the influent column (Figure 11). In order to increase the influent (and thus also load) by 25 %, set the factor to 1.250. You can find this Variation File (“tut_belastung.vrt”) in the folder “Tutorial” as well.



time step	1.influent	return sludge	1.recirculation	excess sludge	2.influent
0- 2 hrs	0.623	1.000	1.000	1.000	1.000
2- 4 hrs	0.560	1.000	1.000	1.000	1.000
4- 6 hrs	0.685	1.000	1.000	1.000	1.000
6- 8 hrs	0.748	1.000	1.000	1.000	1.000
8-10 hrs	0.997	1.000	1.000	1.000	1.000
10-12 hrs	1.246	1.000	1.000	1.000	1.000
12-14 hrs	1.496	1.000	1.000	1.000	1.000
14-16 hrs	1.184	1.000	1.000	1.000	1.000
16-18 hrs	1.122	1.000	1.000	1.000	1.000
18-20 hrs	1.722	1.000	1.000	1.000	1.000
20-22 hrs	0.872	1.000	1.000	1.000	1.000
22-24 hrs	0.745	1.000	1.000	1.000	1.000

	1.influent	return sludge	1.recirculation	excess sludge	2.influent
Factor	1.250	1.000	1.000	1.000	1.000
Average=A	1.000	1.000	1.000	1.000	1.000
A·Factor	1.250	1.000	1.000	1.000	1.000

Figure 11 Increasing the influent.

- At this point you can compute your plant's steady state. This will not influence the results, because relaxation and integration manipulate only the values from the Plant File. This is important to know, if you want to test a variety of scenarios relevant to the steady state. In such case you should enter any load changes in the Plant File.
- Run a dynamic simulation with an increased load for 10 days and let ASIM illustrate all the cycles (by ticking "Show all cycles in plot" in the simulation mask, as illustrated in Figure 12).

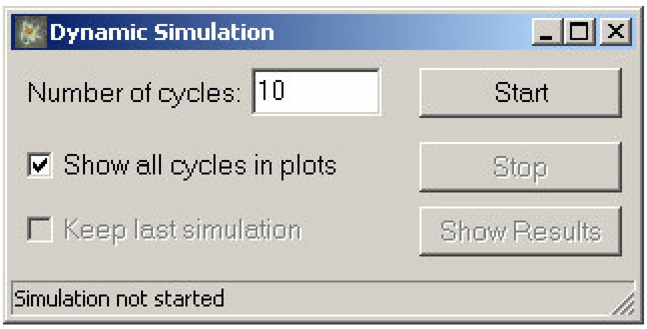


Figure 12: Dynamic simulation for 10 days, showing all the cycles.

- Select TSS in all reactors by clicking "View Single Chart → Particulate Species → X Total Mass TSS of all reactors" and compare the development with Figure 13.

- Set the influent factor in the Variation File back to 1.000 and run another dynamic simulation (compute this time 30 cycles, without integrating beforehand). How long does the plant need to return to the previous state?

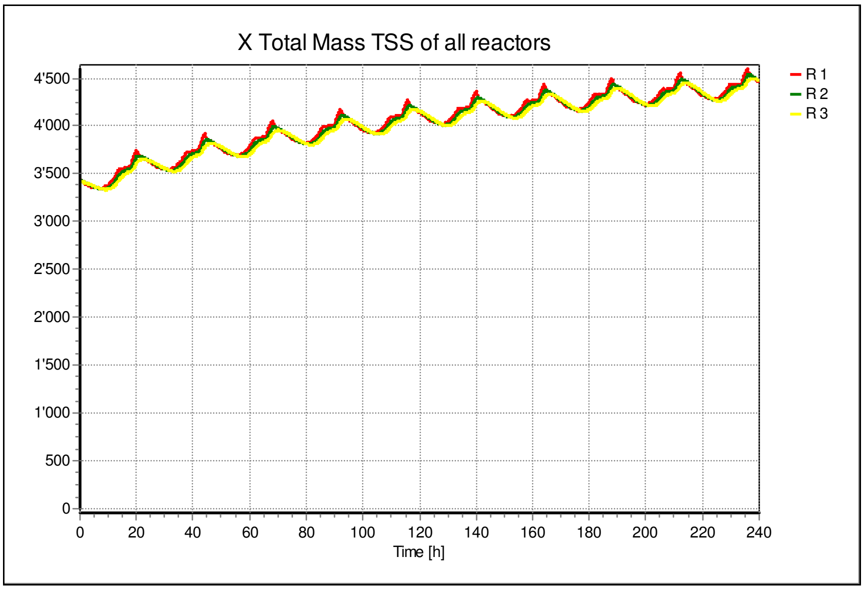


Figure 13: Development of activated sludge concentration during a 10-day increased load situation.

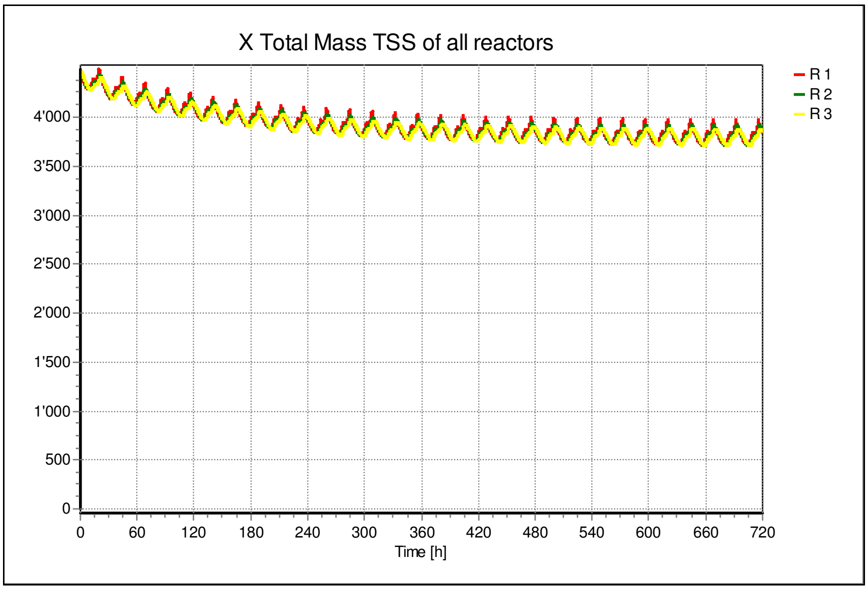
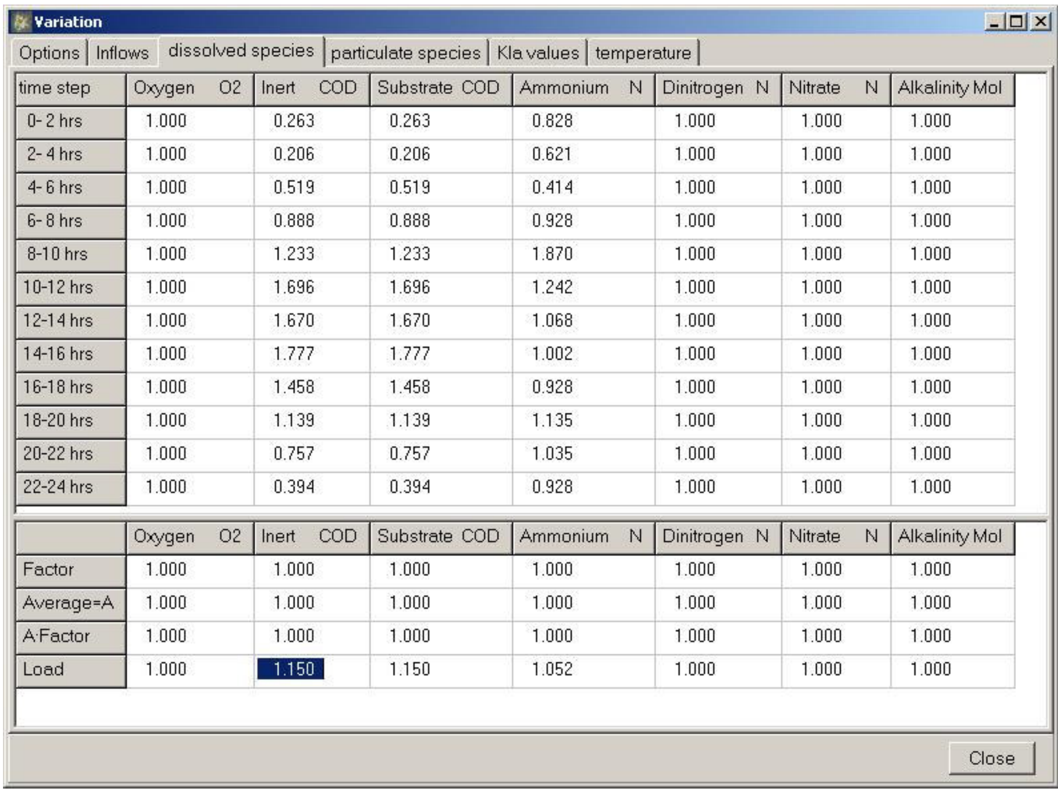


Figure 14: TSS-concentration after a 10-day increased load situation. Approximately 15 days are required for the plant to return to its steady state.

5.2.1.1 EXCURSION: STEADY STATE AND STEADY STATE

It should have become apparent by now that a new steady state no longer returns to the level of the previous one. A steady state in a dynamic simulation obviously doesn't equal to a steady state in a static simulation (integration). If you take a closer look at the Variation File, you will notice a list of mean loads ("load") underneath the concentrations. In Figure 15 these loads are 15 % higher for the COD as in the Plant File.



time step	Oxygen O2	Inert COD	Substrate COD	Ammonium N	Dinitrogen N	Nitrate N	Alkalinity Mol
0- 2 hrs	1.000	0.263	0.263	0.828	1.000	1.000	1.000
2- 4 hrs	1.000	0.206	0.206	0.621	1.000	1.000	1.000
4- 6 hrs	1.000	0.519	0.519	0.414	1.000	1.000	1.000
6- 8 hrs	1.000	0.888	0.888	0.928	1.000	1.000	1.000
8-10 hrs	1.000	1.233	1.233	1.870	1.000	1.000	1.000
10-12 hrs	1.000	1.696	1.696	1.242	1.000	1.000	1.000
12-14 hrs	1.000	1.670	1.670	1.068	1.000	1.000	1.000
14-16 hrs	1.000	1.777	1.777	1.002	1.000	1.000	1.000
16-18 hrs	1.000	1.458	1.458	0.928	1.000	1.000	1.000
18-20 hrs	1.000	1.139	1.139	1.135	1.000	1.000	1.000
20-22 hrs	1.000	0.757	0.757	1.035	1.000	1.000	1.000
22-24 hrs	1.000	0.394	0.394	0.928	1.000	1.000	1.000

	Oxygen O2	Inert COD	Substrate COD	Ammonium N	Dinitrogen N	Nitrate N	Alkalinity Mol
Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Average=A	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Load	1.000	1.150	1.150	1.052	1.000	1.000	1.000

Figure 15: Computed mean load factor.

This is deducible from the fact that the influent and the concentrations increase and decrease over time and the load is a product of these two. (See the example with inert particulate COD in Table 6).

Table 6: Computing the Load in Time Intervals

time step	1.influent	Inert COD	Load = Influent x COD
0- 2 hrs	0.623	0.263	0.164
2- 4 hrs	0.560	0.206	0.115
4- 6 hrs	0.685	0.519	0.356
6- 8 hrs	0.748	0.888	0.664
8-10 hrs	0.997	1.233	1.229
10-12 hrs	1.246	1.696	2.113
12-14 hrs	1.496	1.670	2.498
14-16 hrs	1.184	1.777	2.104
16-18 hrs	1.122	1.458	1.636
18-20 hrs	1.722	1.139	1.961
20-22 hrs	0.872	0.757	0.660
22-24 hrs	0.745	0.394	0.294
		Average:	**1.150**

In most cases these deviations have no significant consequences for simulation results, but they do cause a minor effect on the trend. To eliminate this, you can fill in the reciprocal values of all the concerned species as factors in the Variation File. Thus, the steady state of dynamic computations correlates with the steady state of static computations.

5.2.2 A DIURNAL RUN WITH A MEDIUM COD-LOAD BUT WITH AN INCREASED N-LOAD

Simulate this example on the basis of the winter operating situation with the corresponding Plant, Variation and Model Files. For this purpose, open the Plant File “winter.pln” again (without saving the current plant).

- Integrate your plant until it reaches its steady state.
- Make sure that all the factors in the Variation File are set to 1.000.
- Increase the factor of ammonium by 40 % and that of alkalinity by 20 %. The same Variation File can be found in the folder “Tutorial” (“tut_N.vrt”) as well.
- Run a one-day dynamic simulation and compare the results with Figure 9 and Figure 16.
- You may want to save the intermediate results of your plant (as “winter_N.pln”).
- Set all the factors in the Variation File to 1.000 again and find out how long your plant takes to stay below the limit value of 2 mg NH_4-N l^{-1} (Figure 17).
- Does one day influence the concentration of nitrifying micro-organisms in the activated sludge tank?

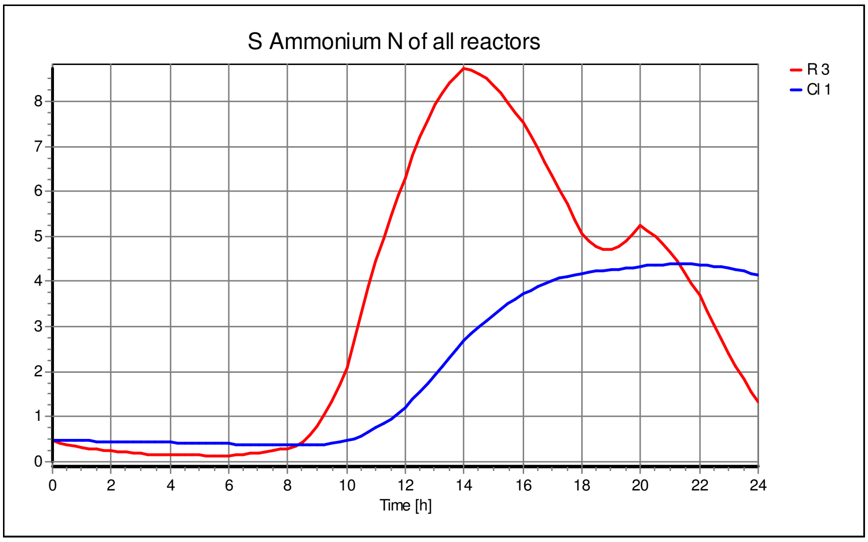


Figure 16: Effluent ammonium concentration with influent load increased by 40 %.

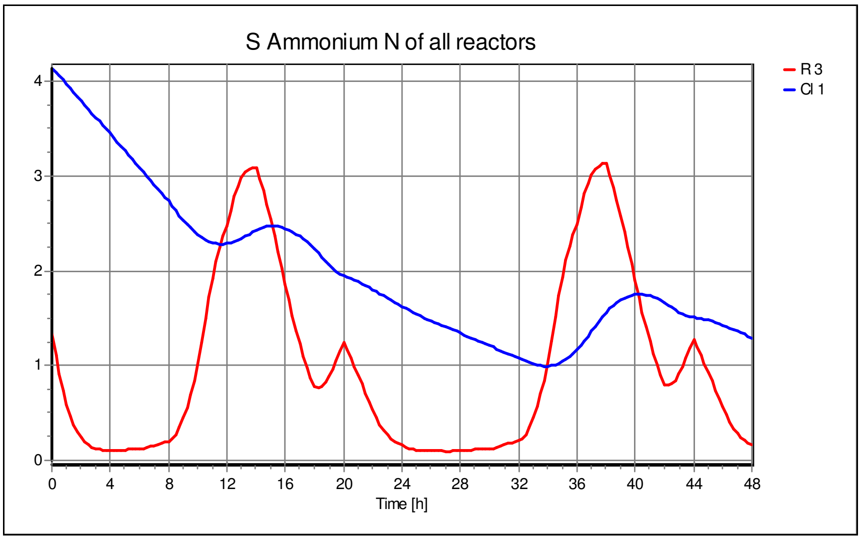


Figure 17: 24 h after increasing the influent load, effluent ammonium value drops again below the limit value.

5.2.3 A DIURNAL RUN WITH AN INCREASED ORGANIC MATTER LOAD

This example deals with an increased COD-load, which may occur due to seasonal variations (e.g. after fruit harvest). However, N-load is not any higher than usually.

Start from the winter situation again.

- Increase all the COD-fractions in the Variation File by 40 %.
- Make sure that all other factors in the Variation File are set to 1.000 (see “tut_CSB.vrt” in the folder “Tutorial”).
- Bring the plant to its steady state.
- Run a week-long simulation with an increased COD-load.
- Observe and interpret effluent COD-curves, concentrations in the activated sludge tank and effluent ammonium values (Figure 18).

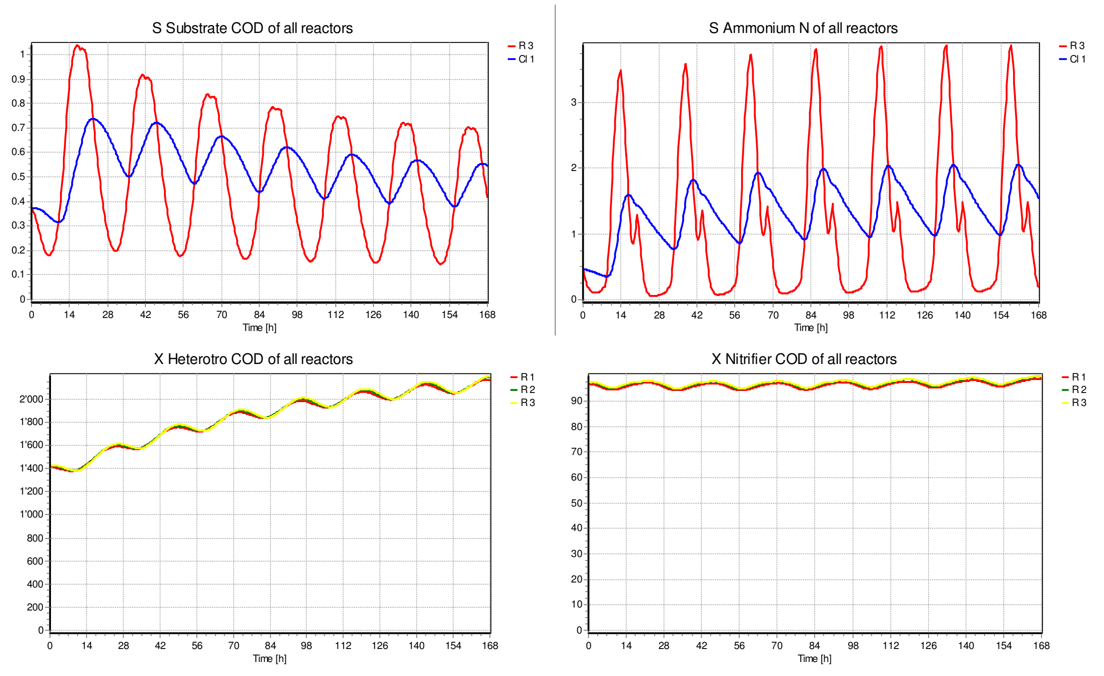


Figure 18: Effluent values of readily biodegradable COD and ammonium (top charts) and development of heterotrophic biomass concentrations and nitrifying micro-organisms (bottom charts).

In the beginning of the period there is an increase in the effluent COD-values. This effect starts leveling off, however, as heterotrophic biomass starts to grow at the same time as the load increases.

The same is true, even though on a smaller scale, for the ammonium concentration. There are two reasons for this: on one hand this occurs due to the effect discussed in Section 5.2.1.1. On the other hand, COD-fractions include nitrogen in different concentrations (i_{NSS}, i_{NXS}, ..) and this increases influent load as well.

6 MANAGING SUPERNATANT

Until now, we have dealt with the influent into the plant. In digestion, however, supernatant accumulates and causes an increase in nitrogen load. This additional load can be simulated by defining a second influent.

In addition to excess sludge accumulating in the plant, there is also sludge from other plants, which is thickened, stabilized and subsequently dewatered together with the plant's own primary sludge. Thus, ammonium-rich supernatant builds up and is fed back to the plant as a return load. This additional return load should not be ignored, as it constitutes up to 30 % of the total nitrogen load. Thus, if the effluent limit values are to be kept under control, the moment when supernatant is fed into the plant is critical. Table 7 includes the supernatant data for our example.

Table 7: Amount and Composition of Supernatant

Amount of Supernatant:	40	$m^3\ d^{-1}$
NH_4-Concentration:	700	mg NH_4-N l^{-1}
Alkalinity:	55	mmol l^{-1}
N-Load:	28	kg NH_4-N d^{-1}
Other Concentrations:	0	mg l^{-1}

The supernatant is fed into the activated sludge tanks in the morning between 8 and 12 hrs.

- Define the additional supernatant as a second influent in the Plant File "winter.pln" (Figure 19) and characterize it (Figure 20).
- Enter the time-dependent feeding of supernatant in the Variation File (don't forget to standardize the mean value of time steps back to 1.000). (Figure 21) (See also "tut_fw_morgen.vrt").
- Bring your plant with its additional load to its new steady state and simulate a series of 5 diurnal runs.
- In the folder "Tutorial" you can find the Plant File for this task as well. ("tutorial_fw.pln").

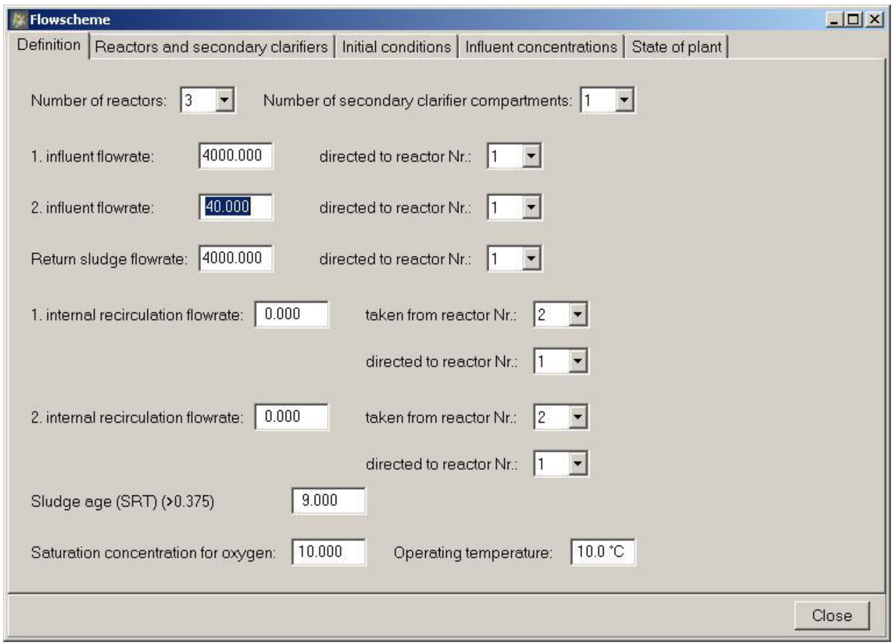


Figure 19: Implementation of the second influent.

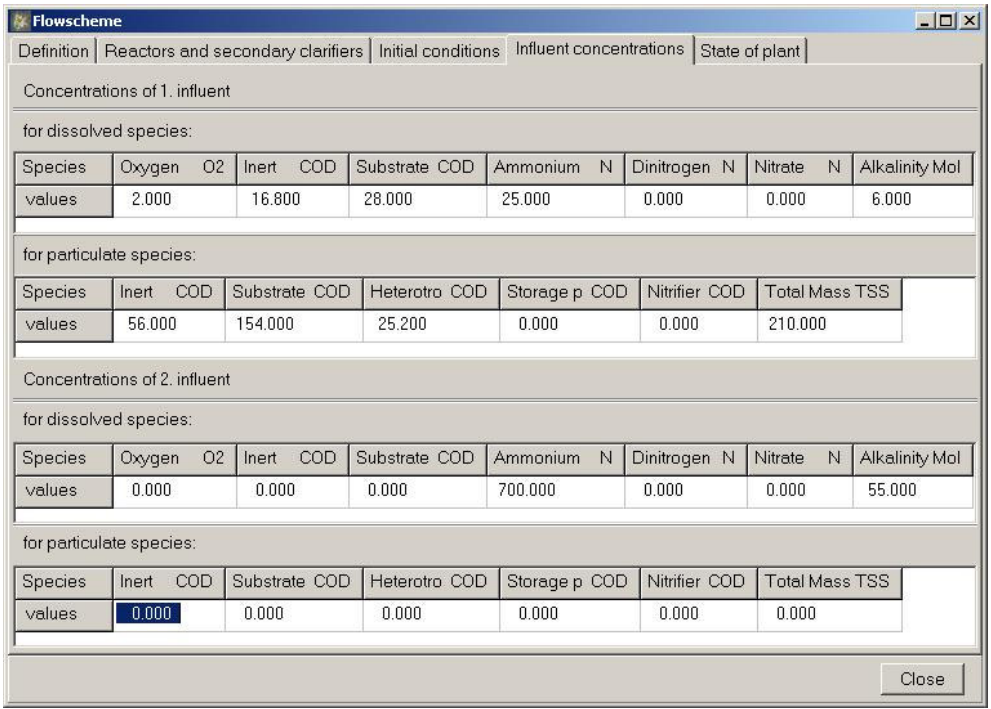
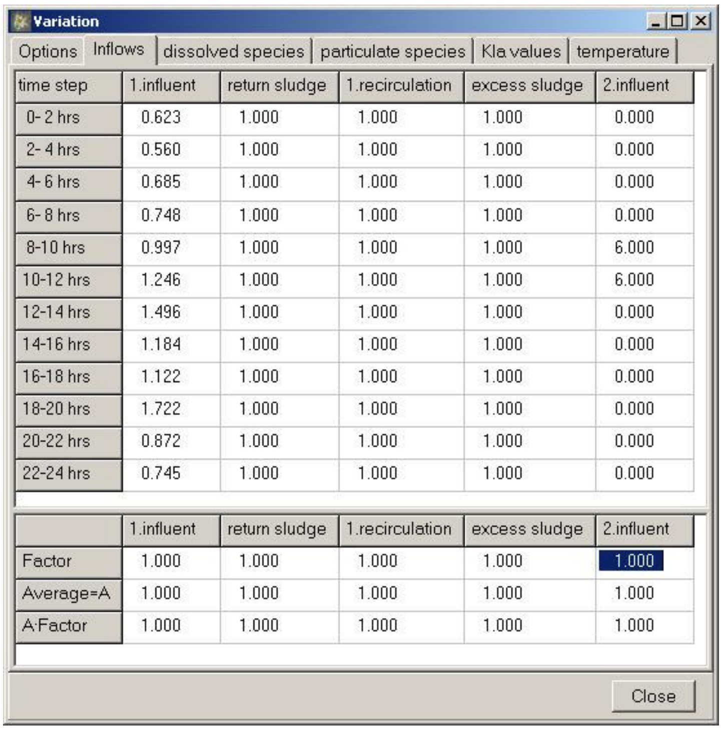


Figure 20: Defining the composition of supernatant at the bottom.



Variation

Options | Inflows | dissolved species | particulate species | Kla values | temperature

time step	1.influent	return sludge	1.recirculation	excess sludge	2.influent
0- 2 hrs	0.623	1.000	1.000	1.000	0.000
2- 4 hrs	0.560	1.000	1.000	1.000	0.000
4- 6 hrs	0.685	1.000	1.000	1.000	0.000
6- 8 hrs	0.748	1.000	1.000	1.000	0.000
8-10 hrs	0.997	1.000	1.000	1.000	6.000
10-12 hrs	1.246	1.000	1.000	1.000	6.000
12-14 hrs	1.496	1.000	1.000	1.000	0.000
14-16 hrs	1.184	1.000	1.000	1.000	0.000
16-18 hrs	1.122	1.000	1.000	1.000	0.000
18-20 hrs	1.722	1.000	1.000	1.000	0.000
20-22 hrs	0.872	1.000	1.000	1.000	0.000
22-24 hrs	0.745	1.000	1.000	1.000	0.000

	1.influent	return sludge	1.recirculation	excess sludge	2.influent
Factor	1.000	1.000	1.000	1.000	1.000
Average=A	1.000	1.000	1.000	1.000	1.000
A·Factor	1.000	1.000	1.000	1.000	1.000

Close

Figure 21: Feeding supernatant between 8 and 12 hrs (*tutorial_fw.vrt*).

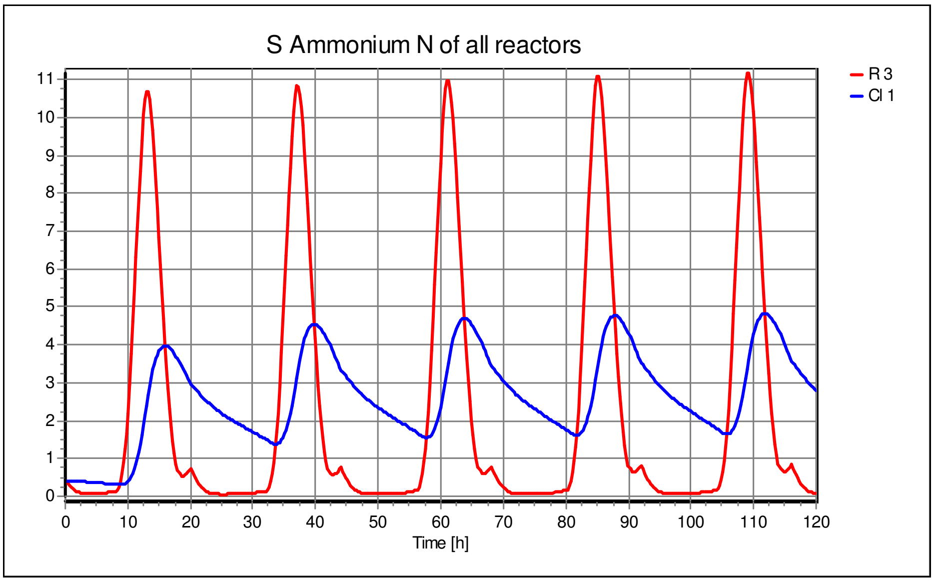


Figure 22: The impact of additional supernatant on effluent ammonium concentration.

As illustrated in Figure 22, effluent ammonium values exceed limit values. As your next step, feed supernatant in doses so that the ammonium load from the plant's catchment area and from supernatant is distributed over the day as evenly as possible. While doing this you may find Figure 23 helpful. It demonstrates the daily distribution of ammonium without additional supernatant and also the mean NH_4-concentration that wastewater influent with the supernatant would cause:

$$\frac{28\frac{kg}{d}+4000\frac{m^3}{d}\cdot 0.025\frac{kg}{m^3}}{4040\frac{m^3}{d}}=32\frac{g}{m^3}$$ Units of NH_4-N

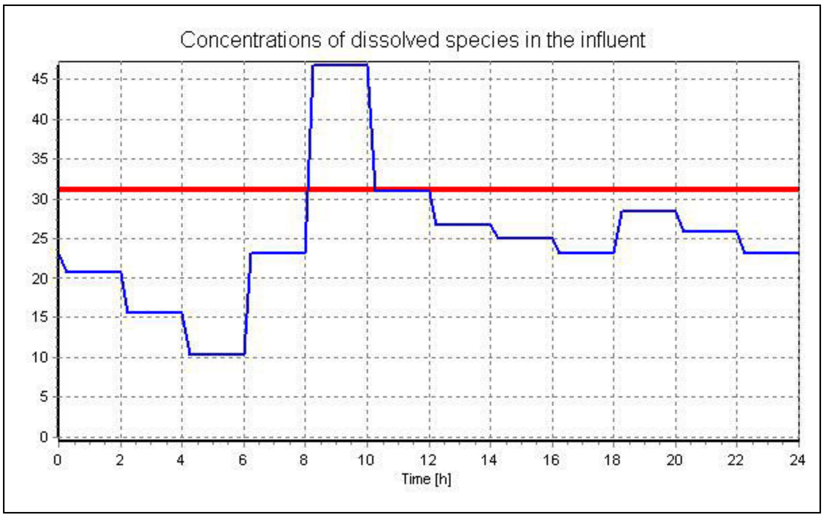


Figure 23: The variation of ammonium concentration in the influent WITHOUT the supernatant. Shown is also the mean NH_4-concentration that the influent WITH the supernatant would cause.

Figure 24 illustrates the simulation results after supernatant is step-fed optimally so that effluent values are kept under control. It becomes evident from Table 8 that during a certain critical time period (when the load from the catchment area is at its maximum) supernatant should not be fed into the plant. By step feeding it is possible to countervail against load fluctuations.

Table 8: Values for Additional Second Influent (Supernatant) with Minimal Loading Times

time step	0- 2 hrs	2- 4 hrs	4- 6 hrs	6- 8 hrs	8-10 hrs	10-12 hrs
2.influent	1.500	2.250	3.000	1.125	0.000	0.000
time step	12-14 hrs	14-16 hrs	16-18 hrs	18-20 hrs	20-22 hrs	22-24 hrs
2.influent	0.375	0.750	1.125	0.000	0.750	1.125

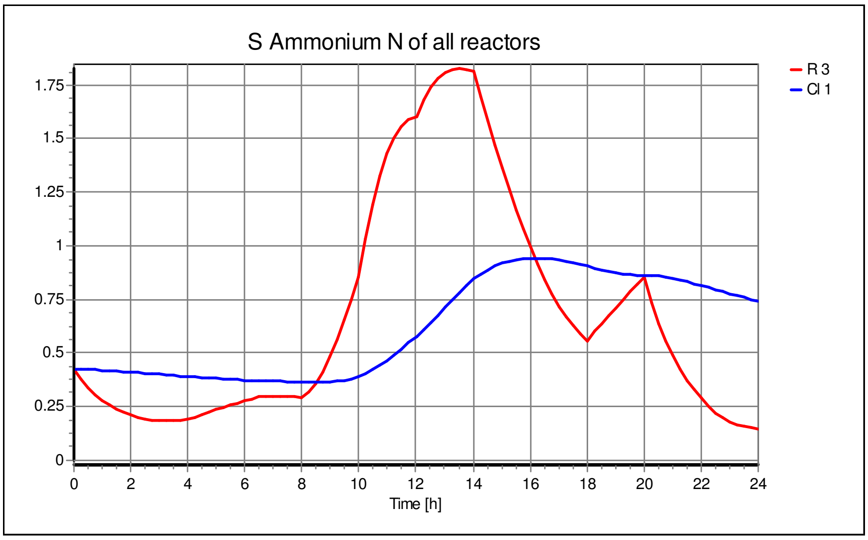


Figure 24: Effluent values if the supernatant is step fed into the plant.

7 EXTENDING WITH DENITRIFICATION

If you use mathematical modeling in the planning state, you can predict how the plant is going to react to different processes or under different operational conditions. In this chapter we will extend our plant with a denitrification stage.

Authorities require you to eliminate nitrate in your plant due to sensitive receiving water. The advising engineer suggests that you extend the nitrification tank and operate its first part anoxic. The influent characterization remains the same. Edit your Plant File according to Figure 25 and Figure 26.

Use the Variation File created earlier. If necessary, in the folder “Tutorial” you will also find the files “tutorial_deni.pln“ and “tutorial_fw.vrt“.

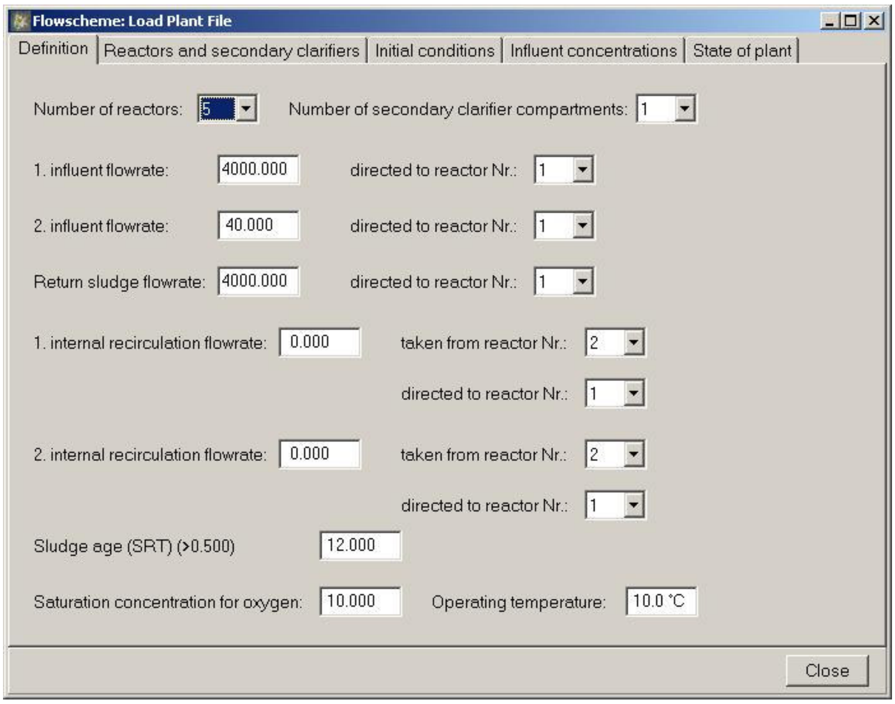


Figure 25: Defining denitrification with 5 reactors and a higher sludge age.

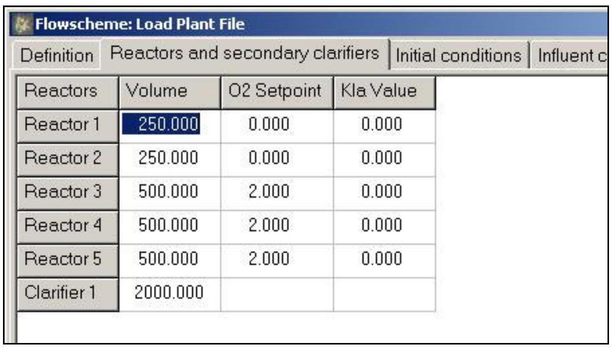


Figure 26: Denitrification takes place in the first two anoxic reactors, each 250 m^3.

The previous activated sludge tanks are now preceded by two smaller, non-aerated reactors. As residual oxygen is consumed rapidly and there is nitrate supplied with return sludge, denitrification can occur in these reactors. Adjusting the sludge age to 12 days compensates for the residence time in the anoxic reactor. Aerobic sludge age remains at 9 days. It follows from the simulation (Figure 27) that some of the nitrate is degraded and turned into N2 (effluent nitrate value was about 30 mg/l earlier).

	1.influent	2.influent	Reactor 1	Reactor 2	Reactor 3	Reactor 4	Reactor 5	Clarifier 1
Flowrate/Volumes	4000.000	40.000	250.000	250.000	500.000	500.000	500.000	2000.000
Oxygen O2	2.000	0.000	0.015	1.19E-4	2.000	2.000	2.000	
Inert COD	16.800	0.000	16.634	16.634	16.634	16.634	16.634	16.634
Substrate COD	28.000	0.000	3.123	1.924	0.522	0.359	0.261	0.262
Ammonium N	25.000	700.000	16.612	16.899	8.418	2.394	0.426	0.426
Dinitrogen N	0.000	0.000	11.883	14.945	15.354	15.709	16.015	16.013
Nitrate N	0.000	0.000	5.103	2.043	10.103	15.865	17.793	17.794
Alkalinity Mol	6.000	55.000	5.044	5.283	4.102	3.260	2.982	2.982
Inert COD	56.000	0.000	1708.045	1708.524	1710.800	1713.083	1715.367	
Substrate COD	154.000	0.000	90.603	77.012	56.683	41.589	30.443	
Heterotro COD	25.200	0.000	1221.069	1223.123	1229.698	1232.620	1232.251	
Storage p COD	0.000	0.000	25.617	29.218	24.176	18.601	14.035	
Nitrifier COD	0.000	0.000	116.047	115.945	117.520	118.525	118.598	
Total Mass TSS	210.000	0.000	3279.272	3273.356	3264.126	3254.707	3245.054	
Oxygen consumption			63.520	0.476	866.524	668.268	372.235	

Figure 27: Steady state with denitrification.

One denitrification stage reduces nitrate in the effluent by about 40 %. Denitrification is influenced by oxygen concentration, readily degradable substrates and available nitrate. As illustrated in Figure 27, readily degradable substrates and the size of the reactor inhibit denitrification (substrate COD in reactors 1 and 2). In a dynamic simulation, you notice how nitrate concentration changes from one tank to another (Figure 28).

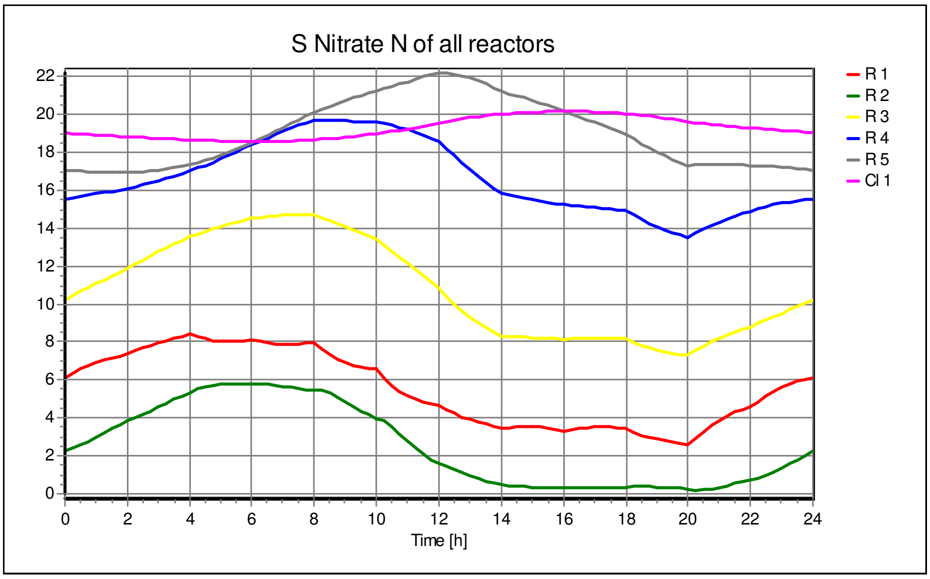


Figure 28: A daily curve of nitrate with denitrification. Low concentration in reactor 1 is deducible to dilution and denitrification, reduction in reactor 2 to denitrification only.

8 INTRODUCING CONTROL MECHANISMS

Operating staff at a wastewater treatment plant can influence the management of their plant to a certain extent. The most important control possibilities concern oxygen concentration and removal of excess sludge as these factors can influence the capacity of the plant quite dramatically. We now introduce control mechanisms for these factors.

8.1 CONTROL IN ASIM

ASIM permits introducing simple control loops. This enables e.g. altering oxygen concentration if a changing influent value makes it necessary. There are two control strategies available:

- On/Off-control: Should a state variable exceed or drop below a certain threshold value, control variable deactivates or activates itself.
- Proportional control: Control variable is operated as a linear function of a state variable.

Control loops can be used only with dynamic computations and with integration, not with relaxation. Control loops are saved in the Plant File.

8.2 CONTROLLING AERATION

Until now we have assumed that the oxygen concentration in the activated sludge tank remains constantly at 2 mgO_2/l. However, a constant value is not realistic in a factual system. The oxygen concentration in the activated sludge tank depends on various factors, e.g. on pollutants load or temperature. Normally, air inflow to the activated sludge tank is controlled according to the oxygen concentration there.

You can evaluate the oxygen demand per tank on the basis of the chart “View Single Chart → Others → Reaction Rates of all Reactors” after a dynamic simulation (Figure 29). This chart reveals that oxygen consumption is highest in reactor 3. Reactors 4 and 5 need less, but demonstrate somewhat higher fluctuations (computed as explained in Chapter 7).

Before introducing control mechanisms, bring your plant to its steady state.

Oxygen inflow into reactors 3 to 5 will now be adjusted consistent to their O_2-concentration. For this purpose, define a control loop under the menu item “Plant Definition → Control Loops”.

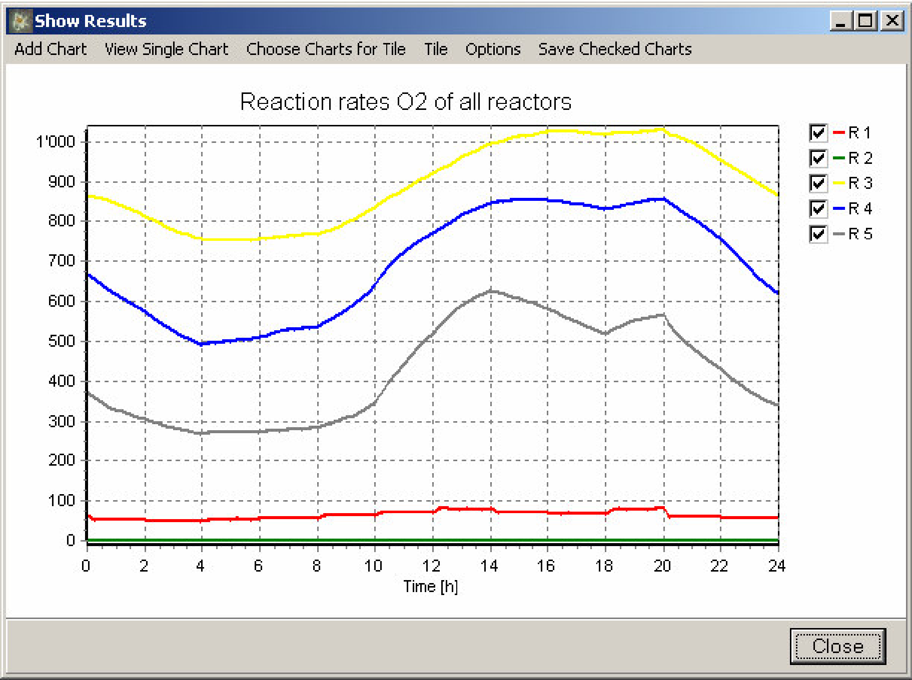


Figure 29: Oxygen demand in the 5 reactors.

After selecting control loops, a dialog box appears (Figure 30).

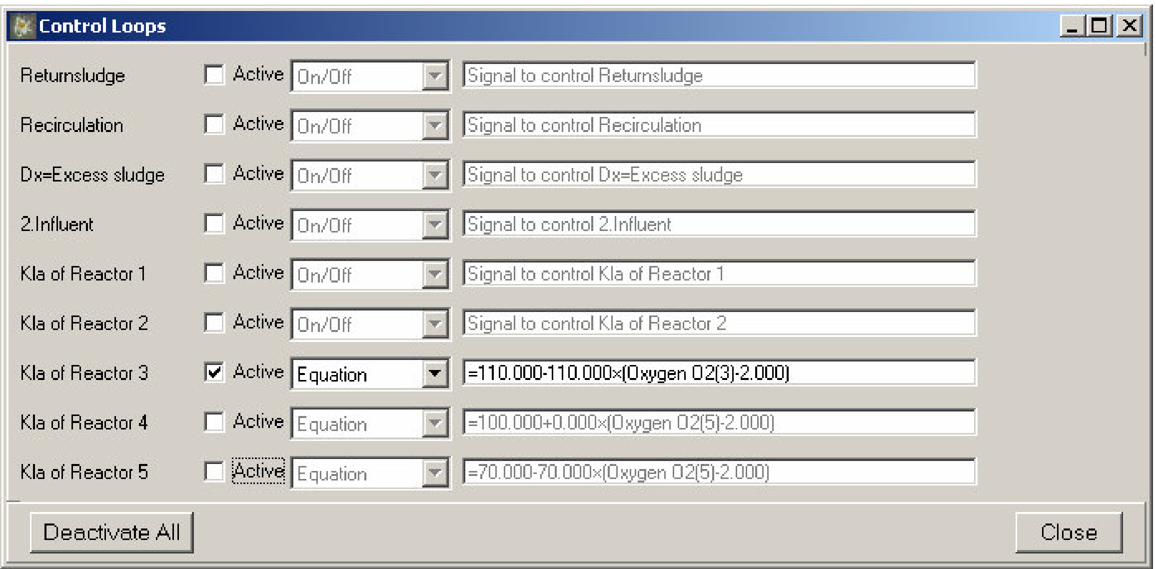


Figure 30: Dialog box for control loops. Illustrated are activated control loops (here the aeration of the reactor 3), and the types of control mechanisms that follow certain strategies.

This dialog box lists all controllable parameters:

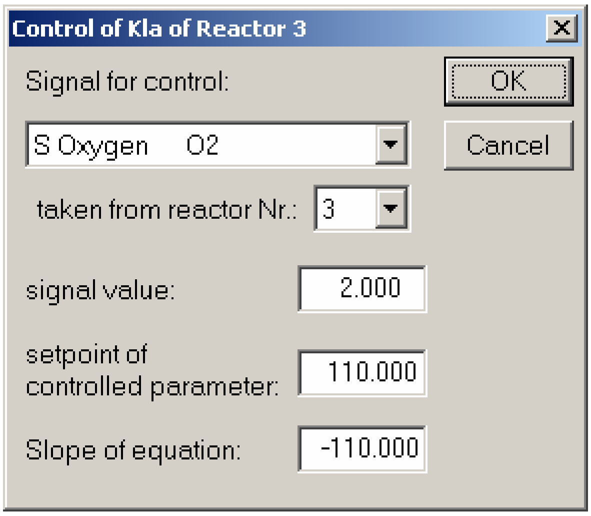
- return sludge
- internal recirculation (if available)
- removal of excess sludge (for controlling the sludge concentration)
- the second influent

- aeration (using the k_La-values of the individual reactors).

The first two reactors are still run anoxic. To activate a control mechanism it is necessary to tick the box next to “k_La of Reactor X”, and subsequently select a type of desired control mechanism. In our present case, a linear control mechanism is needed, thus you select “Equation”. Consequently, a dialog box appears (Figure 31) with various parameters to be filled in:

- Signal for control: What will be measured (state variable)?
- taken from reactor: Where should this parameter be measured?
- signal value: Set value for state variable.
- setpoint of controlled parameter: Value of control variable when state variable has reached its set value.
- Slope of equation: Gain of control function. The steeper the function, the faster the control variable will react, but there is a danger that the system becomes unstable.

For the reactor 3 you enter the following parameters (Figure 31a):



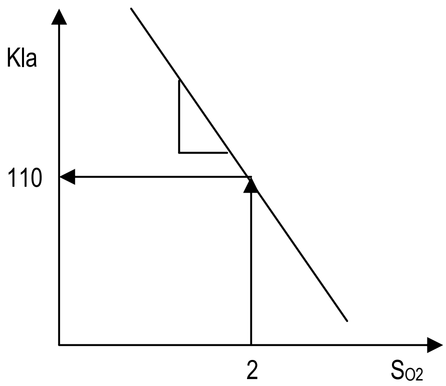


Figure 31a and 31b: Dialog box for a control mechanism using equation. Select first a state variable and where it should be measured, then a set value, value of the control parameter at the set value and the gain of the control function (positive or negative).

The control equation reads thus:

$$K_L a[R3] = 110 - 110 \cdot (S_{O_2}[R3] - 2)$$

Figure 31b shows the control function for reactor 3. As soon as oxygen concentration exceeds 2 mg/l, aeration is restricted, and if the concentration reaches 3 mg/l, blowers are turned off completely (if you wish to set 2.5 mg/l as maximal value for turning off, you must set the slope of equation to –220).

Oxygen concentration is measured both in reactor 3 and in reactor 5. Thus, the following control equations can be defined for the reactors in the rear:

$$K_L a[R4] = 100 - 100 \cdot (S_{O_2}[R5] - 2)$$

$$K_L a[R5] = 70 - 70 \cdot (S_{O_2}[R5] - 2)$$

Using this control strategy it is possible to reach a satisfactory degradation of ammonium (

Figure 32) with relatively little demand for oxygen. The necessary aeration capacity is illustrated in Figure 33.

In the file “tutorial_deni.pln“ these control loops are already given, but they are not active.

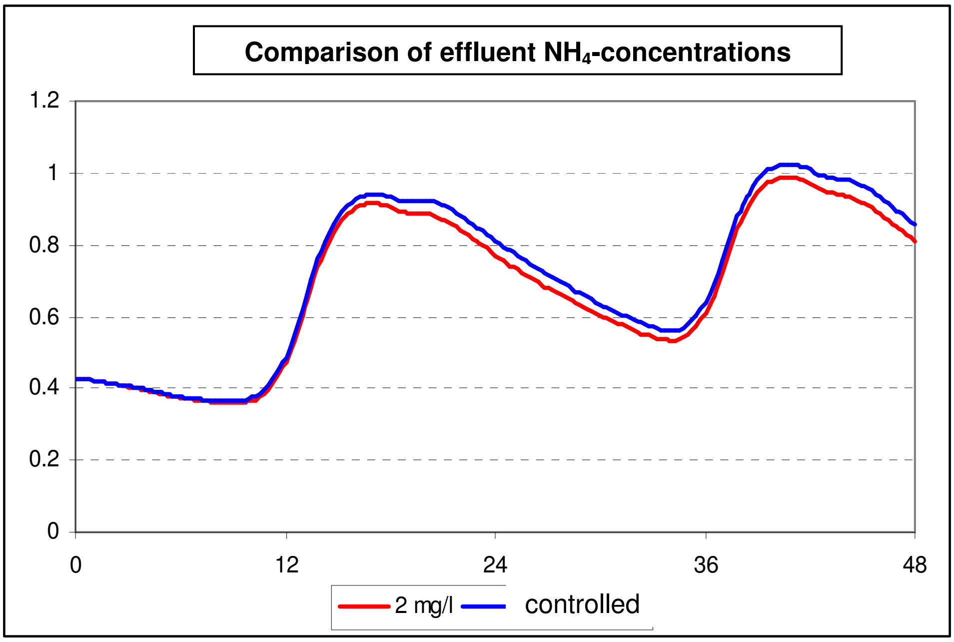


Figure 32: A comparison of effluent ammonium concentrations between a control mechanism and a constant O2-setpoint of 2 mg/l. This control mechanism permits a good simulation of an “ideal case” (compare control and constant O2-concentration by exporting data to Excel).

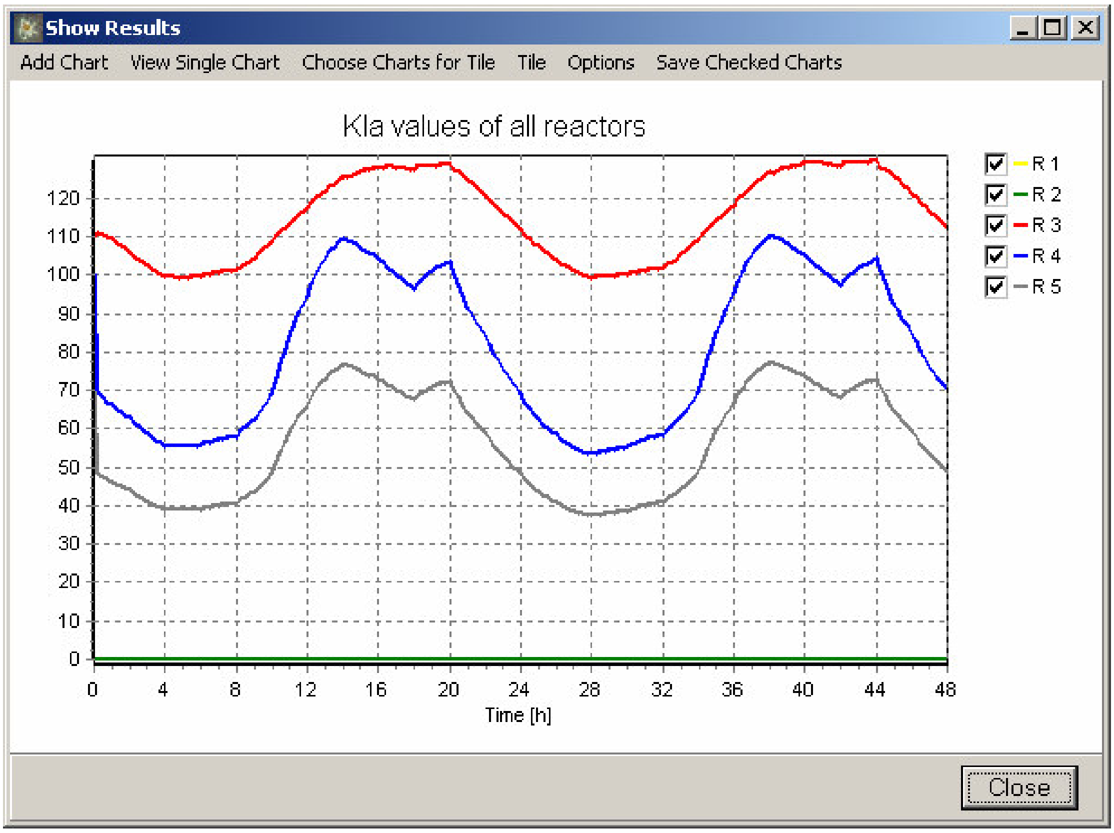


Figure 33: k_La-values (aeration capacity). In reactor 5 relatively little oxygen is added. Reactor 4 operates like reactor 5, but its oxygen concentration drops more often under 2, because the aeration of reactor 4 depends on the sensor in reactor 5. It might be better if the aeration in reactor 4 depended on the sensor in reactor 3.

8.3 ON/OFF-CONTROL: AERATING INTERMITTENTLY

The advising engineer suggests that you run the plant's aeration intermittently in order to save energy costs. This means that blowers are operated in two stages.

There are two options available:

a) Temporary control: Blowers are controlled according to a fixed time plan.

b) On/Off-control: Should a state variable exceed or drop under a certain threshold value, a control variable will be activated or deactivated.

ASIM enables the case a) to be simulated by adjusting the Variation File and the case b) by using an On/Off-control mechanism under „Control Loops“.

We want to aerate reactors 3 to 5 intermittently. For economical reasons, there are only two oxygen sensors (in reactors 3 and 5) available. The oxygen concentration of reactor 3 should not sink below 1.5 mg/l. If it exceeds 2.5 mg/l, aeration will be restricted. In order to avoid clogging the blowers, they will not be turned off completely, but kept running at least with a k_La -value of 25d-1. Reactor 5 is operated similarly, though at the lower aeration capacity level due to lower oxygen demand. Reactor 4 is connected to the sensor in reactor 5 and should be aerated somewhat earlier, i.e. when the oxygen concentration sinks to 1.7 mg/l in reactor 5.

In order to compare intermittent aeration with other control strategies, it must be assumed that initial state is the same for all. For this purpose, deactivate all control mechanisms and bring your plant to its steady state.

Input for this in ASIM is as follows:

1. Activate the kLa -value for reactor 3 in the dialog box for control loops.
2. Select On/Off.
3. Fill in the dialog box as illustrated in Figure 34a.

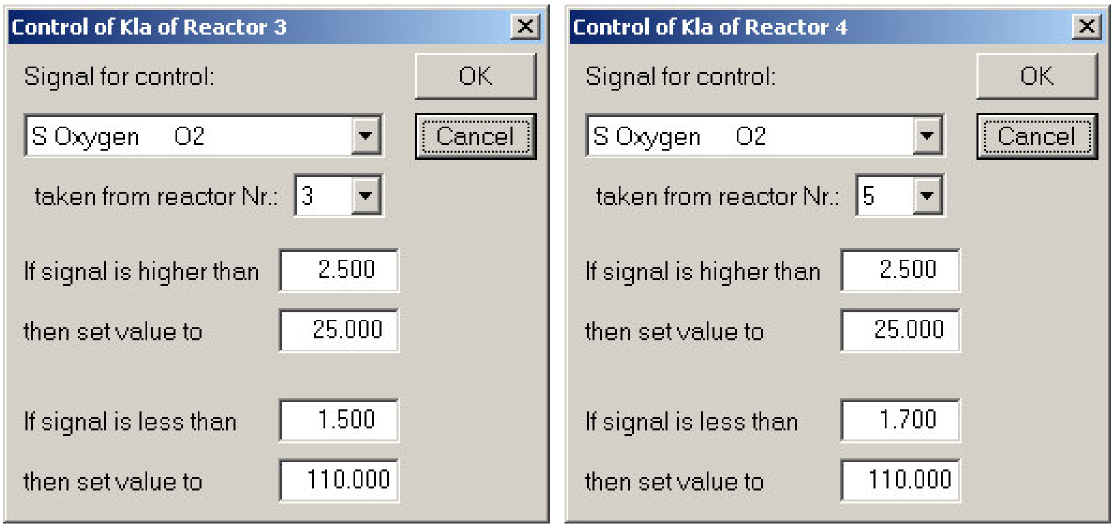


Figure 34a and 34b: On/Off-control for reactors 3 (left) and 4 (right). Reactor 5 has the same values as reactor 4, but is not activated until signal is below 1.5 mg/l.

The values for reactors 4 and 5 are filled in analogously to Figure 34b. Reactors 4 and 5 feature a lower threshold value of 1.7 and 1.5 mg/l, respectively. The maximal aeration capacity in reactor 5 is 90 d-1. The file “tutorial_onoff.pln“ includes this control mechanism.

Effluent values are similar in magnitude, but involve slightly higher ammonium values.

Figure 35 illustrates aeration frequency using k_La -values (“View Single Charts → Others → K_la values of all reactors”). You should notice that reactor 3 is aerated nearly constantly at a maximal level, but in the two rear reactors, aeration is occasionally restricted (Figure 35).

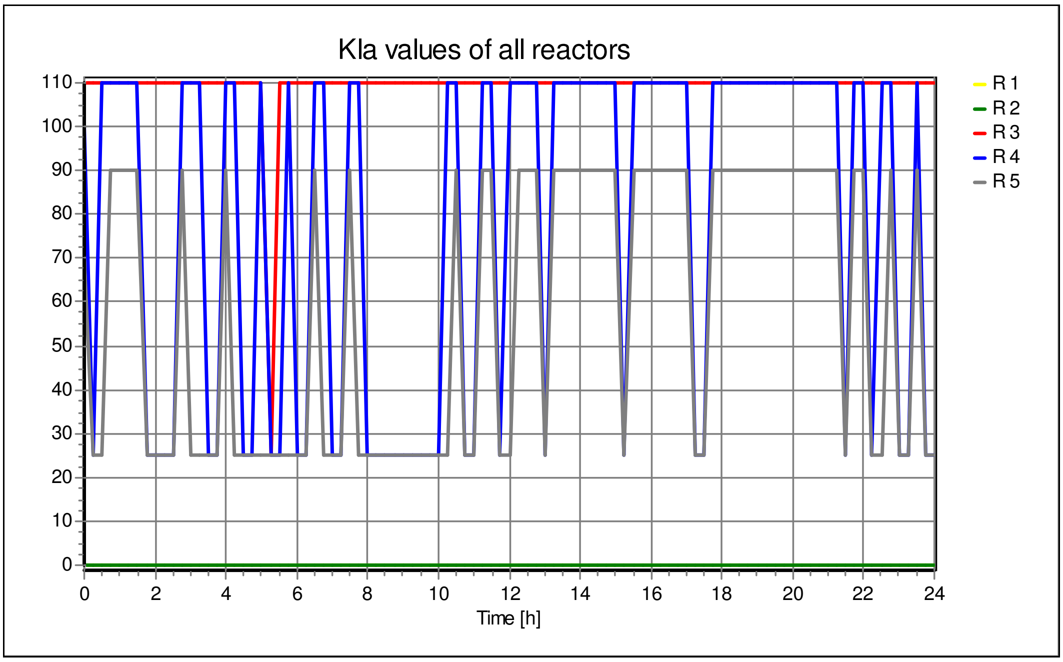


Figure 35: Oxygen inflow in reactors 3, 4 and 5 using intermittent aeration.

Evaluating whether or not you are saving energy is also possible. Clicking the chart with the right mouse button, you can access „Time Series Statistics“. A comparison between the mean kLa -values of these two aeration strategies is illustrated in Table 9.

Table 9: Comparing the Mean k_La -Values of Two Control Strategies

	Mean k_La -Value over 48 hours [d^{-1}]		
	Reactor 3	Reactor 4	Reactor 5
constant control	117	84	59
intermittent aeration	109	77	57

9 SIMULATING DENITRIFICATION IN SECONDARY CLARIFIER

Biological reactions only take place in activated sludge tanks. A modeled secondary clarifier simulates an ideal separation of sludge and provides a hydraulic hindrance for wastewater flow. Therefore, biological processes taking place in the secondary clarifier must be implemented elsewhere.

9.1 BACKGROUND

Activated sludge is pushed into a secondary clarifier, where it settles and builds up a so-called sludge blanket. Micro-organisms in the sludge require energy and start consuming residual oxygen in the secondary clarifier. Subsequently, once all the oxygen is depleted and if any nitrate is available, denitrification commences. Thus, sludge flocs start appearing on the surface attached to rising N_2-bubbles. Denitrification in the secondary clarifier can be substantial and may result in undesirable “sludge islands” on the surface of the clarifier and thus also in an increased TS-concentration in the effluent.

9.2 SIMULATION

9.2.1 REACTOR

Given a secondary clarifier with a volume of 2000 m^3, we assume that the sludge blanket constitutes about 20 % of the total volume, i.e. 400 m^3. In ASIM there are no biological processes running in a secondary clarifier; the aim is merely to provide an ideal separation of particulate species. The sludge blanket must therefore be modeled as an individual reactor, which is then added to the system and positioned prior to other reactors. Influents enter now the second reactor and the volume of the secondary clarifier needs adjusting. This yields the flow scheme in Figure 36.

If you have any problems, you can always take a look at the file “tutorial_sb.pln”.

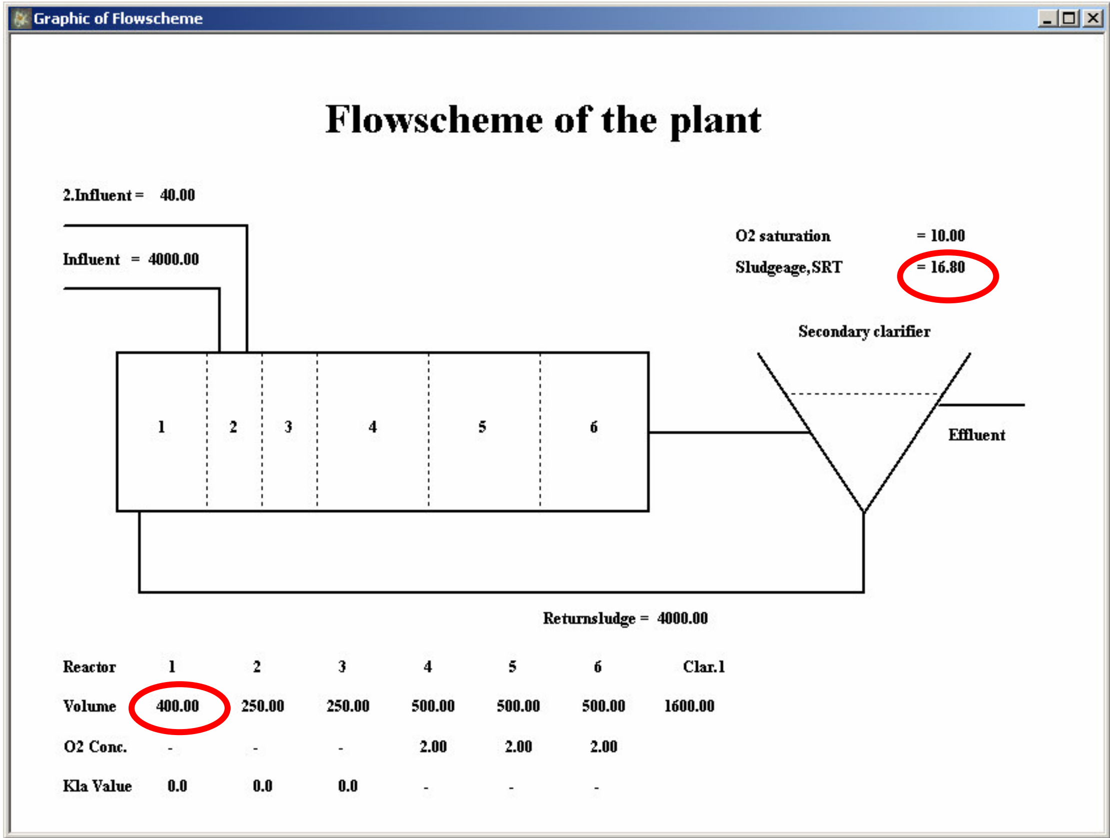


Figure 36: A new flow scheme with a sludge blanket represented as reactor 1. Influents enter reactor 2 and return sludge is fed into the sludge blanket in reactor 1. The last three reactors are aerated. Sludge age needs adjusting due to the additional reactor 1.

9.2.2 SLUDGE AGE

Due to a longer residence time, sludge age needs adjusting. The new sludge age is computed from the mass balance over the secondary clarifier:

$$SA_{neu} = SA_{alt} \cdot (1 + \frac{V_{SB}}{V_{BB}} \cdot (1 + \frac{Q_{in}}{Q_R}))$$

The new sludge age is 16.8 days.

Make sure that control mechanisms are turned off and O_2-setpoints in reactors 4 to 6 are returned to 2 mg/l. Compute subsequently a steady state and one daily run.

The results (Figure 37) reveal an increase in denitrification capacity, which is not very high in this example, as denitrification already functions well enough. This model plant eliminates about 45 % of its nitrogen.

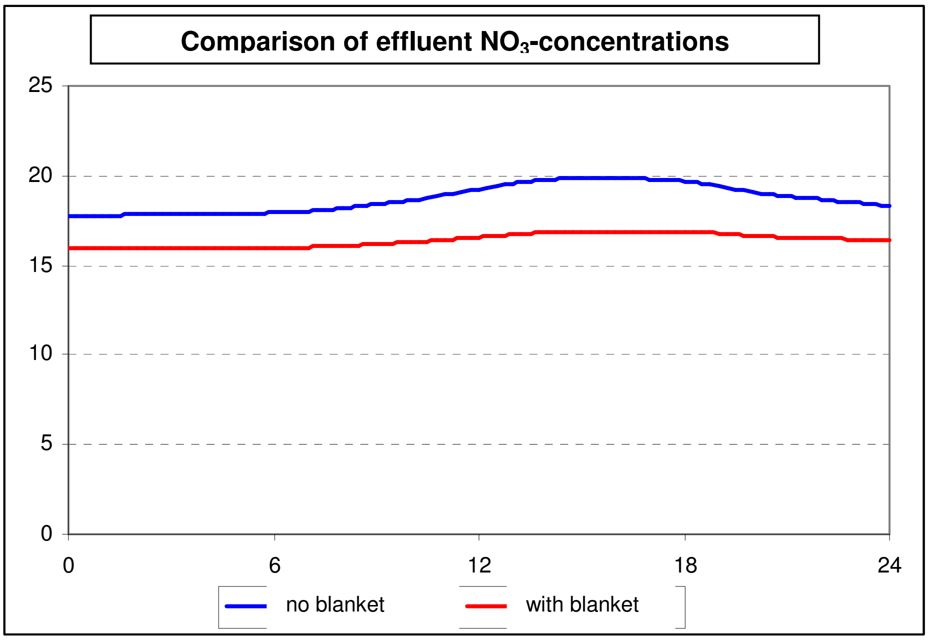


Figure 37: A comparison of effluent nitrate values with and without a sludge blanket. It becomes evident that nitrate is reduced by about 15 %. For comparison, the effluent values have been exported to Excel.

10 IMPORTING / EXPORTING DATA

Dynamic computations may sometimes cover extensive periods of time. It is quite laborious to type in all the data. This is why ASIM allows for the possibility that data is imported directly from a table processing program or from a text file. For further computations you can also export your results from ASIM to other programs.

10.1 IMPORTING

ASIM lets you import entire files only, such as Plant Files (*.pln), Model Files (*.mod) or Variation Files (*.vrt). You can access them by selecting “Load *-File” from the menu. The Variation Files are an exception, however. These files allow you to import and export individual values to and from Excel. To do this, you operate with the usual copy command and then click on the desired column head using your left mouse button. In the appearing dialog box you select “from Clipboard”.

10.2 EXPORTING

10.2.1 STATIC COMPUTATIONS

You can export the results of static computations by clicking a table with the right mouse button and using the command “Copy Table to Clipboard”. Then you import the data into a table processing program.

The same applies for tables in Model and Variation File.

10.2.2 DYNAMIC COMPUTATIONS

You can export the results from dynamic computations either as charts or tables.

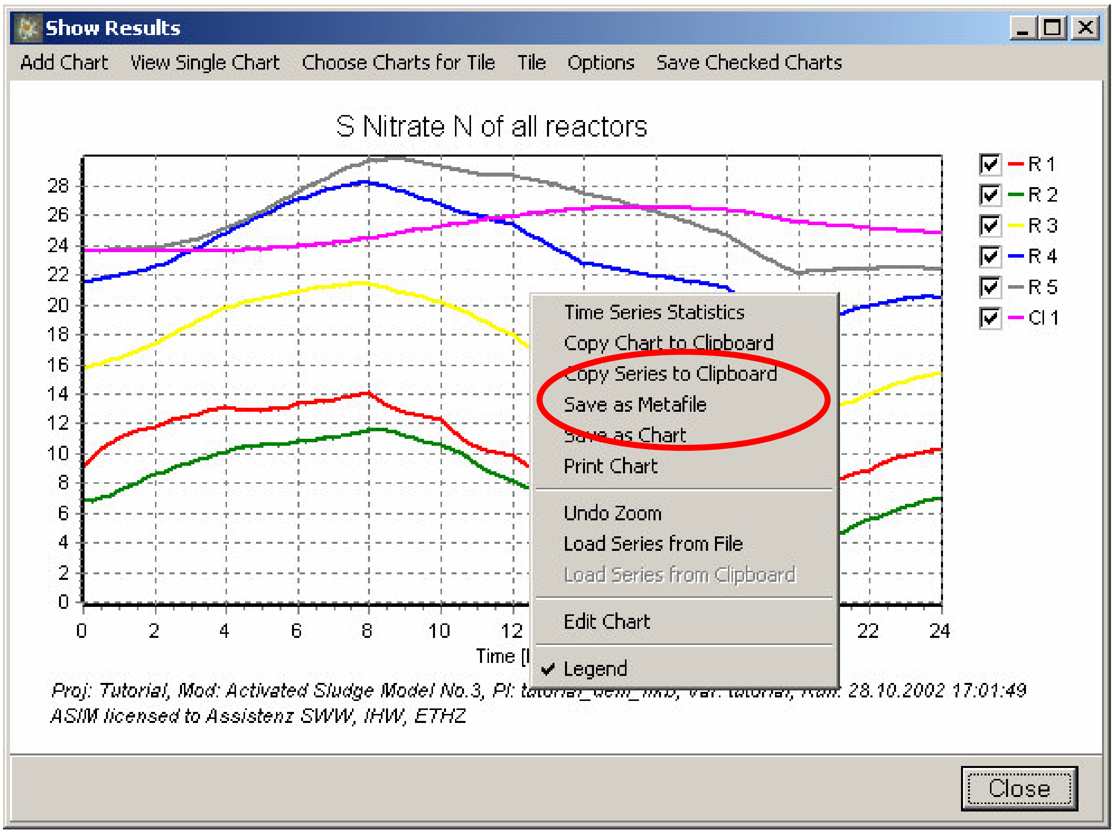


Figure 38: Various saving options for dynamic computations.

After clicking a chart with the right mouse button, the dialog box illustrated in Figure 38 appears.

- Copy Chart to Clipboard: The chart is copied in a visible form and can be inserted elsewhere as a picture, which means that individual curves can be removed.
- Copy Series to Clipboard: The table, which the chart is based on, is exported as an entity.
- Save as Metafile: The chart is saved in the current file directory as .wmf -data file and can be exported to other programs.
- Save as Chart: The chart is saved as .tee -data file and can be loaded again in ASIM (see Chapter 12).

Under the menu “Results” you can additionally save results as .rlt -data files and analyse them later in ASIM (all results from dynamic computations).

11 DOCUMENTING SIMULATIONS

Models and plants are saved in their own data files. In certain circumstances it is useful to be able to study the entire model sequentially. Model and Plant Files can be printed or exported.

ASIM permits studying model entries in text format, as well as printing or exporting them. You find the commands from the menu "Model" (Figure 39).

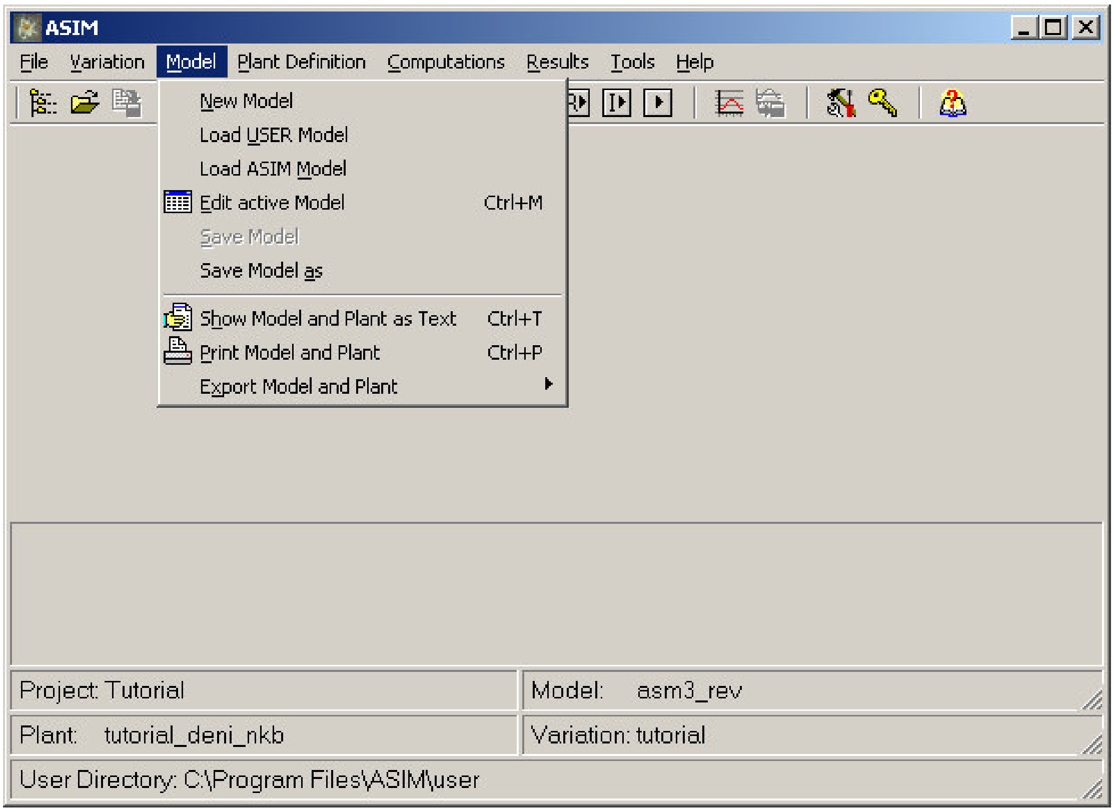


Figure 39: Possibilities for exporting a model and the features of a plant.

All three commands result basically in the same: the model and the plant are represented as text:

- Model: involved species, processes, stoichiometric matrices, kinetics.
- Plant: reactors, volumes, influents.

Using the command "Show Model and Plant as text" you can choose which of the features you want to see.

12 COMPILING CHART TEMPLATES

When applying ASIM in practise, it is often necessary to give charts a uniform look. You may want to study the concentrations of several species in a single chart. Let us consider our last computed example (denitrificated sludge blanket). Compile a single chart for the effluent values of nitrate and ammonium (during a single diurnal run). For this purpose, select the command "Add Chart→ Define New" from the chart mask, opt for "Add Chart" in the appearing dialog box and enter a title, e.g. nitrogen effluent (Figure 40).

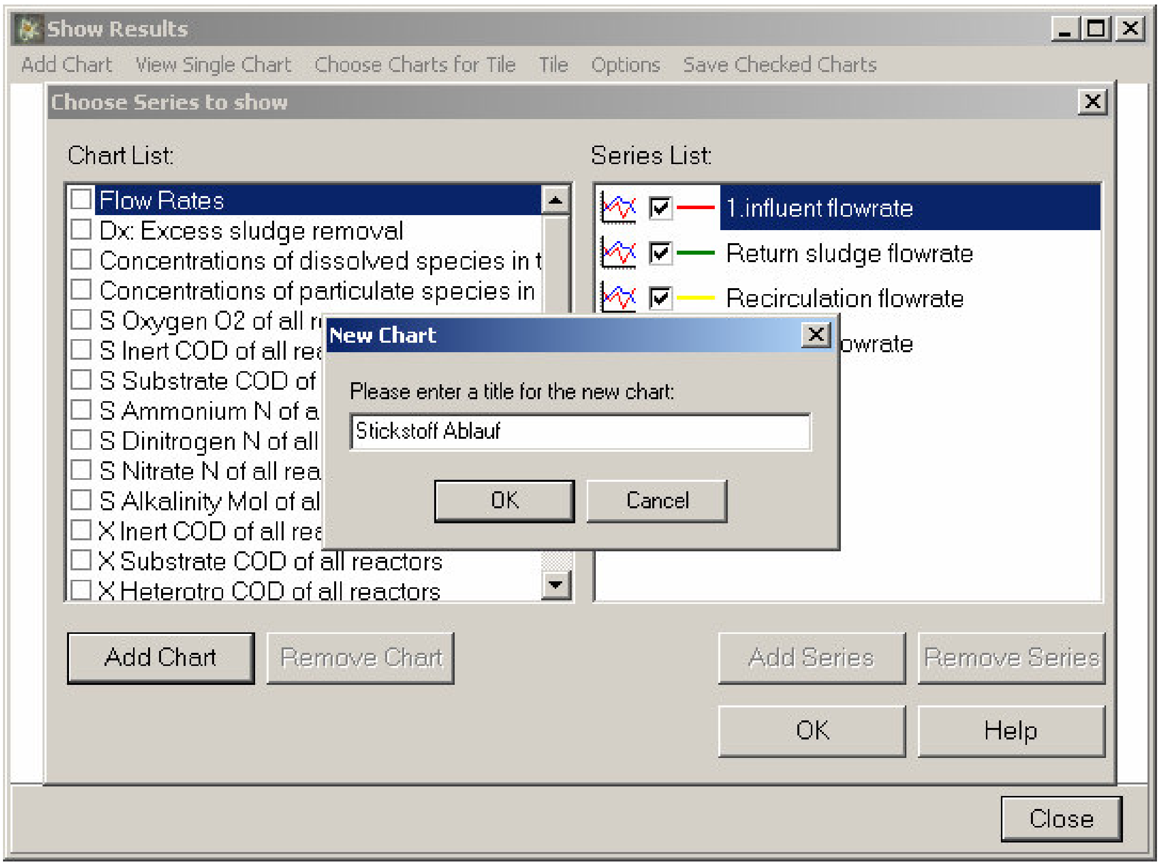


Figure 40: Inserting new graphics.

If you click the button "Add Series", you can access all computed and entered daily runs to create a chart (Figure 41). Select "Cl:1 S Ammonium" and "Cl:1 S Nitrate" and return to the chart.

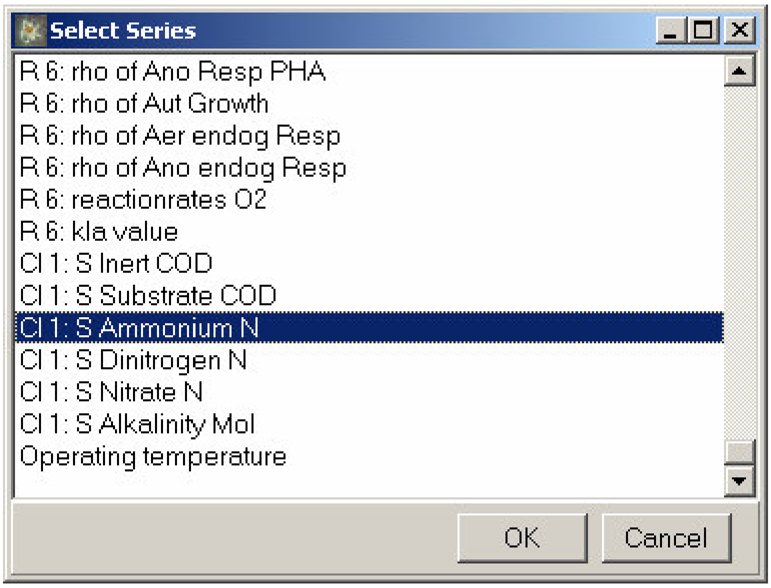


Figure 41: All the concentrations, rates and limiting factors (temperature, aeration) are available.

Now you can manipulate your chart to your liking by using the right mouse button on the chart itself and the command “Edit Chart” (you can adjust axes and colours, select a title, include or exclude grid lines etc.). Once you are satisfied with your chart, you can save it as a template:

1. With the right mouse button you click on the chart and select the command “Save as Chart“ (save as .tee -file).

2. You can access the saved charts (or entries) under “Add Chart → Load as Template”.

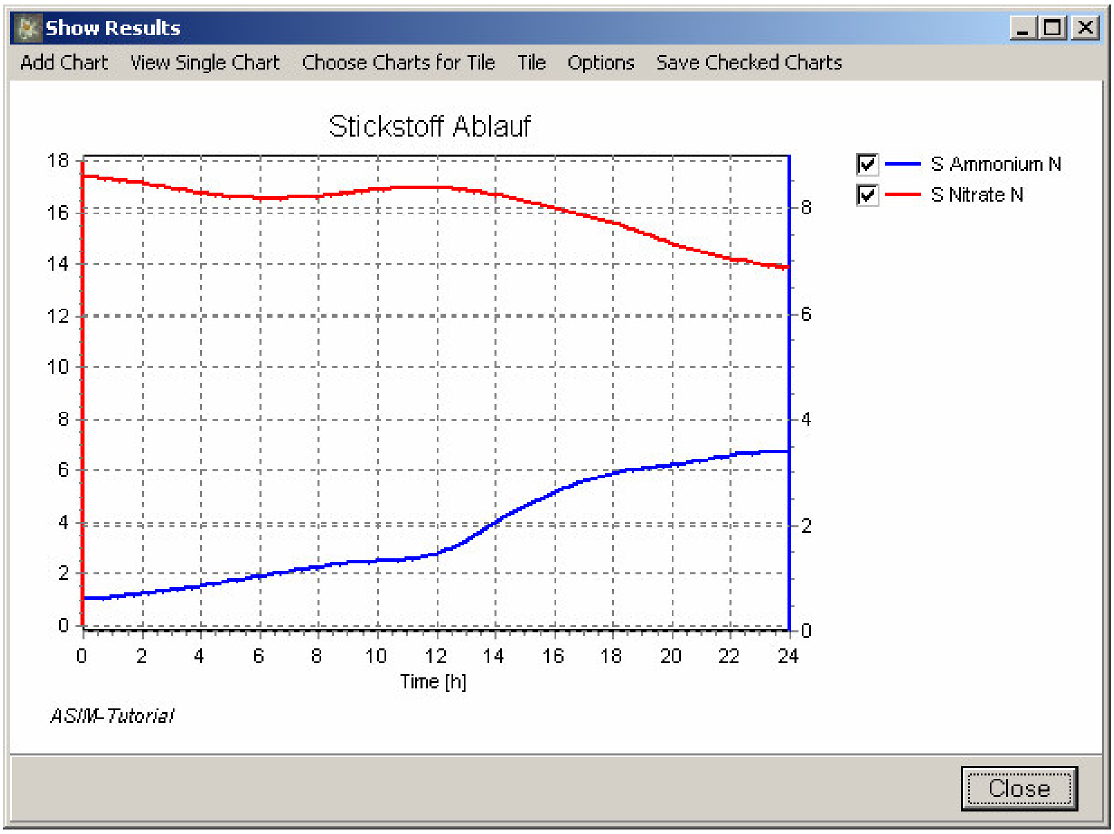


Figure 42: An example of a manipulated chart. It can be saved and accessed later as a template.

Berne, Switzerland, 1th of March, 2006

Author: Jan Suter / Christian Abegglen (EAWAG)

HOLINGER AG

LITERATURE

- Gujer, W., Henze, M., Mino, T. and van Loosdrecht, M.C.M. (1999), Activated Sludge Model No. 3, Wat. Sci. Technol. 39 (1), 183-193
- Koch, G., Kühni, M., Gujer, W. and Siegrist, H., 2000, Calibration and Validation of activated sludge model no. 3 for swiss municipal wastewater, Wat. Res. Vol. 34, pp. 3580-3590.

APPENDIX A – THE MODEL FILE

This appendix explains the Model File and is not directly relevant for actual problem-solving. However, understanding a model thoroughly is necessary for calibration procedures (altering of the stoichiometric and kinetic parameters is not recommended).

The names of all Model Files end in *.mod and these files include all the information required to characterize a biokinetic model: stoichiometry, kinetics, kinetic parameters, temperature coefficients, and a set of typical initial conditions and influent concentrations.

With ASIM you can make use of a number of different biokinetic models. Some classic models are delivered with the program. These models are available in the folder "\ASIM\text" and you can access and load them with the command "Model → Load ASIM Model".

SETUP OF A MODEL FILE

Select "Model → Edit Active Model". A dialog box with eight registers appears.

Info

The register "Info" includes information about the chosen model, the number of dissolved and particulate species, and the number of transformation processes. If you wish to create a new model, enter the number of transformation processes and the number of the dissolved and particulate species in this register.

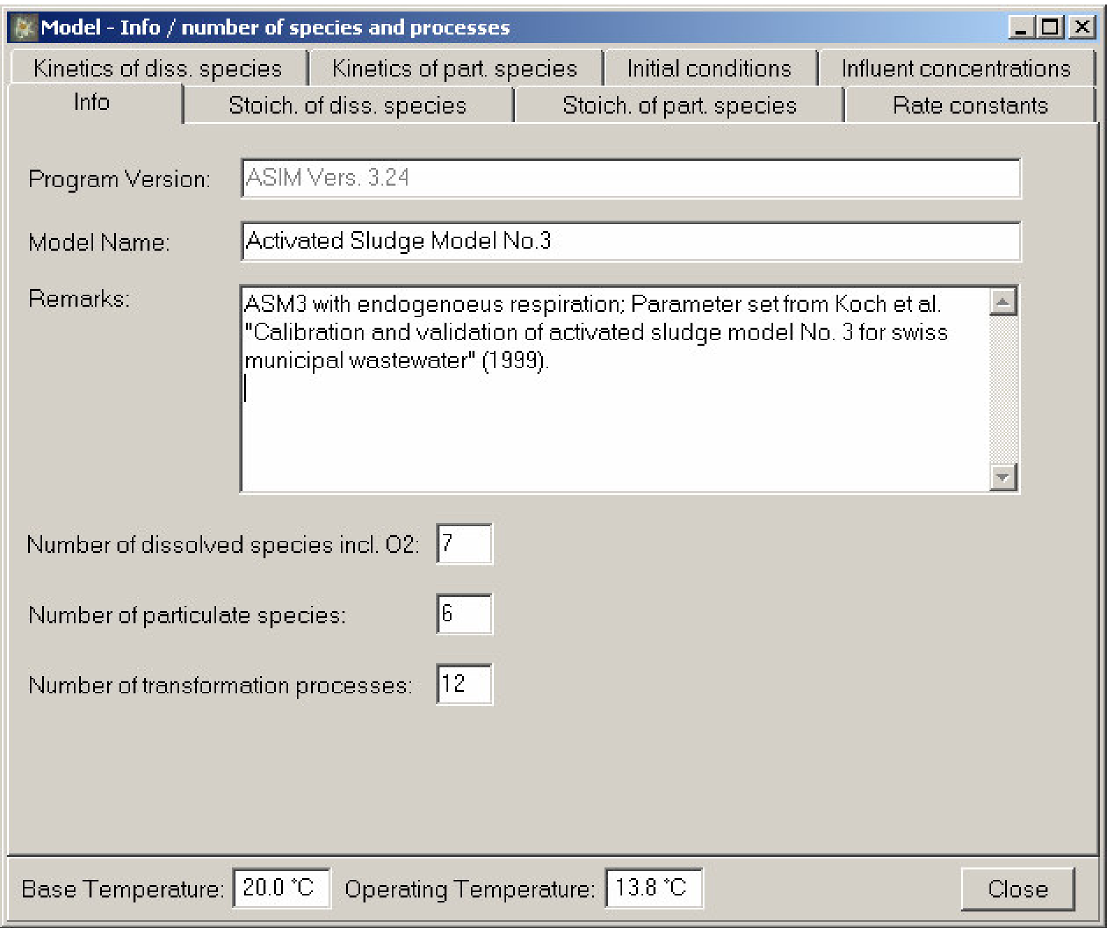


Figure 43: Overview of a model (here the Activated Sludge Model No.3)

STOICHIOMETRY OF DISSOLVED SPECIES

Select the register “Stoich. of dissolved species” with a stoichiometric matrix for the dissolved species of your model. Each process and each species has a stoichiometric coefficient. Empty boxes mean that this certain species does not actively participate in the process. If you create a model by yourself, you are free to choose between units (mass, mole). However, it is crucial to operate properly with different units.

STOICHIOMETRY OF PARTICULATE SPECIES

You find a stoichiometric matrix for the particulate species in the register “Stoich. of part. species”. The particulate species are ideally separated in the secondary clarifier.

KINETICS OF DISSOLVED SPECIES

The register “Kinetics of diss. species” determines the term of a reaction, using12 available options.

Table 10: Description of the Kinetic Parameters for Dissolved Species

Abbreviation	Explanation
K	Half-saturation constant
S	Concentration of dissolved species
A	Species A
B	Species B
n	Factor / Exponent
r_{kin}	Kinetic constant (defined under „rate constants“)

1. Zero Order: Kinetics of zero order. This species has no influence on kinetics.

$$r_{kin}$$

2. First Order: The process rate is proportional to the concentration of the species.

$$r_{kin} \cdot S_A$$

3. Variable Order: The process rate is proportional to the concentration of the species to the power of n.

$$r_{kin} \cdot S_A^n$$

4. Monod: Monod kinetics. This species influences the process rate with saturation kinetics.

$$r_{kin} \cdot \frac{S_A}{K_A + S_A}$$

5. Inhibition: This species inhibits the process rate.

$$r_{kin} \cdot \frac{K_A}{S_A + K_A}$$

6. Two substrates: Two species influence the process parallel. This kinetics requires a definition of a further substrate.

$$r_{kin} \cdot \frac{S_A}{K_A + S_A} \cdot \frac{S_A}{S_A + S_B}$$

7. Gas stripping: This species is stripped from the reactor proportionally to its concentration and to the kLa -value.

$$r_{kin} \cdot K_L a \cdot (S_A - K_{A,Gas})$$

8. Exponential: The reaction rate depends exponentially on the concentration.

$$r_{kin} \cdot \exp(S_A \cdot K_{\exp})$$

9. Monod II: Monod kinetics, depends on an exponential factor.

$$r_{kin} \cdot \frac{S_A^n}{K_A^n + S_A^n}$$

10. Inhibition II: The process rate is inhibited; operating takes place with an exponential factor.

$$r_{kin} \cdot \frac{K_A^n}{K_A^n + S_A^n}$$

11. Gas stripping II: The species is stripped depending on its concentration, but independent of the kLa -value.

$$r_{kin} \cdot (S_A - K_{A,Gas})$$

12. Gas stripping III: The process rate depends on the concentration of the species A, but also on the concentration (and a factor) of another species.

$$r_{kin} \cdot (S_A - K_{Gas} \cdot S_B)$$

KINETICS OF PARTICULATE SPECIES

The register “Kinetics of part. Species” determines the term of a reaction depending on particulate species. There are six options available:

Table 11: Description of the Kinetic Parameters for Particulate Species

Abbreviation	Explanation
K	Half-saturation constant
S	Concentration of dissolved species
X	Concentration of particulate species
A	Species A
B	Species B
n	Factor / Exponent
r_{kin}	Kinetics constant (defined under „rate constants“)

1. Zero Order: This species has no influence on reaction kinetics.

$$r_{kin}$$

2. First Order: The process rate is proportional to the concentration of the species.

$$r_{kin} \cdot X_A$$

3. Variable Order: The process rate is proportional to the concentration of the species to the power of n.

$$r_{kin} \cdot X_A^n$$

4. Adsorption: This species influences the process rate with saturation-adsorption-kinetics. For this purpose, at least two particulate species need to be defined.

$$r_{kin} \cdot \frac{X_A / X_B}{K_A + X_A / X_B}$$

5. Inhibition: The bigger the relative concentration XA/XB, the stronger the inhibition of the process.

$$r_{kin} \cdot \frac{K_A}{K_A + X_A / X_B}$$

6. Inh./Saturation: The increase of the ratio XA/XB leads to saturation; the maximal rate is reached with a small ratio.

$$r_{kin} \cdot \frac{K_A - X_A / X_B}{1.05 \cdot K_A - X_A / X_B}$$

RATE CONSTANTS

In the register “Rate constants“ you find the rate constants of each individual process (mentioned in the equation for rkin). k is the product of all rkin in one process. The rate constants must be defined for a basic temperature and provided with a temperature coefficient. The constants depend on temperature and are computed according to the following formula:

$$r_{kin}(T) = r_{kin}(T_{Basis}) \cdot \exp(a \cdot (T - T_{Basis}))$$

In the register cards “Initial Conditions“ and “Influent Concentrations“ you define the initial conditions and influent values for the individual species. This can be done in a Plant File as well.

APPENDIX B – ATTACHED DATA FILES

The folder "\ASIM\user\tutorial" contains nearly all of the files created during this tutorial. These files should never be used as templates in practice (calibration) but rather as a source for help during the tutorial.

The following tables explain these data files.

Table 12: Attached .pln -files (Plant Files)

File name	Chapter	Short description
tutorial_winter.pln	3	The plant, as characterized for operating temperature of 10° C, i.e. in winter conditions.
tutorial_sommer.pln	5.1	As *tutorial_winter.pln*, but with operating temperature of 20°C.
tut_winter_N.pln	3.4	Plant in winter, after a day with increased nitrogen load.
tutorial_fw.pln	6	Plant in winter, with supernatant influent.
tutorial_deni.pln	7	Plant in winter, with supernatant influent and a denitrification zone.
tutorial_onoff.pln	8.3	Plant in winter, with supernatant influent, a denitrification zone and On/Off-control for oxygen.
tutorial_sb.pln	9.2	Plant in winter, with supernatant influent, a denitrification zone and a sludge blanket. Constant oxygen in activated sludge tanks.

Table 13: Attached .vrt -files (Variation Files)

File name	Chapter	Short description
tutorial.vrt	3	Variation File with normal load.
tutorial_belastung.vrt	5.2.1	Flow rate increased by 25 %.
tut_N.vrt	5.2.2.	Increase in ammonium (40 %) and in alkalinity (20 %).
tutorial_CSB	5.2.3	All COD-fractions increased by 40 %.
tut_fw_morgen.vrt	6	Normal load, supernatant step fed between 8 and 12 o'clock.
tutorial_fw.vrt	6	Normal load, optimal doses of supernatant