Exercise 1:

Introduction to ASIM – Implementation of a AS plant into the ASIM simulation software

Objective

To be able to implement a AS plant into the ASIM simulation software

Components of a AS plant model

For the implementation of a AS plant into a model the following sub-models are required:

- Flow model: describes the hydraulic behaviour of the plant
- Biokinetic model: describes the transformation and elimination processes for C, N and P
- Influent characterisation: relates measurements and model parameters (e.g. COD)

Plant data

Table 1 contains the required information for the specification of the AS plant.

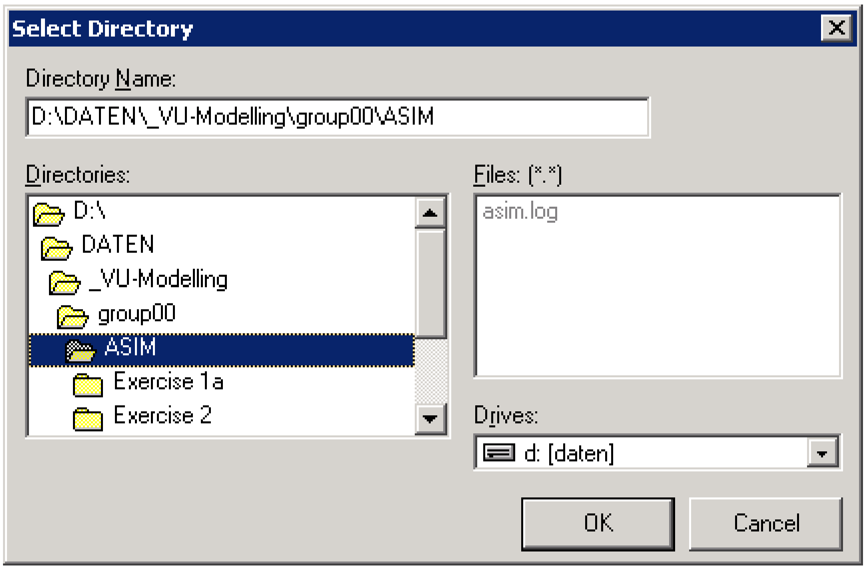
Table 1: Plant data

Parameter	**Unit**	**Value**	**Comments**
Number of tanks		3	Number of tanks as per drawings
V1	m^3	350	Volume of anoxic tank
V2	m^3	400	Volume of swing (anoxic/aerated) tank
V3	m^3	400	Volume of aerated tank
Total volume	m^3	1150	Total volume of the AS tank
Secondary clarifier	m^3	-	0 tanks - Ideal clarifier
Average influent	m^3/d	1200	Mean influent flow
Return activated sludge	m^3/d	1200	RAS whole plant
Internal recirulation	m^3/d	3050	from tank 3 to tank 1
Sludge age	d	11.7	-
Temperature	°C	12	Operating temperature

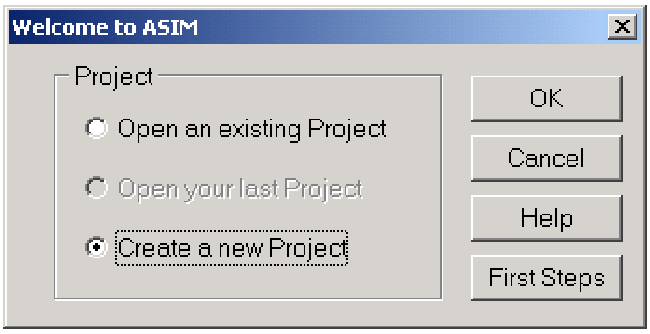
Implementation of the given plant layout into ASIM

The given layout of the AS plant shall be now implemented into ASIM.

1. Select User directory (select your group number)

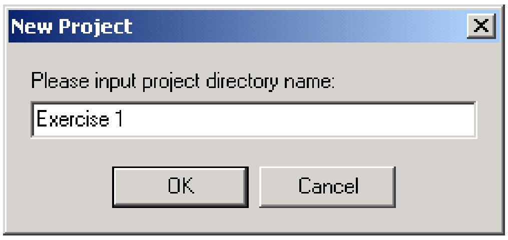


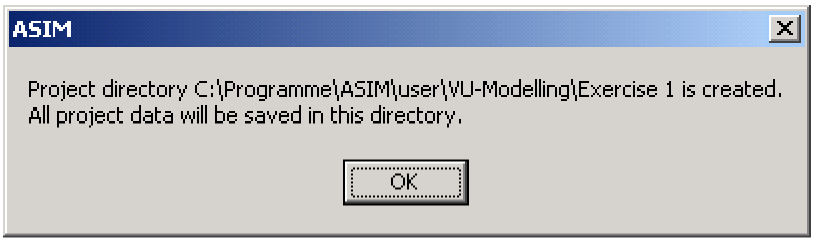
2. Open ASIM and choose <<Create a new Project>>. Click OK.



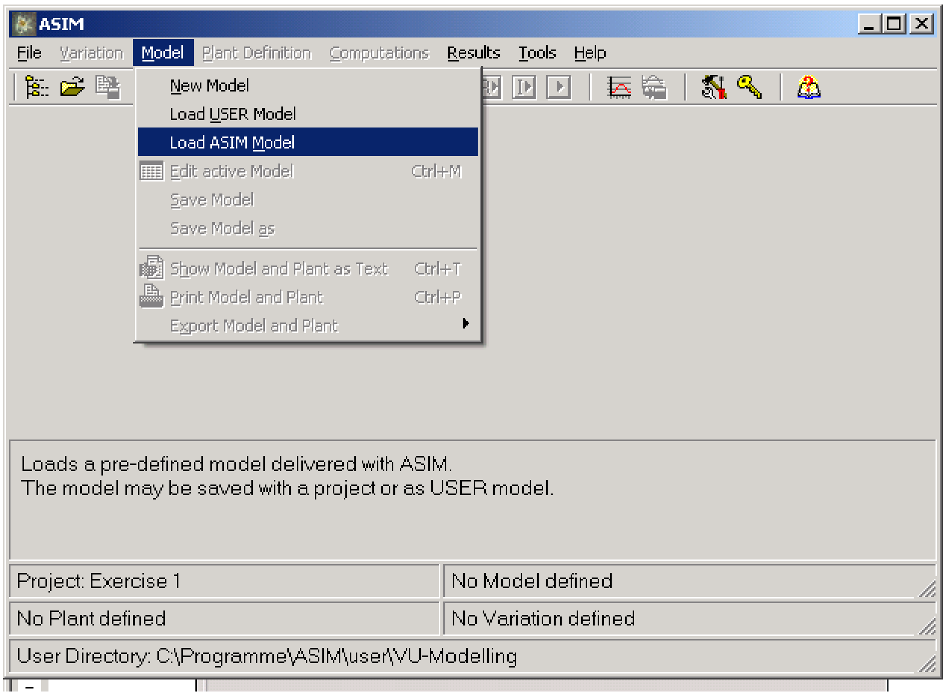
3. Enter name of the project

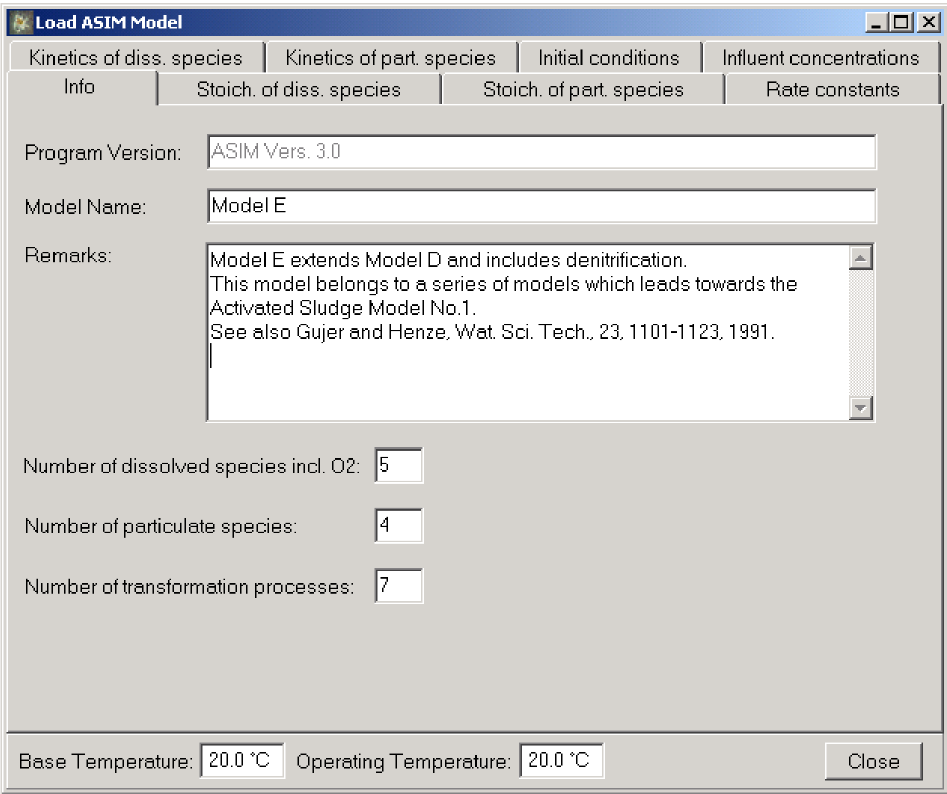
all input data for and all results of the simulation are saved in a directory with this name



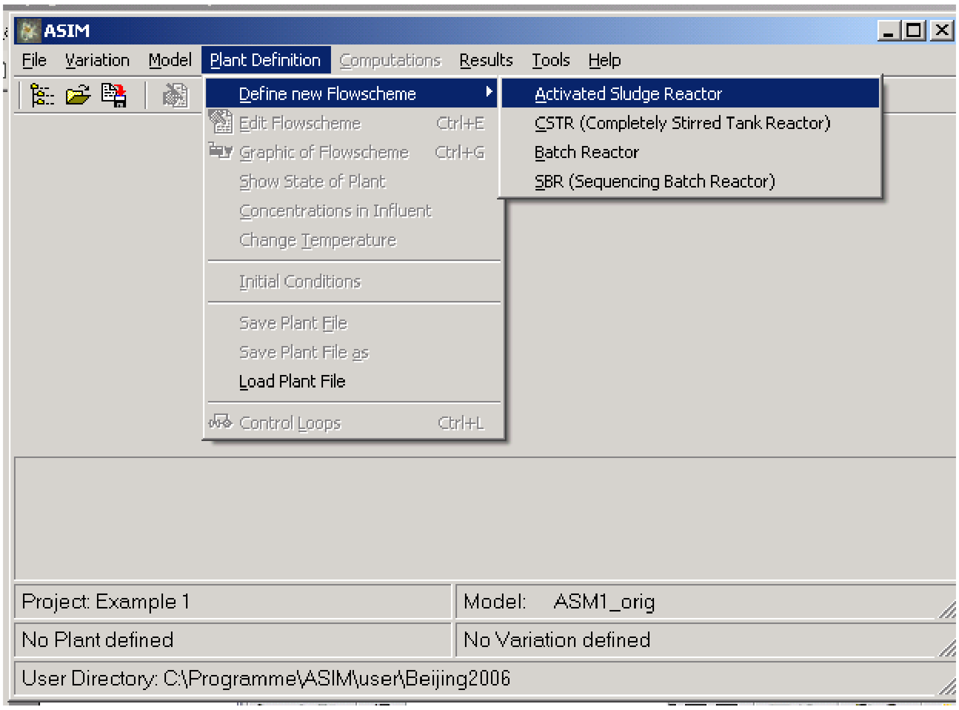


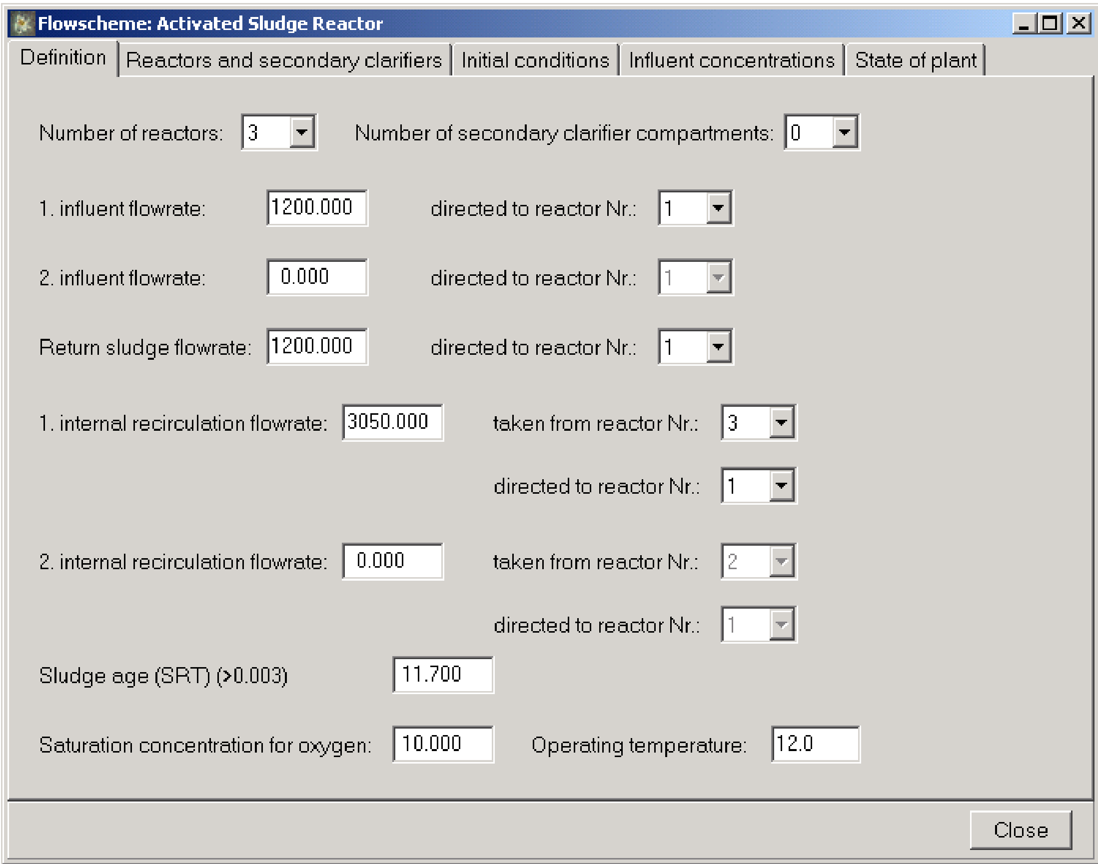
4. Load Biokinetic model: Model//Load ASIM Model; choose "Model E"

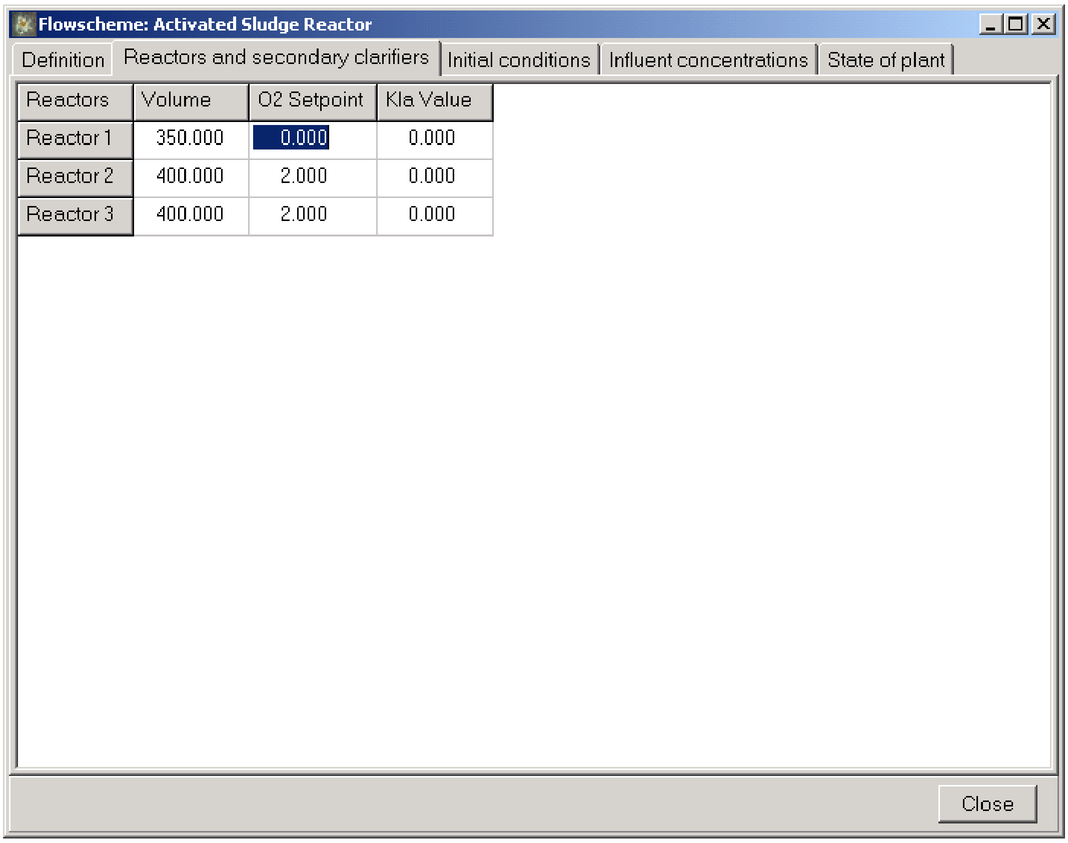


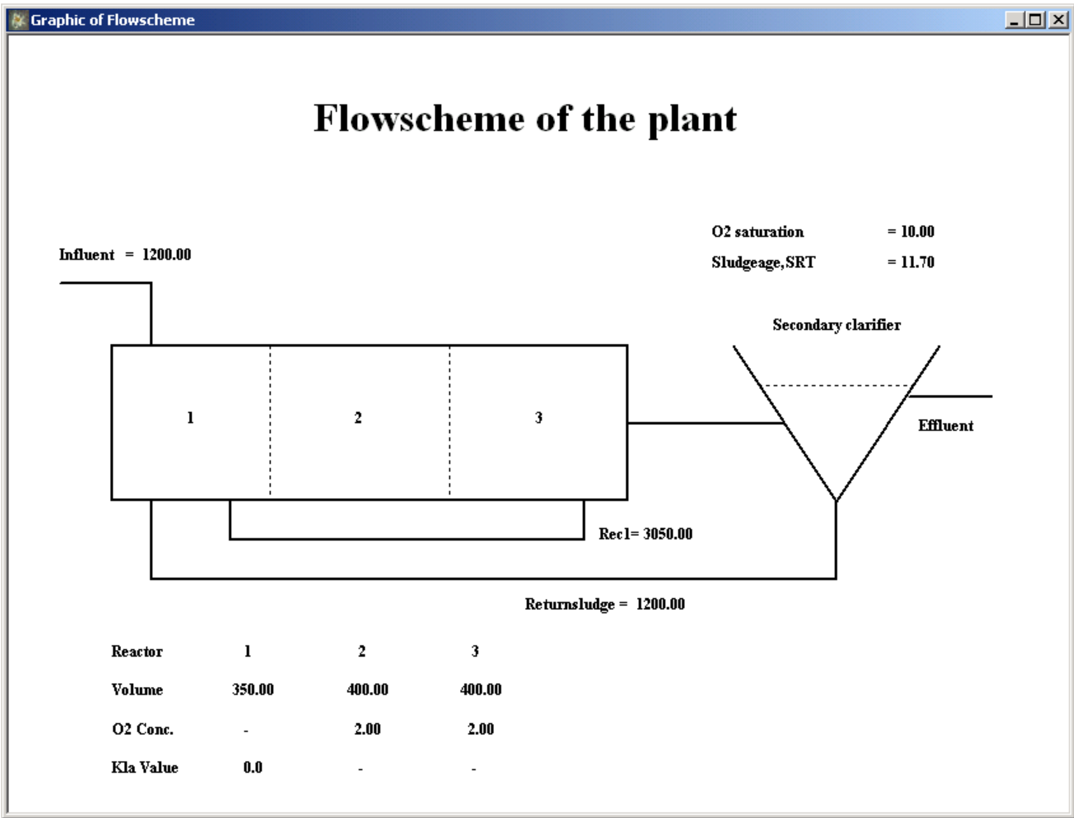


5. Define plant configuration: according to Table 2






Flowscheme: Activated Sludge Reactor
Definition
Reactors and secondary clarifiers
Initial conditions
Influent concentrations
State of plant
Reactors | Volume | O2 Setpoint | Kla Value
Reactor 1 | 350.000 | 0.000 | 0.000
Reactor 2 | 400.000 | 2.000 | 0.000
Reactor 3 | 400.000 | 2.000 | 0.000
Close


Graphic of Flowscheme
Flowscheme of the plant
Influent = 1200.00
O2 saturation = 10.00
Sludgeage,SRT = 11.70
Secondary clarifier
1
2
3
Effluent
Recl= 3050.00
Returnsludge = 1200.00
Reactor 1 2 3
Volume 350.00 400.00 400.00
O2 Conc. - 2.00 2.00
Kla Value 0.0 - -

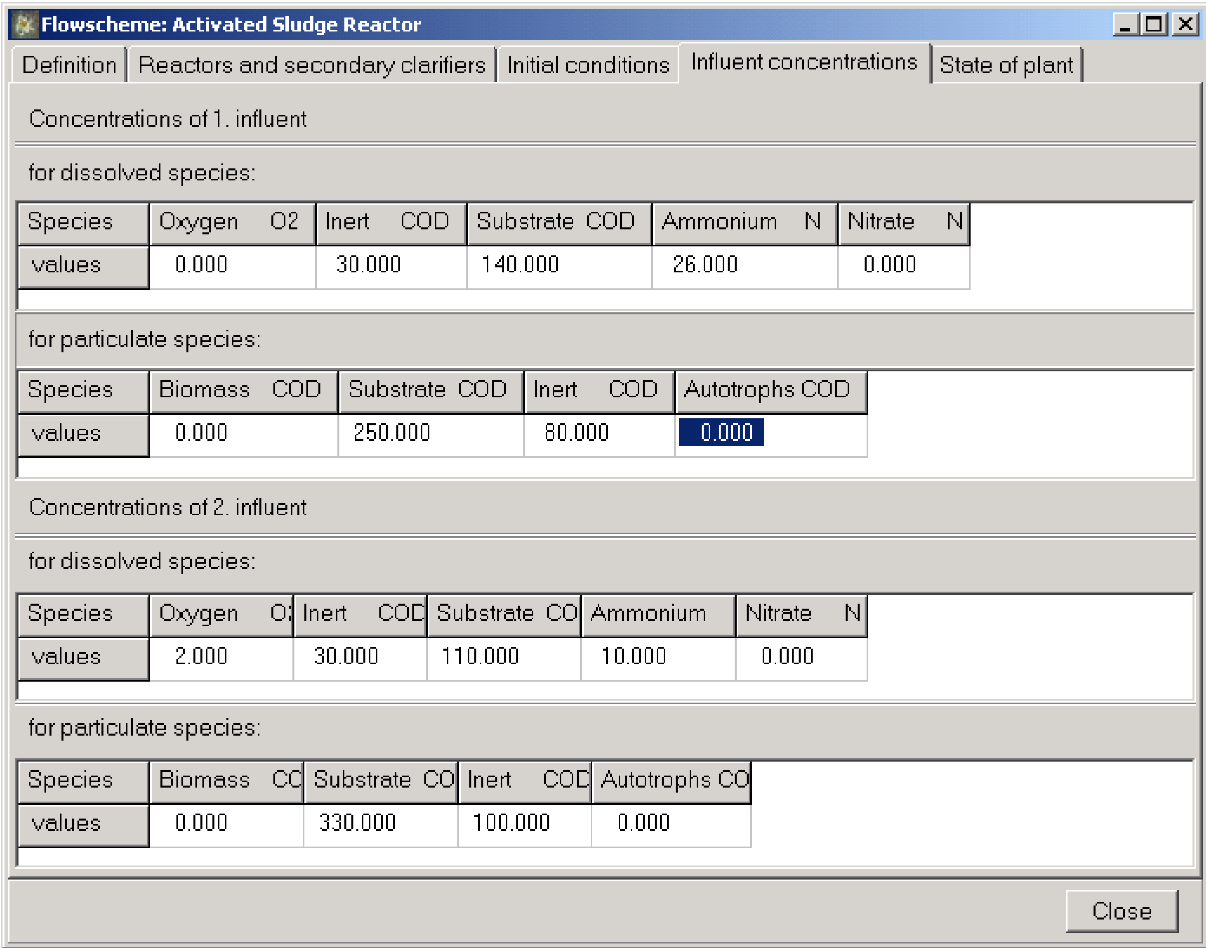
6. Influent concentrations and influent fractionation

a) Influent concentrations (effluent primary clarifier):

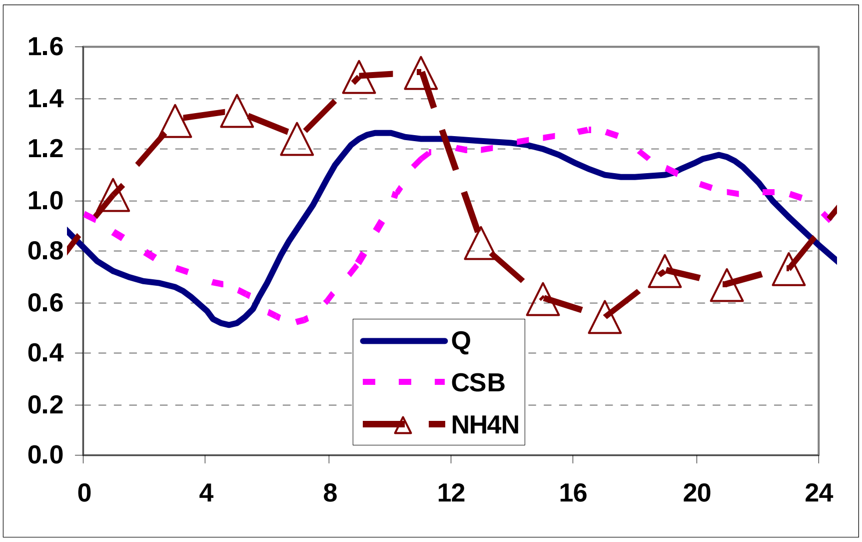
$C_{BOD5,in}$ = 250 mg/L; $C_{COD,in}$ = 500 mg/L; $C_{TSS,in}$ = 292 mg/L; $C_{TKN,in}$ = 46 mg/L

b) Influent fractionation

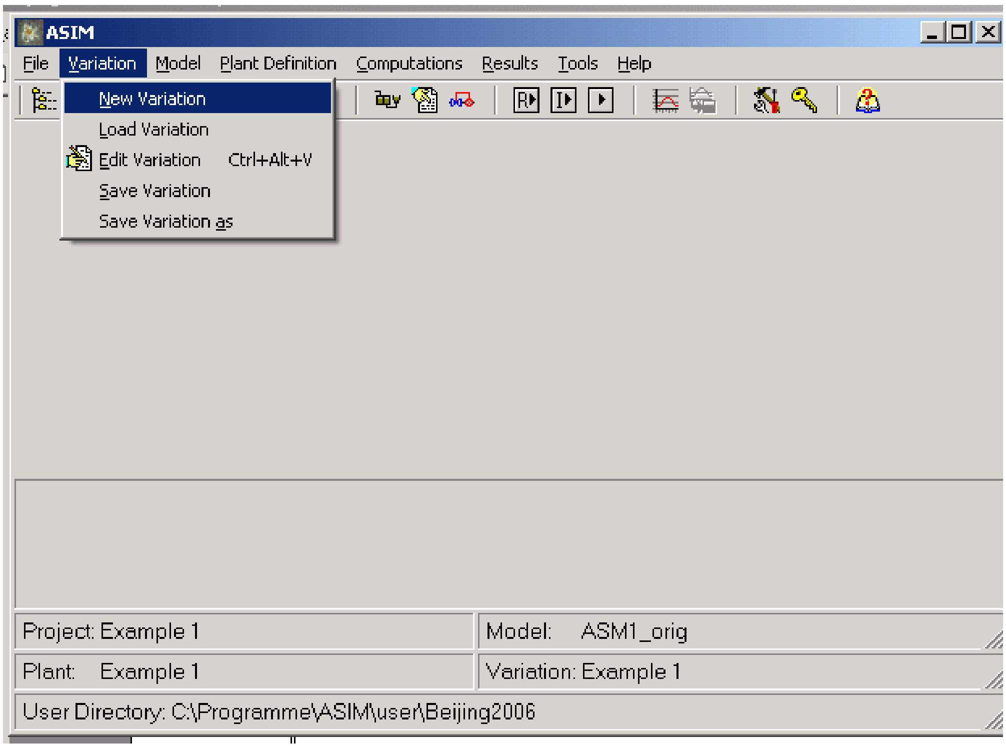
S Oxygen O2 =	-	X Biomass COD =	-
S Inert COD =	30 mg/L	X Substrate COD =	250 mg/L
S Substrate COD =	140 mg/L	X Inert COD =	80 mg/L
S Ammonium N =	26 mg/L	X Autotrophs COD =	-
S Nitrate N =	-	Temperatur =	12°C

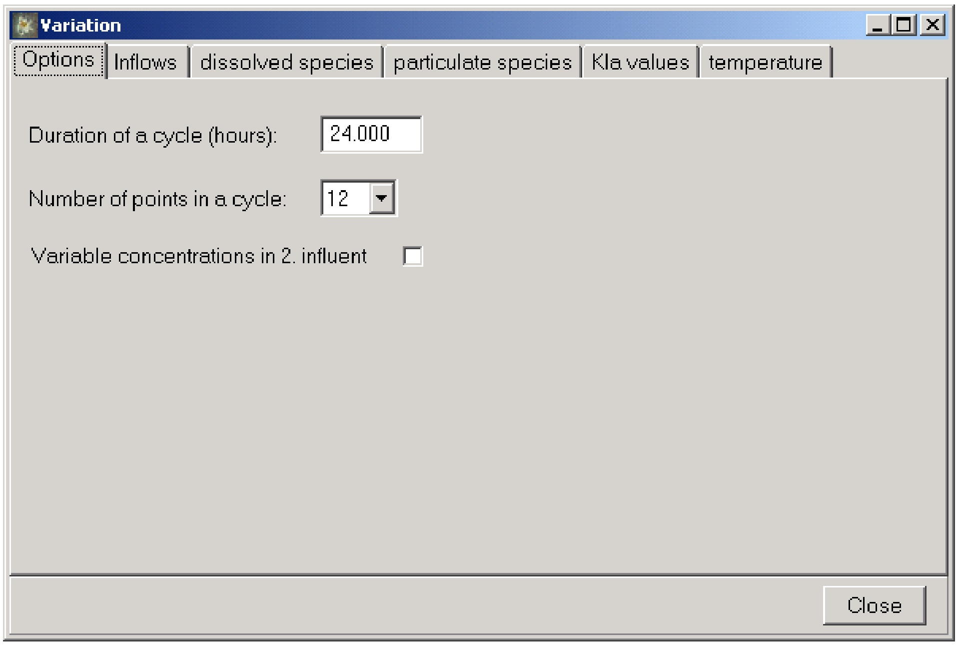


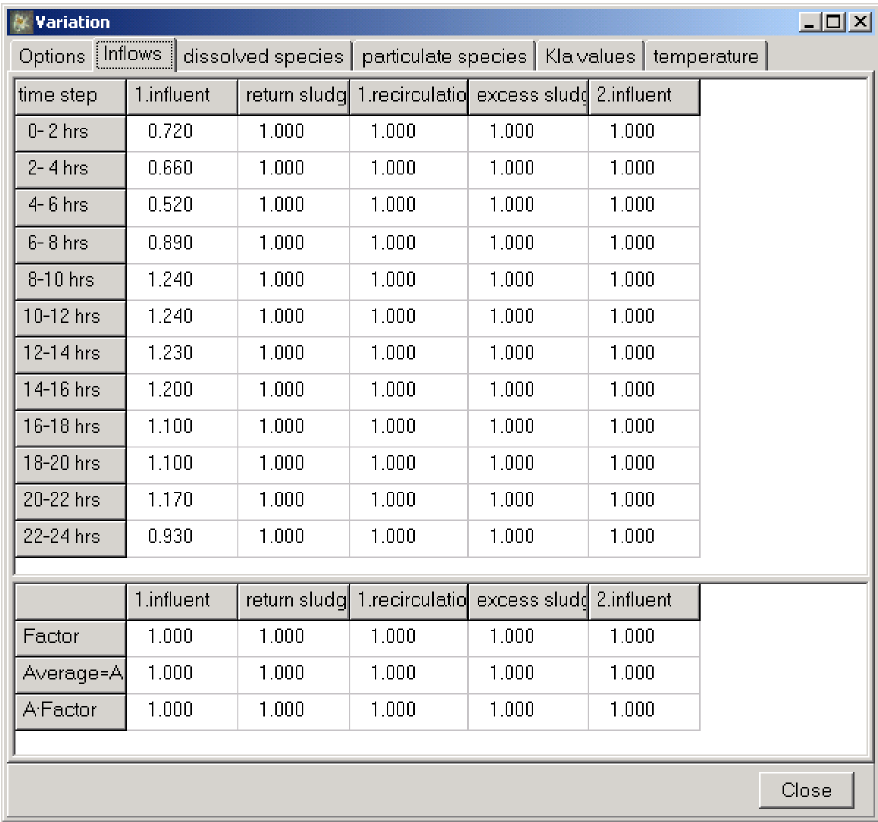
7. Variation of the influent



Zeit	Q	CSB	NH4N	P
0 - 2	0.72	0.87	1.02	0.87
2 - 4	0.66	0.73	1.31	0.73
4 - 6	0.52	0.64	1.35	0.64
6 - 8	0.89	0.52	1.24	0.52
8 - 10	1.24	0.75	1.48	0.75
10 - 12	1.24	1.16	1.50	1.16
12 - 14	1.23	1.19	0.83	1.19
14 - 16	1.20	1.24	0.61	1.24
16 - 18	1.10	1.26	0.54	1.26
18 - 20	1.10	1.12	0.72	1.12
20 - 22	1.17	1.03	0.67	1.03
22 - 24	0.93	1.02	0.73	1.02

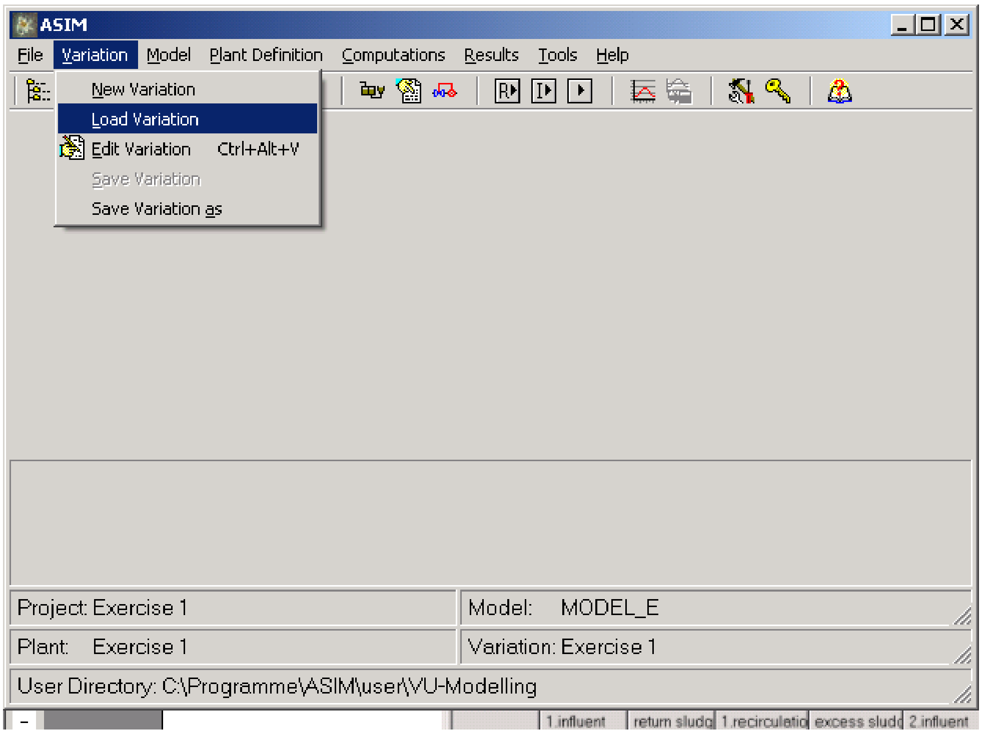


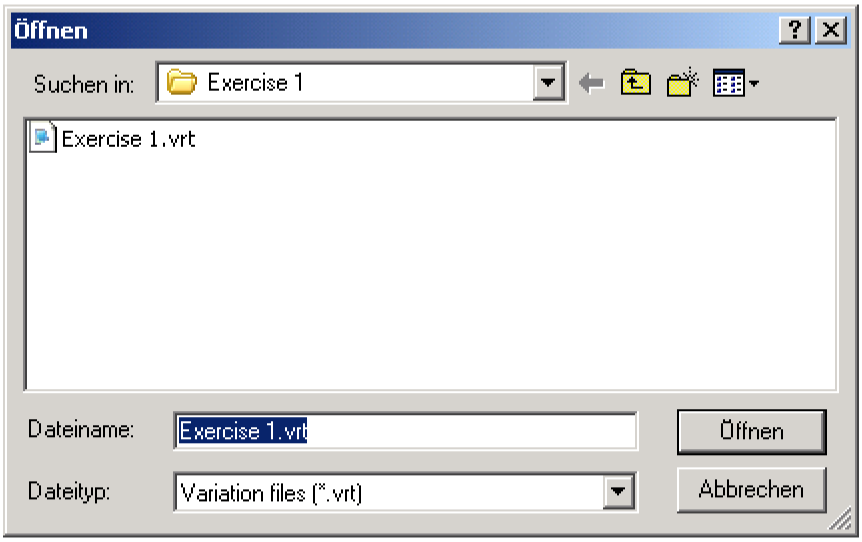




time step	1.influent	return sludg	1.recirculatio	excess sludg	2.influent
0- 2 hrs	0.720	1.000	1.000	1.000	1.000
2- 4 hrs	0.660	1.000	1.000	1.000	1.000
4- 6 hrs	0.520	1.000	1.000	1.000	1.000
6- 8 hrs	0.890	1.000	1.000	1.000	1.000
8-10 hrs	1.240	1.000	1.000	1.000	1.000
10-12 hrs	1.240	1.000	1.000	1.000	1.000
12-14 hrs	1.230	1.000	1.000	1.000	1.000
14-16 hrs	1.200	1.000	1.000	1.000	1.000
16-18 hrs	1.100	1.000	1.000	1.000	1.000
18-20 hrs	1.100	1.000	1.000	1.000	1.000
20-22 hrs	1.170	1.000	1.000	1.000	1.000
22-24 hrs	0.930	1.000	1.000	1.000	1.000

	1.influent	return sludg	1.recirculatio	excess sludg	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


ASIM
File Variation Model Plant Definition Computations Results Tools Help
New Variation
Load Variation
Edit Variation Ctrl+Alt+V
Save Variation
Save Variation as
Project: Exercise 1
Model: MODEL_E
Plant: Exercise 1
Variation: Exercise 1
User Directory: C:\Programme\ASIM\user\VU-Modelling

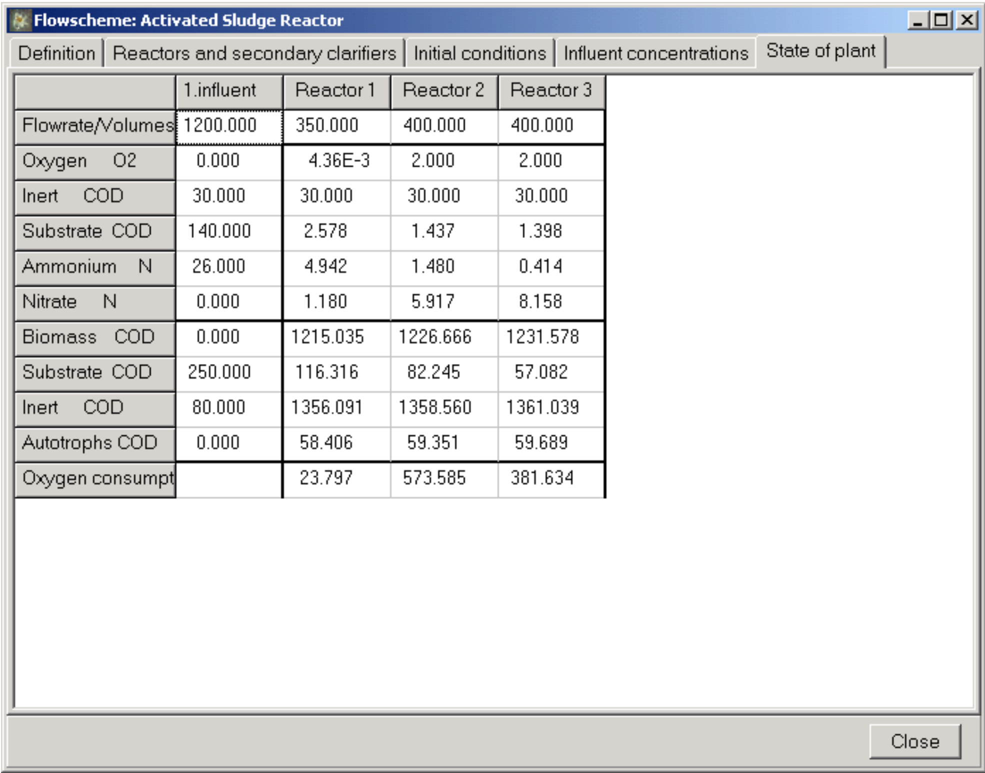

Öffnen
Suchen in:
Exercise 1
Exercise 1.vrt
Dateiname:
Exercise 1.vrt
Öffnen
Dateityp:
Variation files (*.vrt)
Abbrechen

8. Calculations:

<u>Integration</u>: Integrates materials balance equations forward in time, leads towards a steady-state of the plant as presently defined. Considers control loops. Not for batch reactors.

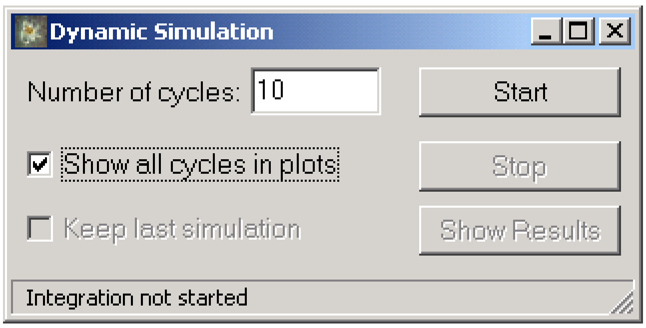
<u>Dynamic Simulation</u>: Simulates the behaviour of the plant under variable loading and temperature conditions. May be used for diurnal variations as well as for batch reactors.

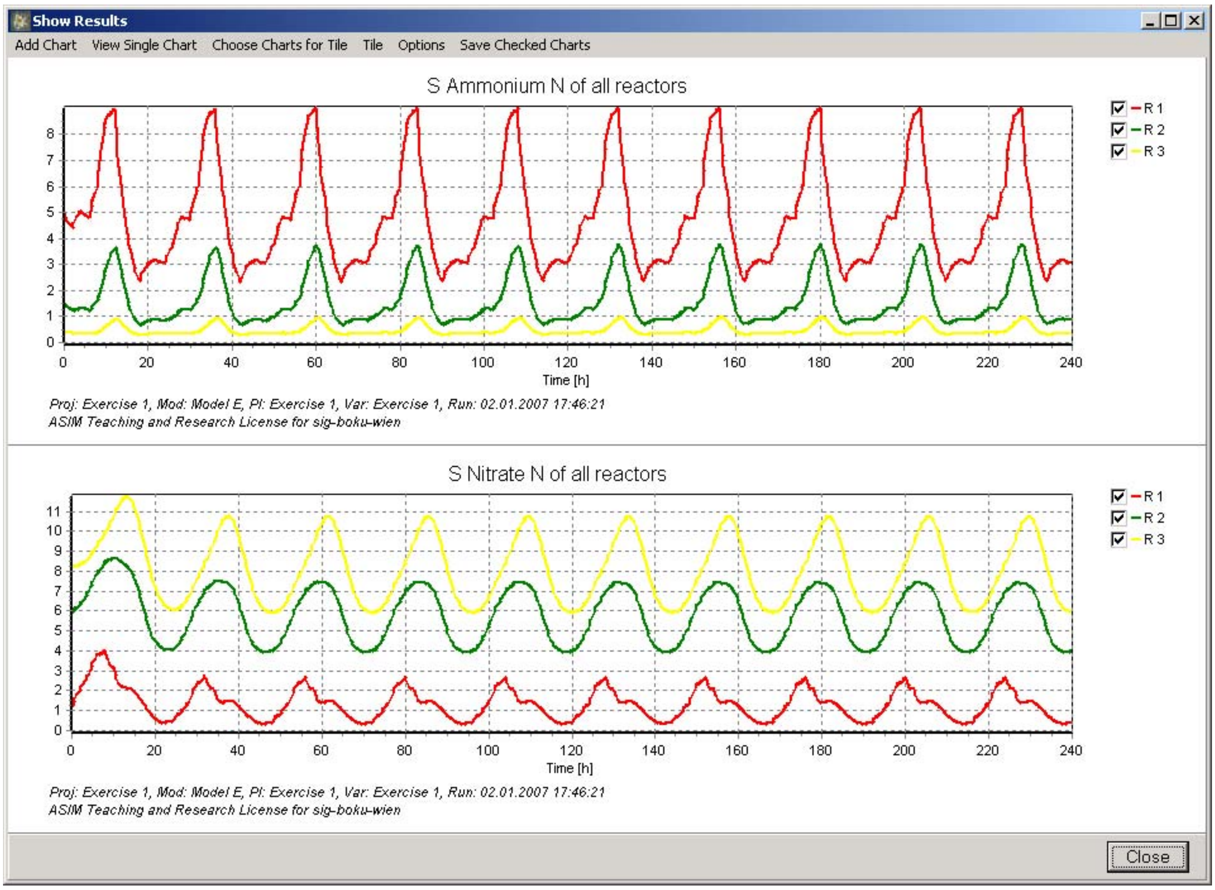
a) Integration over 50 days



	1.influent	Reactor 1	Reactor 2	Reactor 3
Flowrate/Volumes	1200.000	350.000	400.000	400.000
Oxygen O2	0.000	4.36E-3	2.000	2.000
Inert COD	30.000	30.000	30.000	30.000
Substrate COD	140.000	2.578	1.437	1.398
Ammonium N	26.000	4.942	1.480	0.414
Nitrate N	0.000	1.180	5.917	8.158
Biomass COD	0.000	1215.035	1226.666	1231.578
Substrate COD	250.000	116.316	82.245	57.082
Inert COD	80.000	1356.091	1358.560	1361.039
Autotrophs COD	0.000	58.406	59.351	59.689
Oxygen consumpt		23.797	573.585	381.634

b) Dymanic simulation over 10 days





	Maximum	Minimum	Mean
S Ammonium N			
R 1	8.996	2.372	4.794
R 2	3.781	0.718	1.609
R 3	**0.985**	**0.310**	**0.476**
S Nitrate N			
R 1	2.655	0.310	1.244
R 2	7.398	3.925	5.667
R 3	**10.721**	**5.935**	**7.984**

9. Questions

- **Which measures can be taken to increase denitrification (TN elimination)?**

- **What happens when the sludge age is increased/decreased ?**

Exercise 2:
Control of WWTPs

Objective

Implementation of simple control handlings

Control loops for "our" WWTP

1. On-off control of aeration in reactor 3

   "if SO2(3) > 2.0 then kLa(3) = 0"   AND   "if SO2(3) < 1.5 then kLa(3) = 50"

2. Fixed O2 value in reactor 2 (e.g. 1 mg/l)

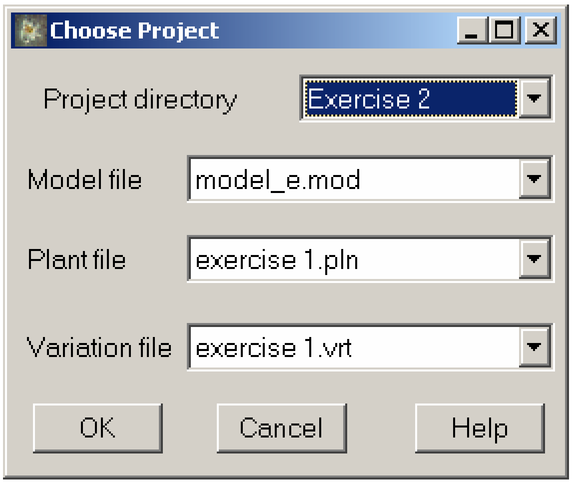
   kLa(2) = 50 – 50 . (SO2(2) – 1.0)

3. Control of O2 in reactor 2 as a function of the NO3-N and/or NH4-N effluent concentration
4. Control of the return sludge (internal recirculation) as a function of the influent flow
5. Control of internal recirculation such that NO3-N at the end of the anoxic zone is maintained at 1.5 mg/l (Aeration minimised while achieving near complete nitrification)

Loading default plant data (from Exercise 1)

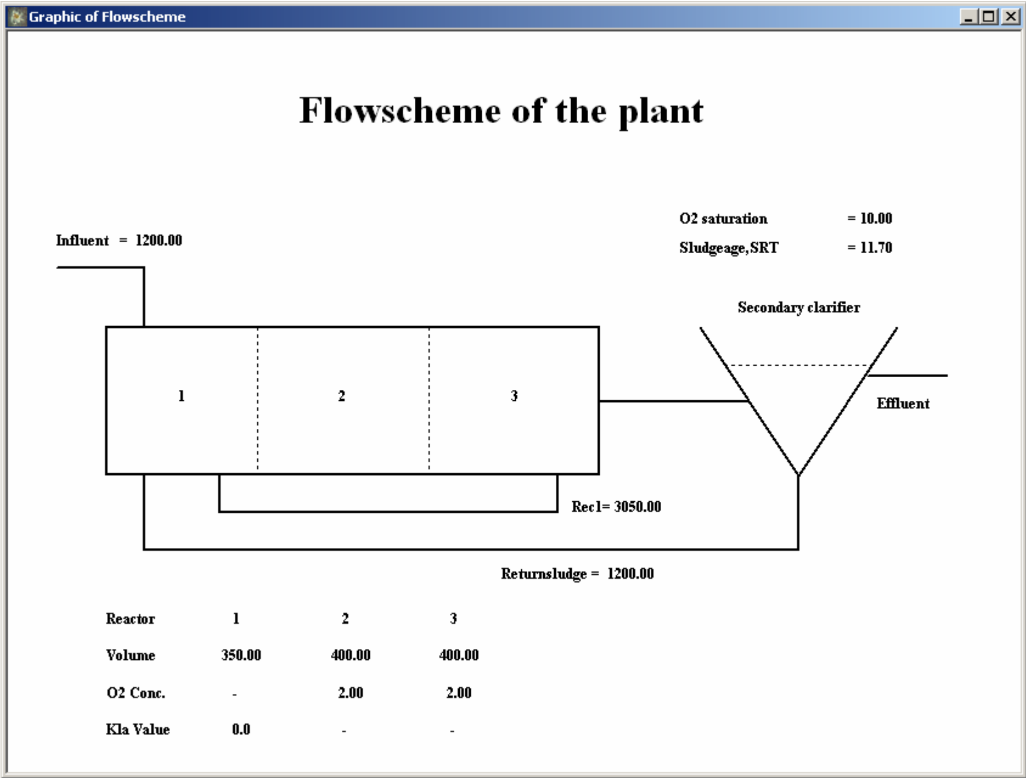
a) Choose **Load Project** from the **File** menu.

b) Load the project **Exercise 2**



- the process model file **model_e.mod**,
- the plant configuration file **Exercise 1.pln** and
- the influent flow variation file **Exercise 1.vrt**.

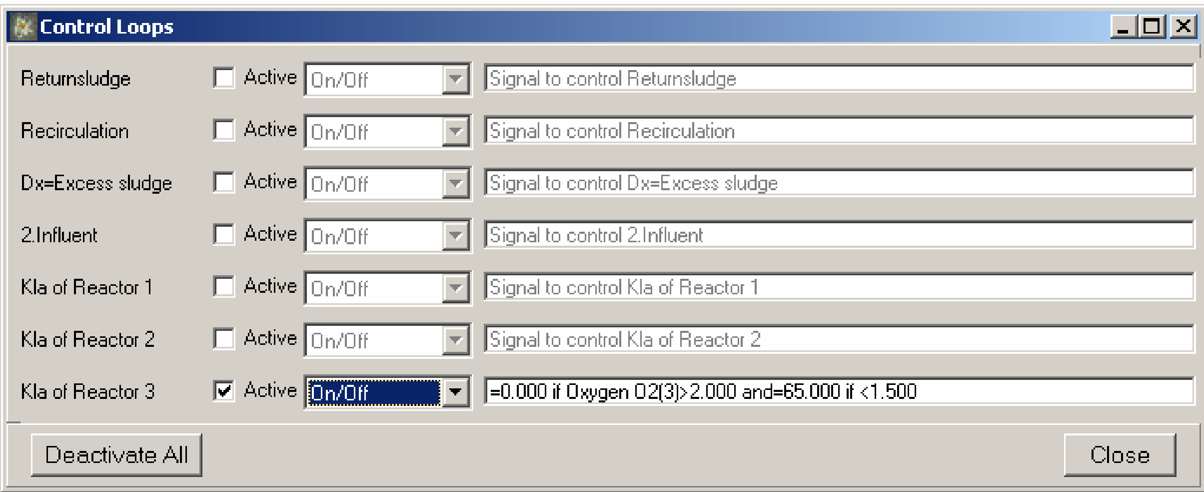
Click OK. This will load all required file components:



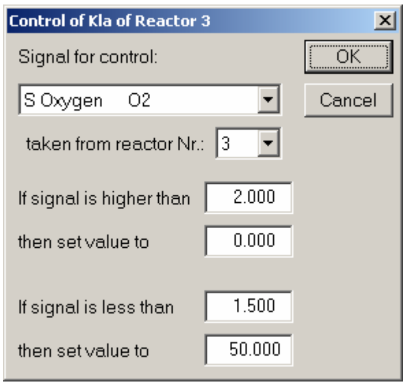
1) On-off control of aeration in reactor 3

"if SO2(3) > 2.0 then kLa(3) = 0" AND "if SO2(3) < 1.5 then kLa(3) = 50"

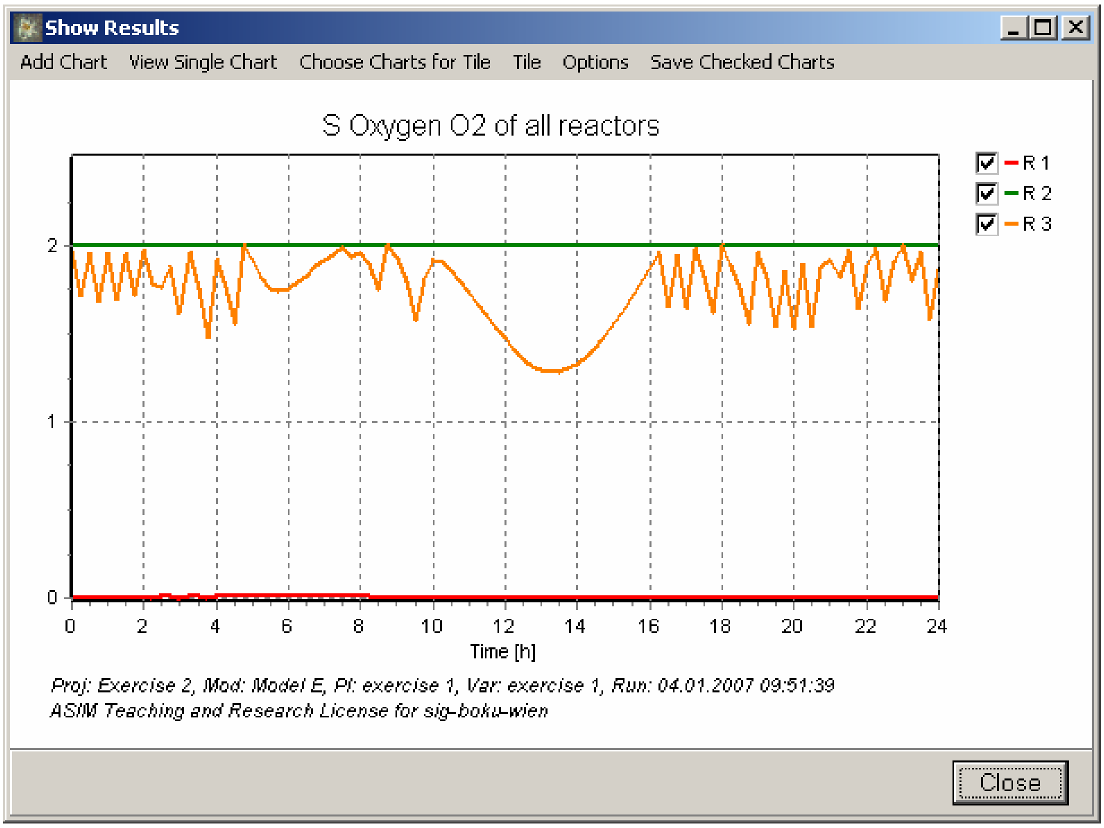
a) To implement a DO controller go to `Plant Definition` ➔ `Control Loops` and activate the Kla controllers for reactor3.



b) Set control parameters for on/off control



c) Run a dynamic simulation for 10 days and view results of S Oxygen O2

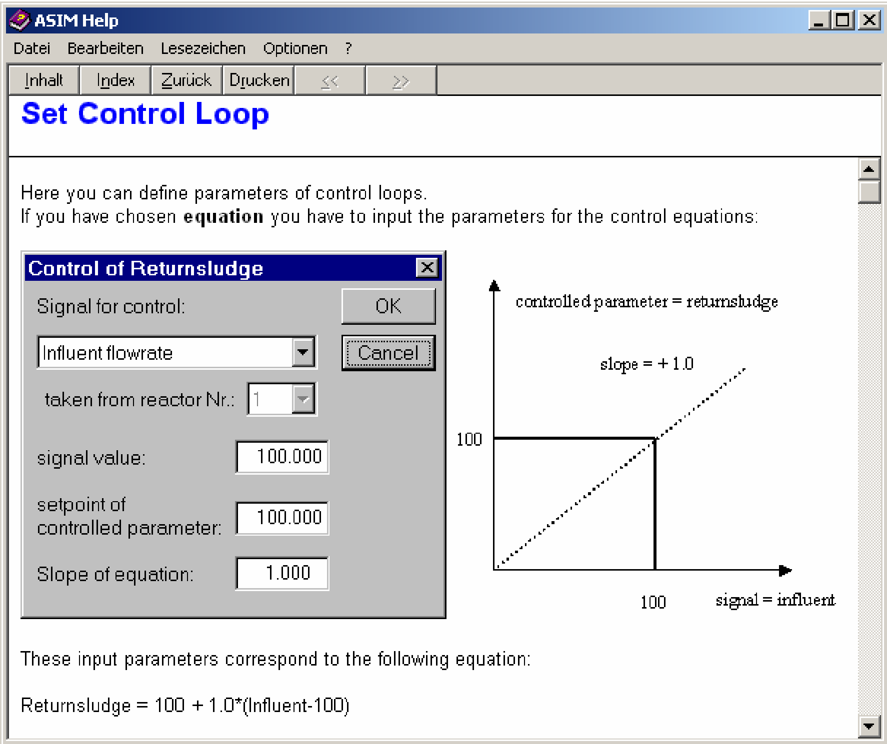


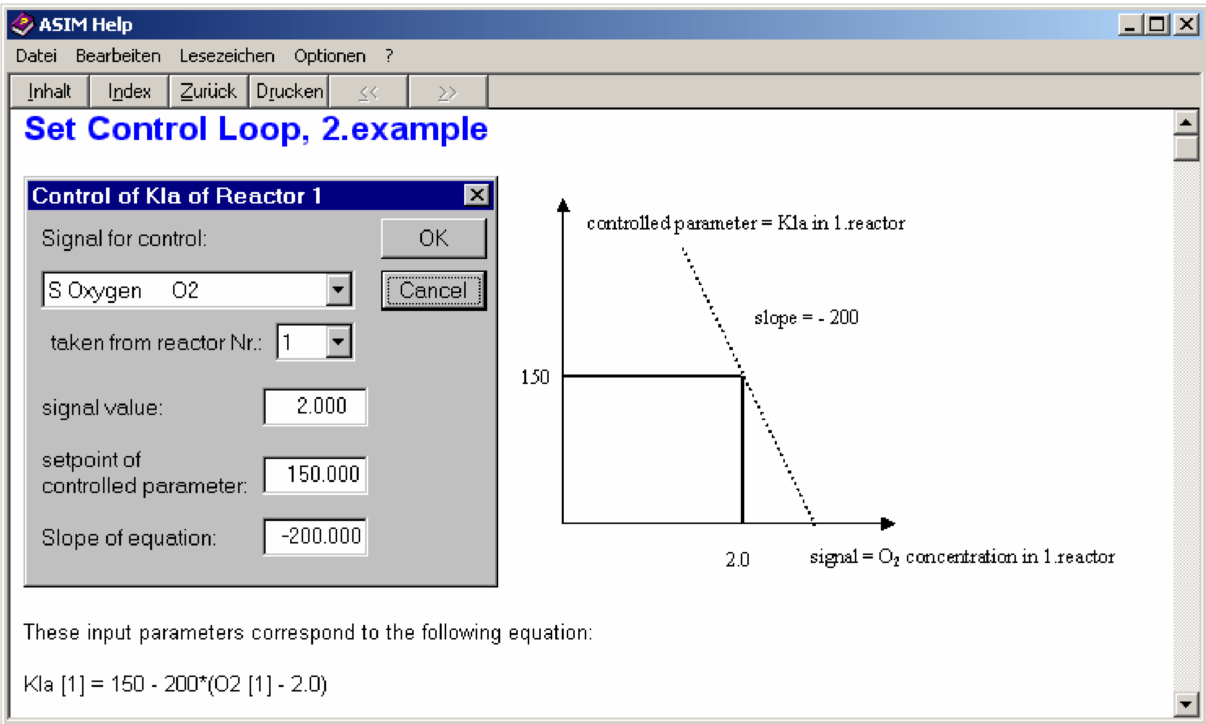
2) Fixed O2 value in reactor 2 (e.g. 1 mg/l)

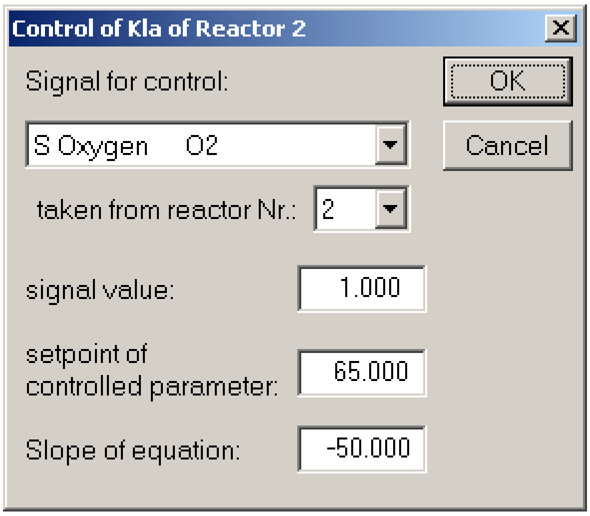
$$kLa(2) = 50 - 50 \cdot (SO2(2) - 1.0)$$

a) Activate the Kla controllers for reactor 2.

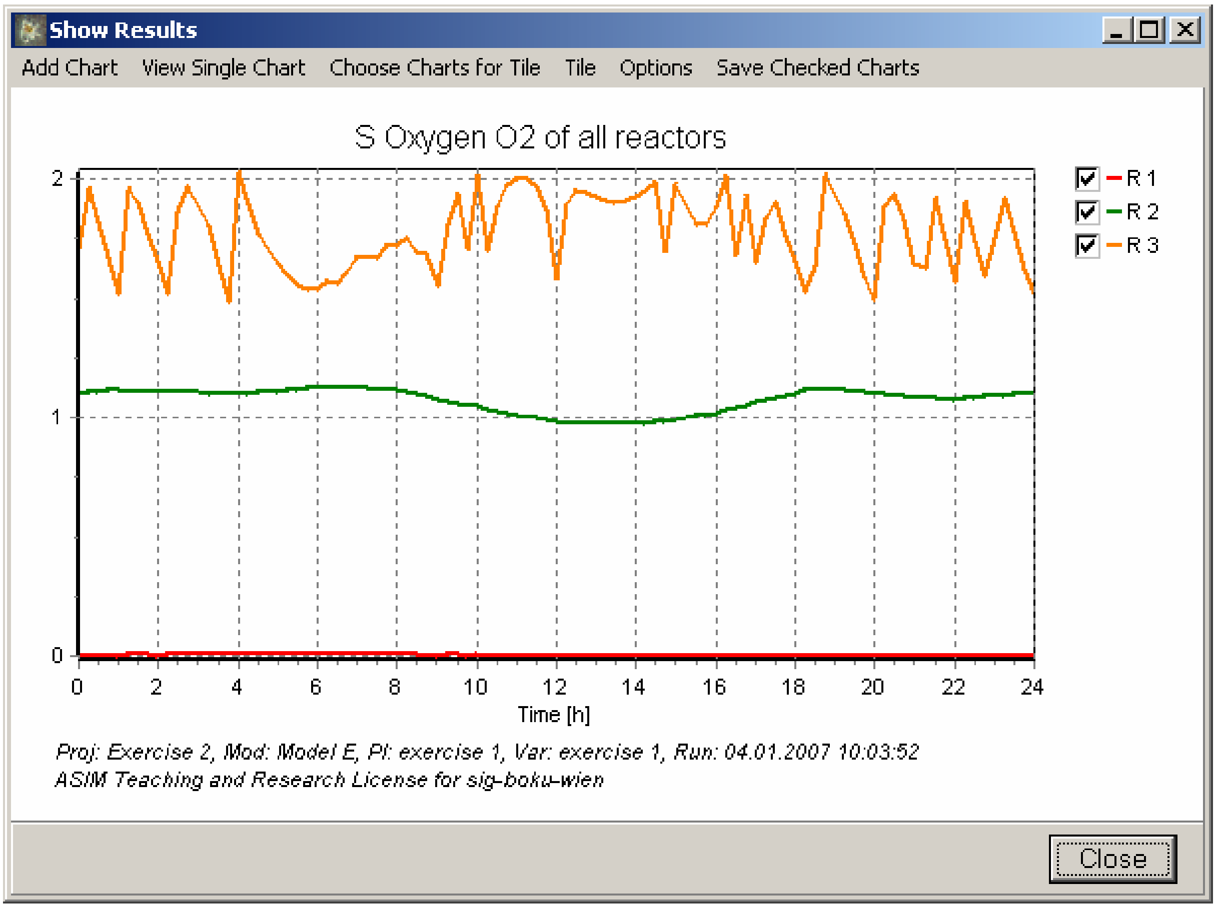
b) Set control parameters for "Equation"







c) Run a dynamic simulation view results



3) Control of O2 in reactor 2 as a function of the NO3-N and/or NH4-N effluent concentration

4) Control of the return sludge (internal recirculation) as a function of the influent flow

5) Control of internal recirculation such that NO3-N at the end of the anoxic zone is maintained at 1.5 mg/l (Aeration minimised while achieving near complete nitrification)

Exercise 3:
Introduction to plant model calibration

This exercise is based on an example prepared by Leiv Rieger and Imre Tacáks for the Course on "Modelling Activated Sludge Plants", 7-9 September 2006, Beijing, PR China, organised by the IWA Task Group on "Good Modelling Practice"

Goal of the exercises

The following exercises should give an insight into the procedure of plant model selections and model calibration. It will be shown that the system calibration has a major influence on the results and that most often a sufficient calibration can be done without changing bio-kinetic parameters.

WWTP description

The wastewater treatment plant Btown is located in Western Europe and is designed for 50’000 population equivalents (PE). The biological stage consists of two non-aerated and one bigger aerated reactor. Figure 1 shows the plant layout and Table 1 gives the required information.

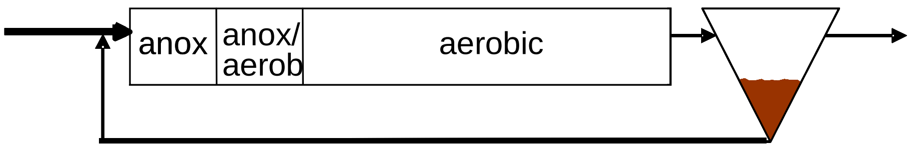


Figure 1: Flow scheme of Btown wastewater treatment plant

The plant is connected to a small river and therefore should reduce the ammonia concentration as well as the total nitrogen discharge. In addition a comparison with other plants revealed that the energy consumption is rather high. A detailed modelling study should evaluate possibilities to improve the plant efficiency and reduce the energy consumption.

Model calibration

In this exercise a plant model shall be calibrated using the IWA **A**ctivated **S**ludge **M**odel No.1 (ASM1). A typical procedure is shown in the following list:

1. Calibration of the hydraulic behaviour of the plant
2. Influent characterization
3. Sludge production: The sludge production can be calibrated for the measured COD concentrations by changing the percentage of the inert particulate organic matter (X_I) in the influent. TSS is not a state variable in ASM1 and therefore has to be calculated outside the model. This can be done by using measured ratios in the activated sludge tanks (e.g. TSS/COD or VSS/COD and TSS/VSS).
4. Nitrification: Major influence on modelling of the nitrification has the aeration system. A calibration of the biokinetic model should be done only if all measurements and the plant model are checked.

5. Denitrification: Also in this step the modelling of the DO input is of greatest importance. In addition it should be checked if a significant denitrification in the sludge blanket in the secondary clarifier takes place.
6. *For WWTPs with enhanced biological phosphorus removal the calibration of the phosphorus removal is the last step of the procedure* (not relevant for this exercise!).

It should be kept in mind that this is not a straight forward approach but an iterative procedure.

Procedure

The following example is simplified. Only values for one day are given whereas for a real study more data will be necessary. What is required depends on the objectives of the study. As a rule of thumb data of one sludge age is often used for a typical calibration procedure. A data set from differing operational or environmental conditions is necessary for a validation.

Moreover, plant model calibration is an iterative procedure. In the presented example you shall resolve the exercises step by step. Only the interim results are required and not the overall performance of the plant. If you have problems with one exercise you can proceed with the next step without loosing data.

Exercise 3A) Calibration of Plant Hydraulics

Objective

To calibrate the hydraulic behaviour of the plant set-up by determining the number of reactors for a given plant configuration

Introduction

Setting up a plant configuration, and specifically determining the number of tanks in series used to represent the plug-flow behaviour of an actual tank is the first step before process simulations can be performed.

One method to estimate the number of tanks is based on a tracer experiment. A given amount of tracer material is added suddenly at the head of the tank, and a washout curve (concentration leaving the tank) is measured over time.

This experiment was performed for the example plant and the data is available. Your objective is to determine the number of tanks that need to be used for properly describing the tracer experiment and the hydraulics of the plant.

During the experiment 160 kg sodium-bromide (NaBr) was added to the return activated sludge (RAS) stream and samples were taken every 30 min at three different locations.

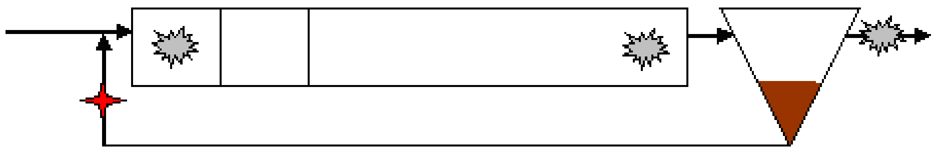


Figure 2: Layout of tracer experiment. Dosage in RAS and sampling at three points in the activated sludge tank and the effluent of the secondary clarifier

Exercise: Simulate tracer experiment

Try to model the plant such that a good agreement between measured and modelled tracer concentrations is achieved. An initial model setup (**Exercise 3a Tracer**) is provided. This contains the tracer time series results, the influent flow variation during the day, and the tracer dosage (as initial tracer concentration in tank #1).

Steps

a) Open ASIM and choose Open an existing Project. Click OK.

b) Load the project **Exercise 3a Tracer**

- the process model file **tracer.mod**,
- the plant configuration file **Exercise 3 tracer1 start.pln** and
- the influent flow variation file **tracer.vrt**.

Click OK. This will load all required file components:

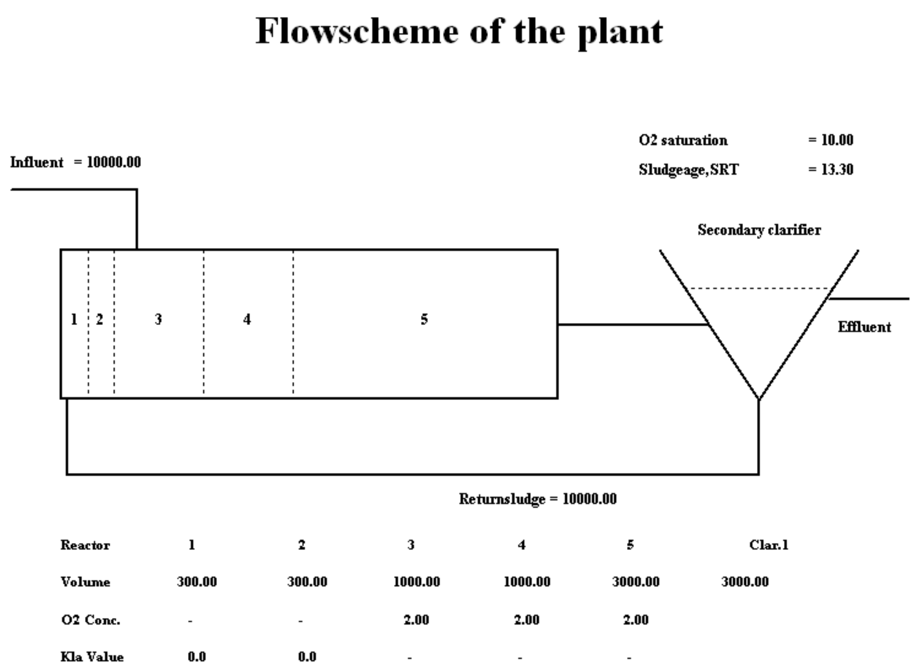
This model is set up with three (3) activated sludge tanks, the actual number of tanks at the plant. However the 3rd tank is much larger than the 1st and 2nd, and it may have to be split into several "zones" later to properly describe the plant hydraulics.

Table 1 contains the required information for the specification of the plant. This is already entered in the **Exercise 3a Tracer** model.

Table 1: Bdorf WWTP plant data

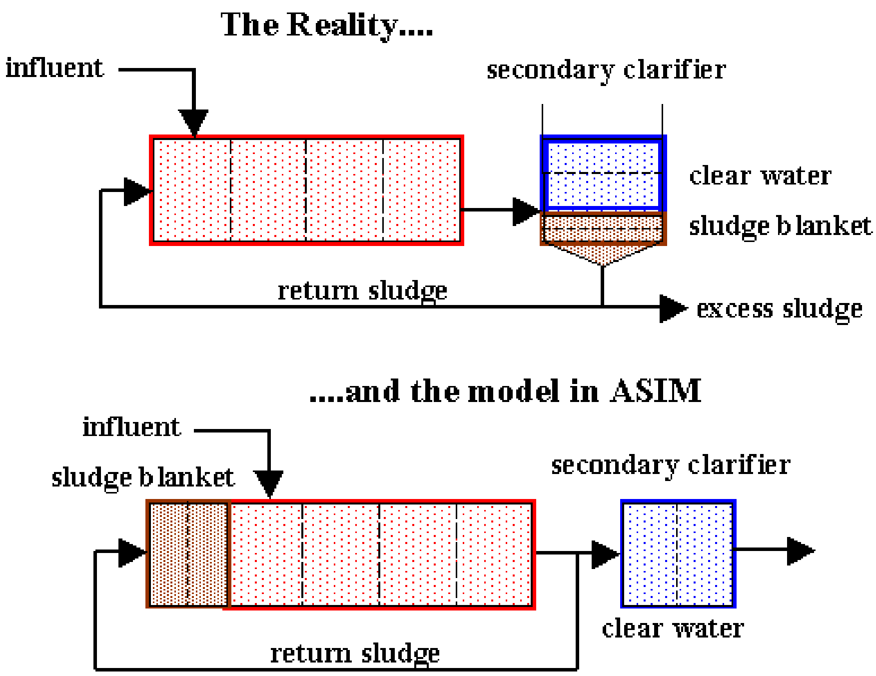
Parameter	**Unit**	**Value**	**Comments**
Average influent	m^3/d	10000	Mean influent flow during the tracer experiment
Return activated sludge	m^3/d	10000	RAS whole plant
Sludge retention time	d	13.3	Not relevant for tracer experiment
Temperature	°C	15	Not relevant for tracer experiment
Number of tanks		3	Number of tanks as per drawings
V1 and V2	m^3	1000	Volume of first two tanks (anoxic and swing)
V3	m^3	3000	Volume of aerated tank
Total volume	m^3	5000	Total volume of the AS tank
Secondary clarifier	m^3	3600	Total volume of secondary clarifiers (represented as one clarifier)
Digester supernatant flow	m^3/d	75	Digester supernatant as second influent
Tracer dose	kg	160	Tracer dose (as sodium-bromide)

c) You should see the following graphic



Modelling of the sludge blanket level in ASIM:

To model a secondary clarifier with a sludge blanket and a clear water zone you have to model the sludge blanket by inserting additional reactors in front of the existing reactors. The clear water zone is modeled by clarifier compartments. The graph below shows an example:



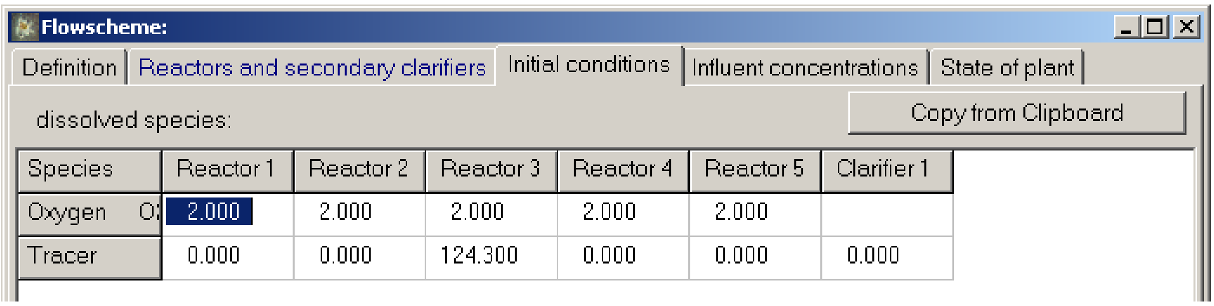
The dosage of the tracer can be modelled in two ways:

a) Dosing the tracer as a second influent, with proper flow variation (a flow spike for short time). For simplicity, this method **will not be** discussed in this example.

b) By calculating the concentration of the tracer in the first reactor directly after dosage, assuming that the tracer is completely mixed with the activated sludge and nothing has left the first reactor yet. The calculated concentration has to be set as initial value for the state variable of the tracer model. The required concentration can be calculated considering:

- **i.** 160 kg NaBR was added and only bromide is measured in the test.
- **ii.** Sodium has a molar weight of 23 g/mol, while that of Bromine is 80 g/mol. The added bromide is 80 / (80+23) = 77.7% of the NaBr salt or 124.3 kg.
- **iii.** In the model the dosage will be given as an initial concentration in the first reactor: 124.3 kg/1000 m^3 reactor volume or **124.3 g/m^3**.

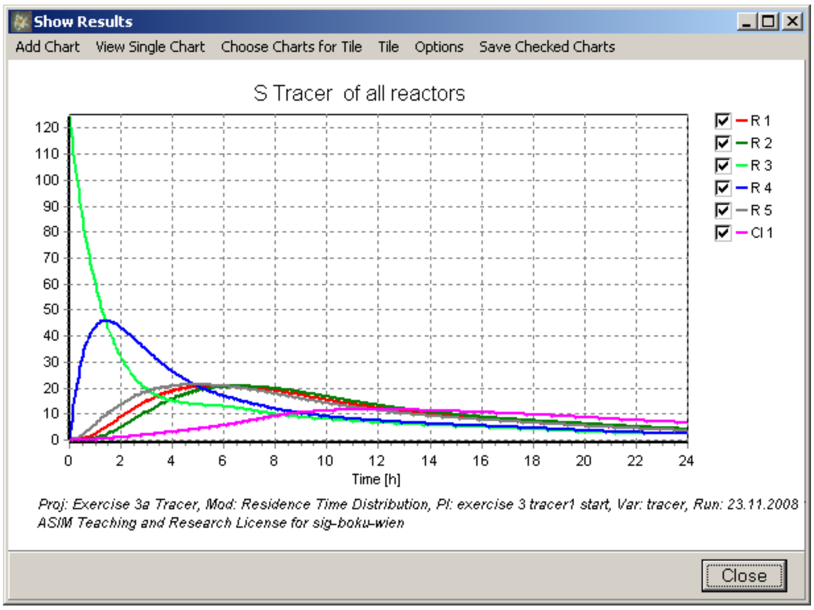
d) Set dosage using method b). Select `Plant Definition` ▶ `Initial Conditions` and enter 124.3 into the first tank initial concentrations for tracer. The oxygen has no influence in the tracer model. Click `Close` on the bottom right hand corner.



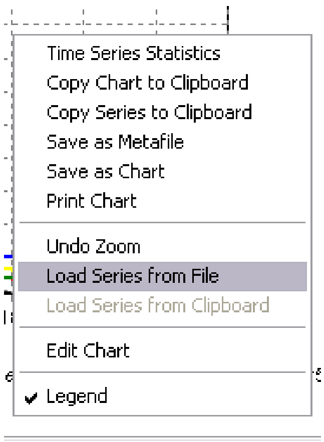
e) Now, all is prepared for the first simulation. Run a dynamic simulation over one cycle (24 hours). Select `Computations` ▶ `Dynamic simulation` or CTRL-D. Press `Start`.

When your simulation is finished you have to look at the results.

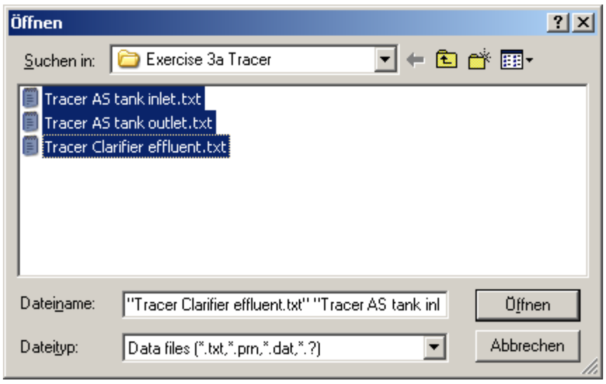
f) Display model results by selecting `View Single Chart` ▶ `Dissolved Species` ▶ `S Tracer of all reactors`.



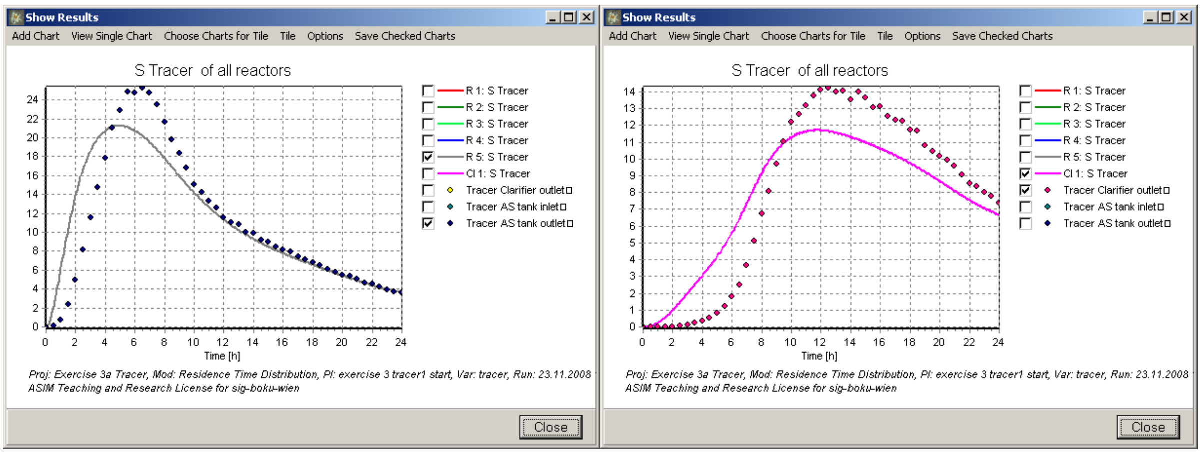
g) To be able to compare measured and values you have to load the measured concentrations into the chart. Click on the chart using the right mouse button and select „`Load Series from File`“ from the menu.



h) Load all three measured datasets (Reactor inlet tracer.txt, Reactor outlet tracer.txt, Effluent tracer.txt). Highlight all and select `Open`.



i) It is worthwhile to maximize the chart to full page and compare one set of measurement with the relevant model signal at the same time. Curves can be deselected by simply clicking on the box in front of the name. For example, looking at the clarifier effluent your graph should look similar to this:



Simulation results are shown with continuous lines, and data is represented by symbols.

Two conclusions can be drawn from the graph:

1. The peak concentration arrives around the same time in the model as measured in the clarifier effluent. This means that the influent flow and the total plant volume (5000 m^3 reactor + 3600 m^3 clarifier) is correctly represented in the model.
2. In reality the tracer peak is sharper than the modelled signal. This means that the plant hydraulics in reality is more plug-flow like (more tanks in series) than in the model.

Question

Your objective is to find the flow scheme which is most suited to model the measured data. You can change the scheme by introducing additional reactors, and by representing the clarifier in more detail (several zones). The total volume of the plant should always stay 5000 m^3 for the reactors and 3600 m^3 for the clarifier.

When running a new dynamic simulation you have to check the initial tracer concentration

a) 124.3 g/m^3 tracer in the first reactor only,

b) all other tracer concentrations have to be zero!

Exercise 3B) Influent characterization

Objective

To define or calculate all the required input (state) variables for ASM1.

Introduction

The ASM1 has 13 components or state variables. The organic matter is differentiated into six COD fractions (see Figure 3). Nitrogen is differentiated into ammonia and nitrate and the organic nitrogen fractions S_{ND} and X_{ND} (see Figure 4). The remaining two fractions are dissolved oxygen (S_O) and alkalinity (S_{ALK}).

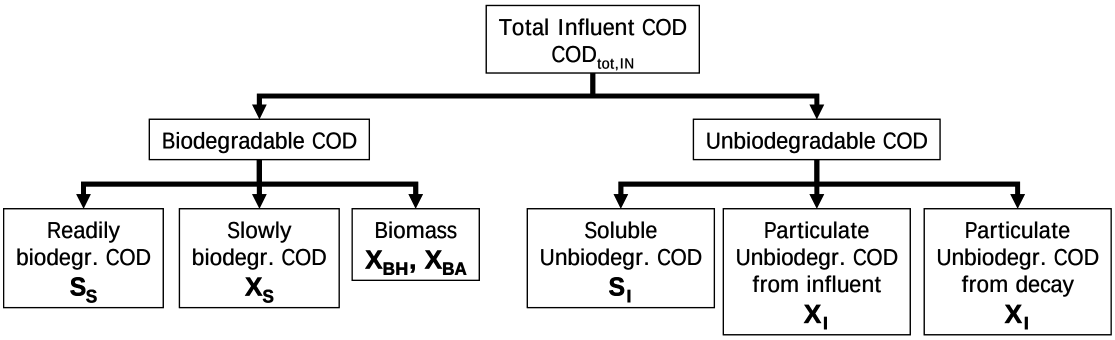


Figure 3: COD fractionation for ASM1

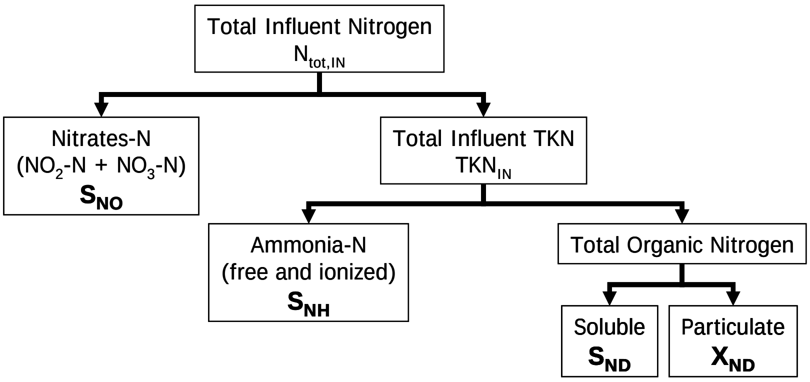


Figure 4: Nitrogen fractionation for ASM1

Not all state variables can be measured directly. In the next paragraph some information are given to define or calculate the state variables. Variables marked with green are easy to measure; yellow variables require some assumptions but have normally only a minor effect on the simulation results. Red variables have a significant influence on the model results and are difficult to measure.

Steps to calculate state variables as model input:

1. Measured S_I (as S_{COD} in the effluent) and NH_3 can be used directly (**green**)
2. S_{ALK} is measured (check if conversion is required. Model input is in mmol) (**green**)
3. O_2, NO_3, X_{BA}, X_P are assumed to be zero (**green**)
4. X_{BH} is assumed to be 5% of COD since it does not have a large effect on the modelling results. Some models run with zero % (**yellow**)
5. The sum of S_{ND} and X_{ND} is TKN minus NH_3. Split SND : XND 50-50, since X_{ND} will hydrolyze to S_{ND} during treatment (**yellow**)
6. S_S is S_{COD} minus S_I but colloids have to be taken into account. Colloids are slowly degradable COD (-30%) (**yellow**)

7. The remaining variables are X_I and X_S. Three methods are often used:
   A) Fit the measured BOD_5 values
   B) Fit O_2 and sludge production
   C) Run SBR experiment to measure X_I.
   For this exercise assume typical 13% X_I (red)
8. To guarantee that the measured COD_{tot} equals the sum of all COD components, X_S should be calculated as COD_{tot} minus the sum of all established COD components (**red**)
9. Checking model predicted combined variables

Exercise 3B.1: Calculation of state variables and basic run

In this exercise all the state variables for model input have to be defined. Please calculate the missing cells by using the provided EXCEL sheet ***Exercise-3.xls***.

Measured values and calculated ratios

Measured values

	Symbol	Value
COD_{tot}	C_{COD}	**495.0**
Particulate COD	X_{COD}	**350.0**
Filtered COD	S_{COD}	**145.0**
Effluent filtered COD	S_I	**25.0**
TKN	TKN	**40.0**
NH_3-N	S_{NH}	**30.0**
VSS	VSS	**218.8**
TSS	TSS	**254.4**
BOD_5	BOD	**271.4**
Alkalinity	S_{ALK}	**220.0**

Calculated fractions (for data quality check)

	Symbol	Value	Comment	typical
Filtered COD fraction	S_{COD}/C_{COD}			0.4
Ammonia fraction	NH_3/TKN			0.6-0.8
COD/VSS ratio	X_{COD}/VSS			1.5-1.8
VSS/TSS ratio	VSS/TSS			0.8-0.9
COD/BOD ratio	C_{COD}/BOD			2.0-2.5

Resulting states

Soluble Species	Symbol	Value
Oxygen O_2	S_O	
Inert COD	S_I	
Substrate COD	S_S	
Ammonium N	S_{NH}	
Nitrate N	S_{NO}	
Organic Nitrogen	S_{ND}	
Alkalinity mmol	S_{ALK}	

Particulate Species	Symbol	Value
Inert COD	X_I	
Substrate COD	X_S	
Het Biomass COD	X_{BH}	
Aut Biomass COD	X_{BA}	
Part XP COD	X_P	
Organic Nitrogen	X_{ND}	

Checking model predicted combined variables

	Symbol	Model	Measured	
Biodegradable COD	BCOD			All biodegradable COD
Carbonaceous BOD5	BOD		271.4	Approx. 2/3rd of BCOD
VSS	VSS		218.8	All particulate COD divided by COD/VSS ratio.
TSS	TSS		254.4	VSS divided by VSS/TSS ratio.
COD_{tot}	C_{COD}		495.0	All COD states.

Basic run

The next step is to run a simulation and check the model output. Please note that an additional internal recycle is introduced for this example. In the following exercise we will concentrate on the influence of the influent characterization on denitrification (NO_3) and the sludge production (TSS concentration). To do this, please follow the steps given below:

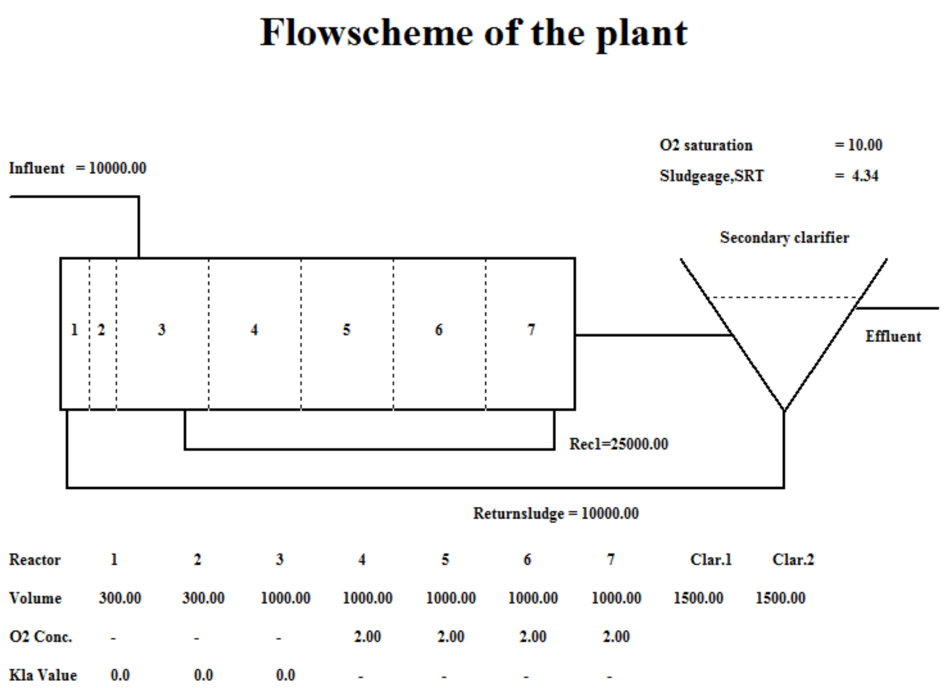
Steps

a) Choose **Load Project** from the **File** menu.

b) Load the project **Exercise 3b Influent**

- the process model file **asm1_orig.mod**,
- the plant configuration file **Exercise 3 influent1 start.pln** and
- the influent flow variation file **Exercise 3 influent.vrt**.

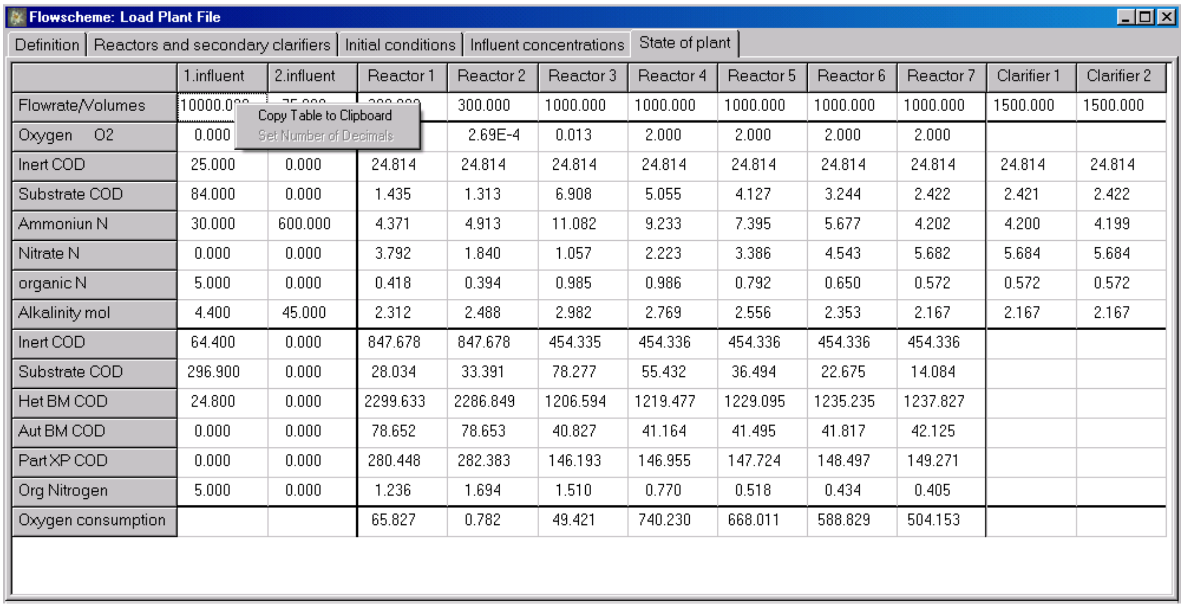
Click OK. This will load all required file components:



In these files the influent and the reactor configuration is already prepared. The influent characterization is according to the first exercise. TSS consists of organic material (particulate COD in ASM1: X_I, X_S, X_H, X_A, X_P) and particulate inorganic compounds (has to be calculated outside Asim). For the sludge production a static calculation is sufficient. Run integration over 40d.

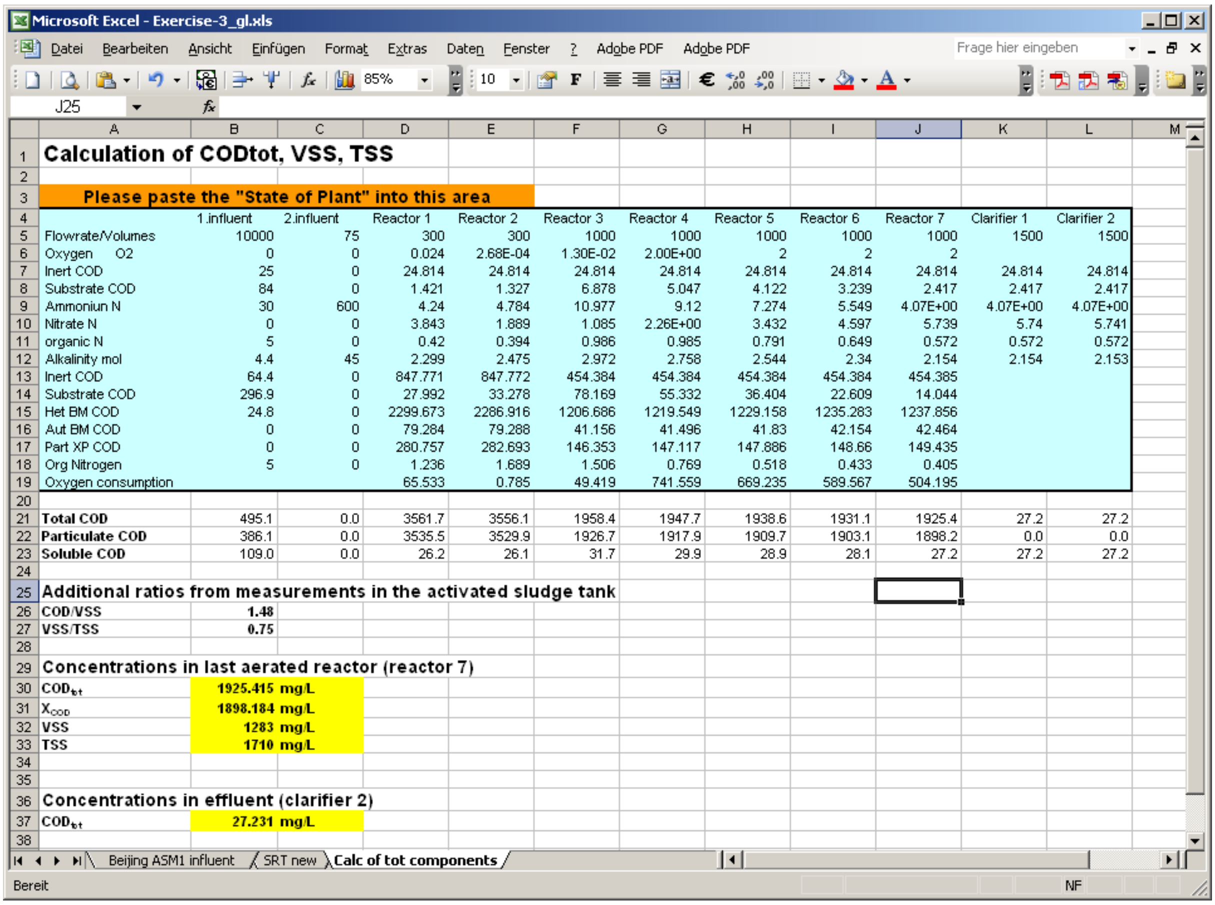
c) To facilitate the evaluation of the model results we have prepared an EXCEL sheet **Exercise3.xls.** Please open the sheet and go to the sheet **Calc of tot components**.

In ASIM you can check the results by going to the State of plant sheet (`Plant Definition` ➔ `Show State of Plant`). If you click with the right mouse button in this window you can copy the whole table to the clipboard (`Copy Table to Clipboard`).



	1.influent	2.influent	Reactor 1	Reactor 2	Reactor 3	Reactor 4	Reactor 5	Reactor 6	Reactor 7	Clarifier 1	Clarifier 2
Flowrate/Volumes	10000.0[illegible]	[illegible]	[illegible]	300.000	1000.000	1000.000	1000.000	1000.000	1000.000	1500.000	1500.000
Oxygen O2	0.000	[illegible]	[illegible]	2.69E-4	0.013	2.000	2.000	2.000	2.000		
Inert COD	25.000	0.000	24.814	24.814	24.814	24.814	24.814	24.814	24.814	24.814	24.814
Substrate COD	84.000	0.000	1.435	1.313	6.908	5.055	4.127	3.244	2.422	2.421	2.422
Ammonium N	30.000	600.000	4.371	4.913	11.082	9.233	7.395	5.677	4.202	4.200	4.199
Nitrate N	0.000	0.000	3.792	1.840	1.057	2.223	3.386	4.543	5.682	5.684	5.684
organic N	5.000	0.000	0.418	0.394	0.985	0.986	0.792	0.650	0.572	0.572	0.572
Alkalinity mol	4.400	45.000	2.312	2.488	2.982	2.769	2.556	2.353	2.167	2.167	2.167
Inert COD	64.400	0.000	847.678	847.678	454.335	454.336	454.336	454.336	454.336		
Substrate COD	296.900	0.000	28.034	33.391	78.277	55.432	36.494	22.675	14.084		
Het BM COD	24.800	0.000	2299.633	2286.849	1206.594	1219.477	1229.095	1235.235	1237.827		
Aut BM COD	0.000	0.000	78.652	78.653	40.827	41.164	41.495	41.817	42.125		
Part XP COD	0.000	0.000	280.448	282.383	146.193	146.955	147.724	148.497	149.271		
Org Nitrogen	5.000	0.000	1.236	1.694	1.510	0.770	0.518	0.434	0.405		
Oxygen consumption			65.827	0.782	49.421	740.230	668.011	588.829	504.153		

After copying go to the EXCEL sheet and paste it in the given area (marked in light blue).



Calculation of CODtot, VSS, TSS

Please paste the "State of Plant" into this area

	1.influent	2.influent	Reactor 1	Reactor 2	Reactor 3	Reactor 4	Reactor 5	Reactor 6	Reactor 7	Clarifier 1	Clarifier 2
Flowrate/Volumes	10000	75	300	300	1000	1000	1000	1000	1000	1500	1500
Oxygen O2	0	0	0.024	2.68E-04	1.30E-02	2.00E+00	2	2	2		
Inert COD	25	0	24.814	24.814	24.814	24.814	24.814	24.814	24.814	24.814	24.814
Substrate COD	84	0	1.421	1.327	6.878	5.047	4.122	3.239	2.417	2.417	2.417
Ammoniun N	30	600	4.24	4.784	10.977	9.12	7.274	5.549	4.07E+00	4.07E+00	4.07E+00
Nitrate N	0	0	3.843	1.889	1.085	2.26E+00	3.432	4.597	5.739	5.74	5.741
organic N	5	0	0.42	0.394	0.986	0.985	0.791	0.649	0.572	0.572	0.572
Alkalinity mol	4.4	45	2.299	2.475	2.972	2.758	2.544	2.34	2.154	2.154	2.153
Inert COD	64.4	0	847.771	847.772	454.384	454.384	454.384	454.384	454.385		
Substrate COD	296.9	0	27.992	33.278	78.169	55.332	36.404	22.609	14.044		
Het BM COD	24.8	0	2299.673	2286.916	1206.686	1219.549	1229.158	1235.283	1237.856		
Aut BM COD	0	0	79.284	79.288	41.156	41.496	41.83	42.154	42.464		
Part XP COD	0	0	280.757	282.693	146.353	147.117	147.886	148.66	149.435		
Org Nitrogen	5	0	1.236	1.689	1.506	0.769	0.518	0.433	0.405		
Oxygen consumption			65.533	0.785	49.419	741.559	669.235	589.567	504.195		
Total COD	495.1	0.0	3561.7	3556.1	1958.4	1947.7	1938.6	1931.1	1925.4	27.2	27.2
Particulate COD	386.1	0.0	3535.5	3529.9	1926.7	1917.9	1909.7	1903.1	1898.2	0.0	0.0
Soluble COD	109.0	0.0	26.2	26.1	31.7	29.9	28.9	28.1	27.2	27.2	27.2

Additional ratios from measurements in the activated sludge tank

COD/VSS	**1.48**
VSS/TSS	**0.75**

Concentrations in last aerated reactor (reactor 7)

COD_{tot}	**1925.415 mg/L**
X_{COD}	**1898.184 mg/L**
VSS	**1283 mg/L**
TSS	**1710 mg/L**

Concentrations in effluent (clarifier 2)

COD_{tot}	**27.231 mg/L**

Exercise 3B.2: Importance of X_I for sludge production and DO demand

Although some simulator packages calculate TSS, the ASM1 is based on COD mass balances and does not provide TSS calculations (in difference to ASM2d/ASM3). Therefore, the sludge production has to be calibrated for COD in a first and for TSS in a second step.

In the first step the sludge production can be calibrated to the measured COD concentrations by changing the percentage of the inert particulate organic matter (X_I) against the amount of slowly degradable substrate (X_S) in the influent.

Steps

Load the project **Exercise 3b Influent**

- the process model file **asm1_orig.mod**,
- the plant configuration file **Exercise 3 influent1 start.pln** and
- the influent flow variation file **Exercise 3 influent.vrt**.

Please go to `Plant Definition` ➔ `Edit Flow Scheme` ➔ `Influent concentrations` and vary the X_I against the X_S fraction (maintain total COD). After each change run the model (40d integration). The COD_{tot} values can be checked under `Plant Definition` ➔ `Show State of Plant`.

The sludge production is calibrated if you reach the measured COD_{tot} values of

2'300 g COD/m^3 at the **end of the biological stage**.

The COD concentrations calculated by ASIM can be seen in table „State of plant" (`Plant Definition` → `Show State of Plant` → `State of Plant`). To facilitate your work please use the EXCEL sheet (**Exercise-3.xls**) as given in the exercise above.

Exercise 3C) Nitrification/Denitrification (calibration of aeration system)

Objective

To calibrate the nitrification and denitrification processes.

Introduction

Main influence on the modelling of the nitrification as well as the denitrification process has the DO distribution within the plant model. The calibration will be done by changing the implementation of the aeration system.

Your task is to adapt the modelled aeration system to reach the measured ammonia concentrations at the end of the last activated sludge tank by changing DO set points, DO control loops and aeration settings.

Measurements:

The following measurements will be automatically loaded and displayed together with the model results.

- DO sensor in the middle of the last AS tank (reactor 6 in the finalized model)
- Additional measurements for DO during the measuring campaign at the front and rear end of the last aerated tank (reactors 5 and 7) and in the swing reactor (reactor 4).
- NH_4-N sensor at the end of the aerated reactor
- NO_3-N sensor in the anoxic tank and at the end of the aerated tank
- Lab measurements for NO_3-N in the return activated sludge available for the measuring campaign

Additional information:

- Only one DO controller is used for the whole plant with a DO set point of 2 g DO/m3. In the first set-up the assumption was that a DO concentration of 2 mg/l could be reached in all four aerated reactors.
- The DO sensor used for control is located in the middle of the aerated reactor (reactor 6 in the model) and the diffusers are equally distributed over the whole area.

Exercise 3C.1: Basic run

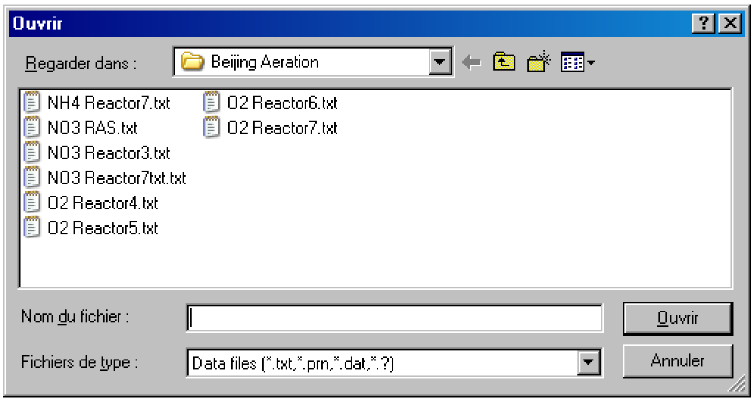
Steps

a) Load the project **Exercise 3c Aeration**
   - the process model file **asm1_orig.mod**,
   - the plant configuration file **Exercise 3 aeration1 start.pln** and
   - the influent flow variation file **Exercise 3 aeration.vrt**.

b) Run an integration over 40d: Select `Computations ► Integration` or CTRL-I. Press `Start`.

c) Run a dynamic simulation over 10 cycles: Select `Computations ► Dynamic Simulation` or CTRL-D. Press `Start`.

d) Check for the DO, NH_4 and NO_3 concentrations. The measured data can be loaded by right clicking on the “Show results” window. Press `Load Series from File` and select the required files:



e) Compare and discuss the modelled with the measured results.

Exercise 3C.2: Implementation of DO controller

In Asim only basic control can be done, for more information on how to control activated sludge plants see day three of the course.

The goal of this exercise is to show the impact of the aeration system implementation on nitrification and denitrification. Starting from 2 mg DO/L in each tank we will implement a DO controller which will better predict the real plant behaviour.

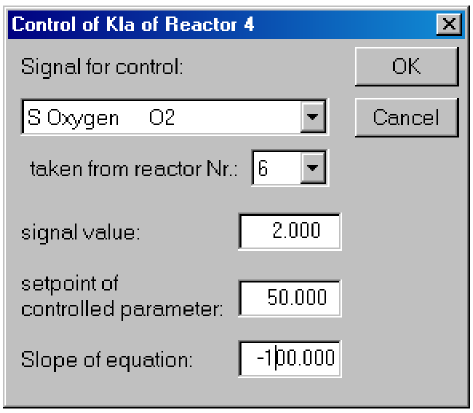
Steps

a) Load the project **Exercise 3 Aeration**

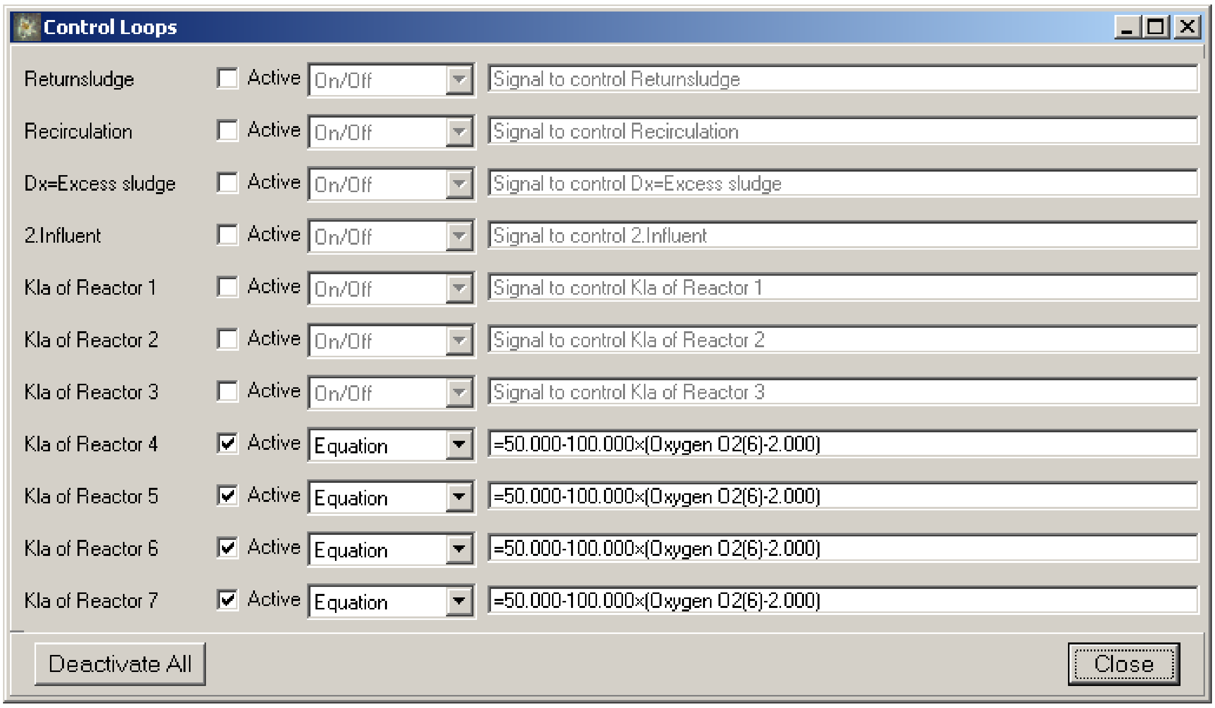
- the process model file **asm1_orig.mod**,
- the plant configuration file **Exercise 3 aeration1 start.pln** and
- the influent flow variation file **Exercise 3 aeration.vrt**.

b) To implement a DO controller go to `Plant Definition` ➔ `Control Loops` and activate the Kla controllers for reactors 4 – 7.

c) Click on the arrow of the pull-down menu and select `Equation`. Fill out the form according to the figure below. Repeat the procedure for each tank.



In the Asim help you can find additional information on the implemented proportional controller.



The result is a control loop which uses the DO concentration of reactor 6 and distributes the same amount of air into each aerated reactor.

d) Run an integration over 40d: Select `Computations` ► `Integration` or CTRL-I. Press `Start`.

e) Run a dynamic simulation over 10 cycles: Select `Computations` ► `Dynamic Simulation` or CTRL-D. Press `Start`.

f) After the calculations are finished press `Show Results`.

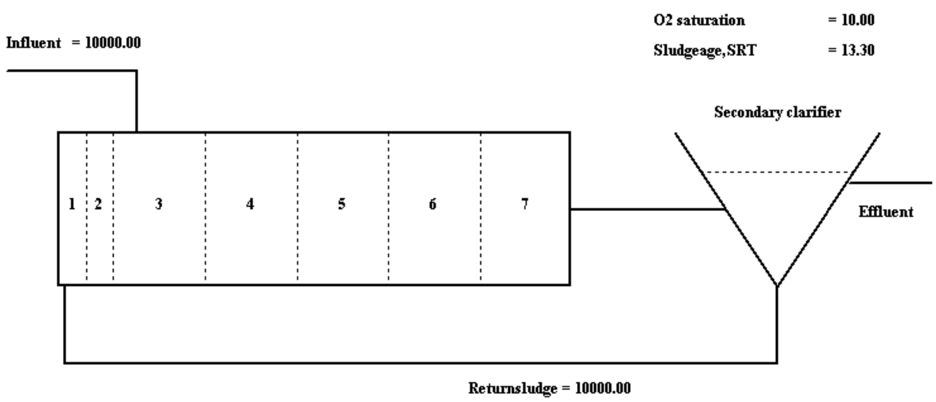
g) Check for the DO, NH_4 and NO_3 concentrations. The measured data can be loaded by right clicking on the “Show results” window. Press `Load Series from File` and select the required files:

h) Compare and discuss the modelled with the measured results.

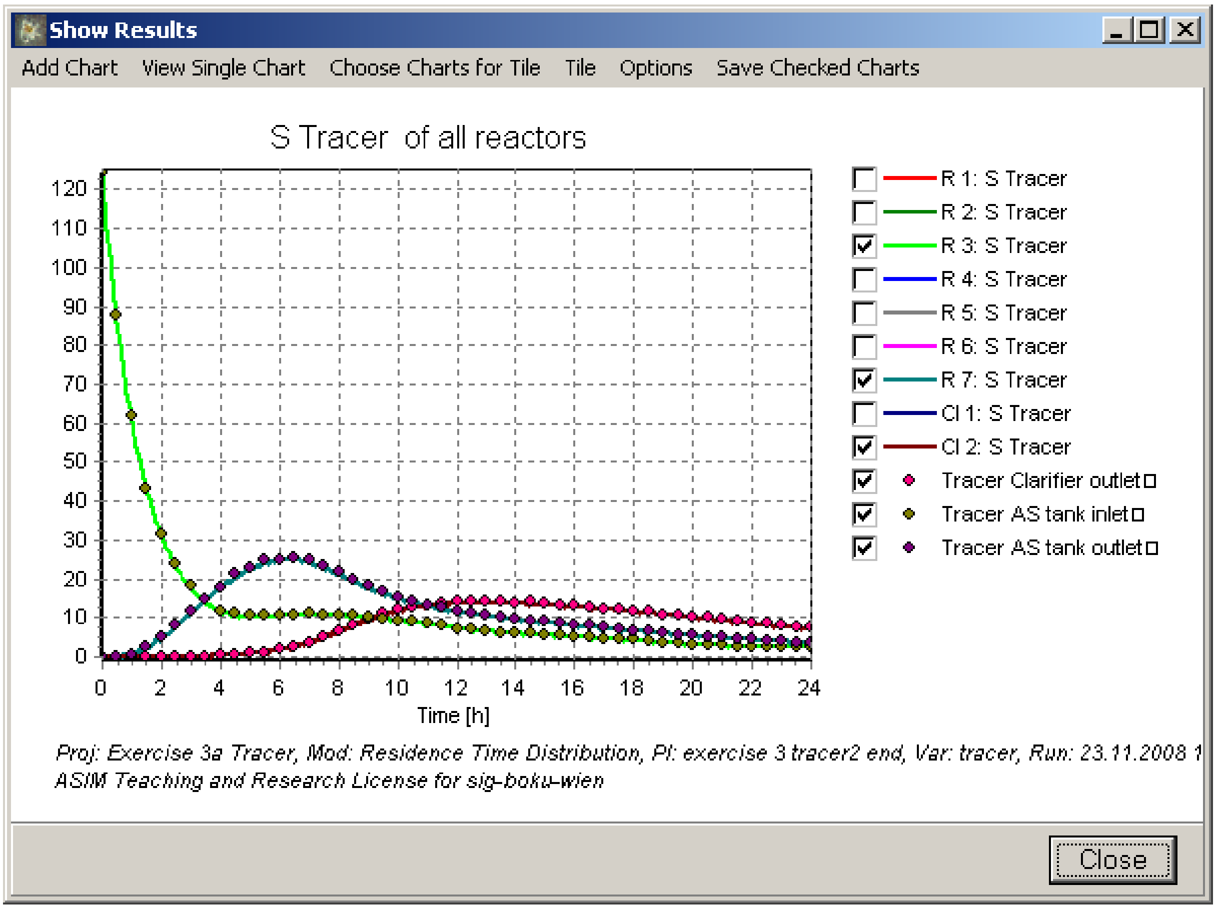
Solutions

Exercise 3A) Calibration of Plant Hydraulics

Flowscheme of the plant

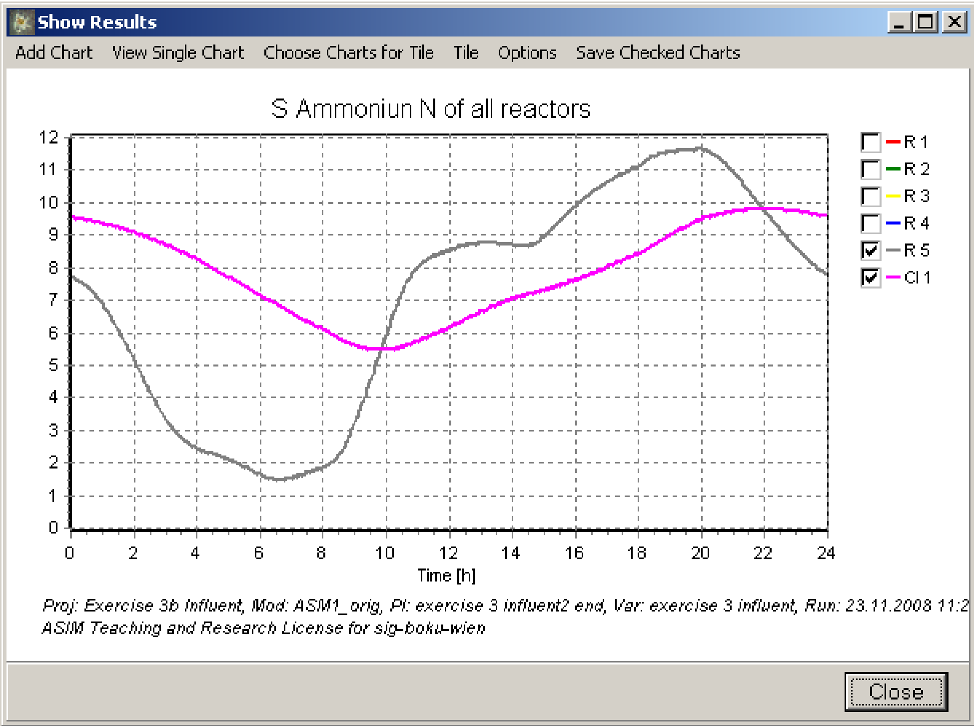


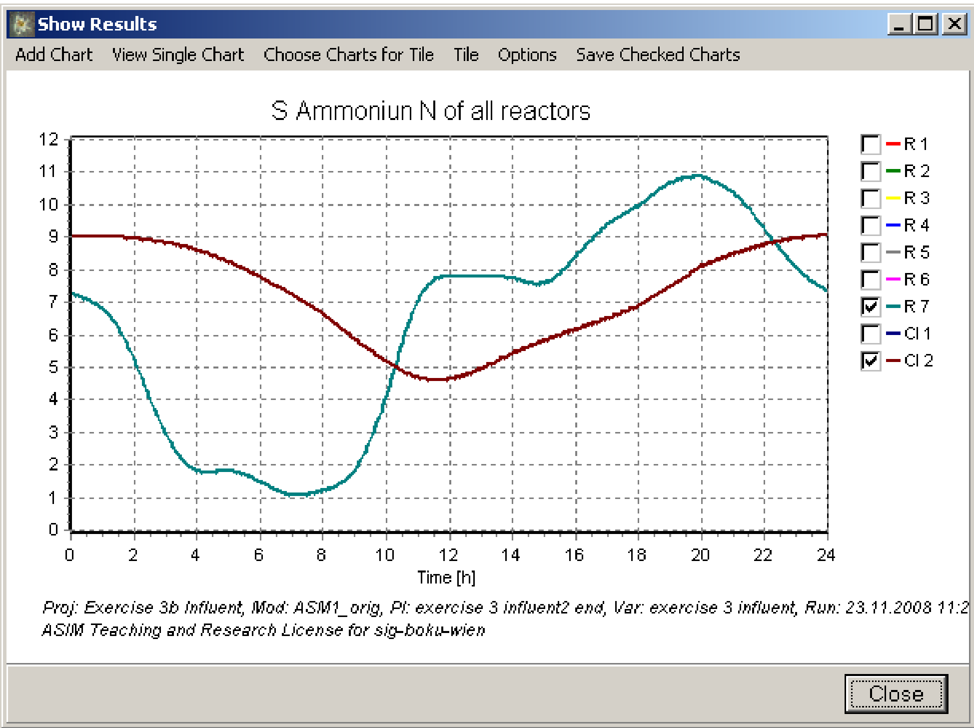
Reactor	1	2	3	4	5	6	7	Clar 1	Clar 2
Volume	300.00	300.00	1000.00	1000.00	1000.00	1000.00	1000.00	1500.00	1500.00
02 Conc.	-	-	2.00	2.00	2.00	2.00	2.00		
Kla Value	0.0	0.0	-	-	-	-	-		



S Ammonium N concentrations in the effluent of the reactor and clarifier, respectively (for 3 and 5 reactors for the AS tank)

	Last reactor	Effluent clarifier
3 reactors:	Mean value = 7.05 (max. 11.66)	Mean value = 7.86 (max. 9.80)
5 reactors:	Mean value = 6.28 (max. 10.89)	Mean value = 7.18 (max. 9.05)



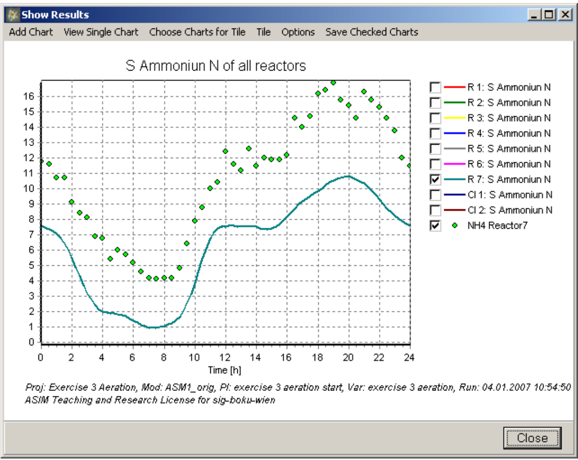


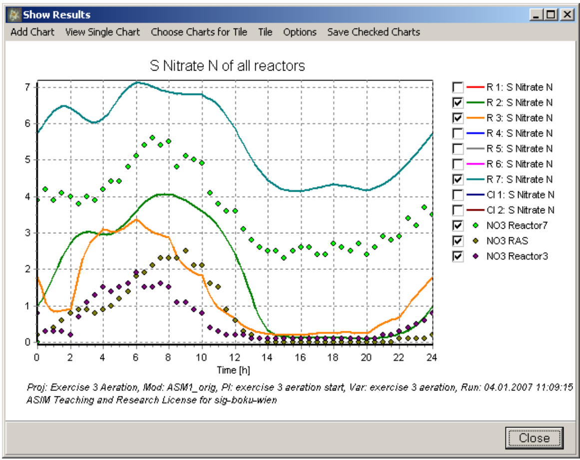
Exercise 3B) Influent characterization

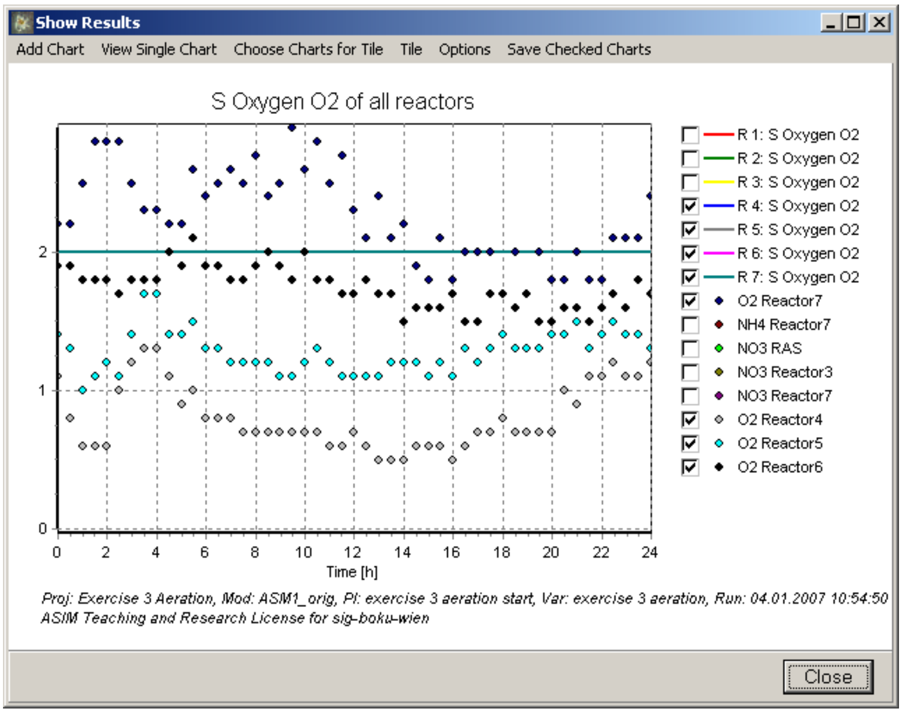
	start	end
XS (mg/L)	296.9	196.3
XI (mg/L)	64.4	165.0
XCOD Reactor 7 (mg/L)	**1'925**	**2'306**

Exercise 3C) Nitrification/Denitrification (calibration of aeration system)

3C.1: Basic run







3C.2: Implementation of the DO controller