Exercise to Lecture 1

1. In general, how do organic compounds differ from inorganic compounds?
2. How long will it take for 95% removal of BOD with an initial concentration of 280 mg/l if $k_1 = 0{,}4$?
3. The following values are known by measurement of a sanitary sewer:

Total COD (taken from homogenized sample)	620 mg/l
Total BOD (taken from homogenized sample)	370 mg/l
Soluble BOD (taken from filtrated sample)	185 mg/l
Total Suspended Solids	380 mg/l

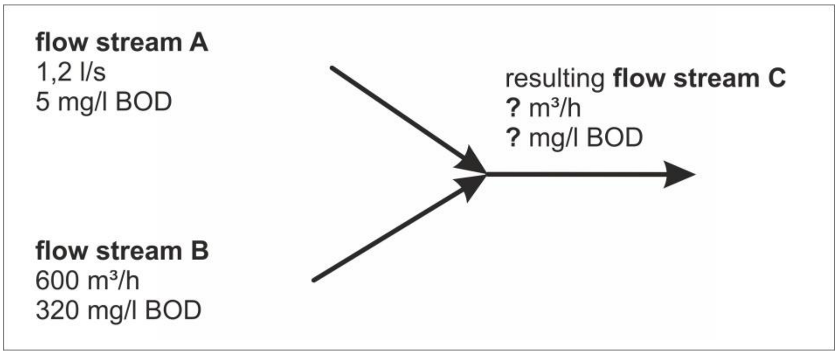
   How much are

   - Soluble COD,
   - Particulate non-degradable COD,
   - Particulate biodegradable COD,
   - Soluble non-degradable COD,
   - Non-volatile Suspended Solids
     and
   - Volatile Suspended Solids

   when particulate COD is 60% of Total COD and 1 g volatile solids is about 1,5 g COD?

4. Why soluble non-degradable BOD should be as small as possible in the influent of a WWTP with biological treatment steps?
5. How much is the volumetric flow rate when a cross-sectional area of 0,3 m² is passed by a flow with a velocity of 30 cm/s?
6. How much is the filtration velocity (= Hydraulic Loading Rate) when a filter with a cross-sectional area of 3,6 m² is charged by a volumetric flow rate of 500 m³/h?
7. How much is the load of a stream with a volumetric flow rate of 150 l/s and a BOD concentration of 120 ppm?
8. How long is the Hydraulic Retention Time of a stream with a volumetric flow rate of 1200 m³/h in a reactor with a volume of 3200 m³?

9. Calculate the volumetric flow rate and the BOD concentration of flow stream C according to the following sketch!



Exercise to Lecture 2

1. Calculate the theoretical COD of the substance isopropanol (C_3H_8O) in $\frac{mg}{l}$!
2. The following values are measured in a sanitary sewer before entering the WWTP:

Total Kjeldahl Nitrogen (taken from homogenized sample)	44 mg/l
Total Kjeldahl Nitrogen (taken from filtrated sample)	37 mg/l
Ammonia	32 mg/l
Nitrate	0 mg/l
Nitrite	0 mg/l

   How much are

   - Total Nitrogen (TN),
   - Total Organic Nitrogen (TON),
   - Total Inorganic Nitrogen (TIN),
   - Dissolved Organic Nitrogen (DON),
   - Particulate Organic Nitrogen (PON),
   - Total Nitrogen bounded (TNb),

   when gaseous nitrogen should be ignored?

3. The following values are measured in the effluent of the same WWTP from question 2:

Total Nitrogen bounded (taken from homogenized sample)	8,4 mg/l
Ammonia	2 mg/l
Nitrate	5 mg/l
Nitrite	0 mg/l

   How much are

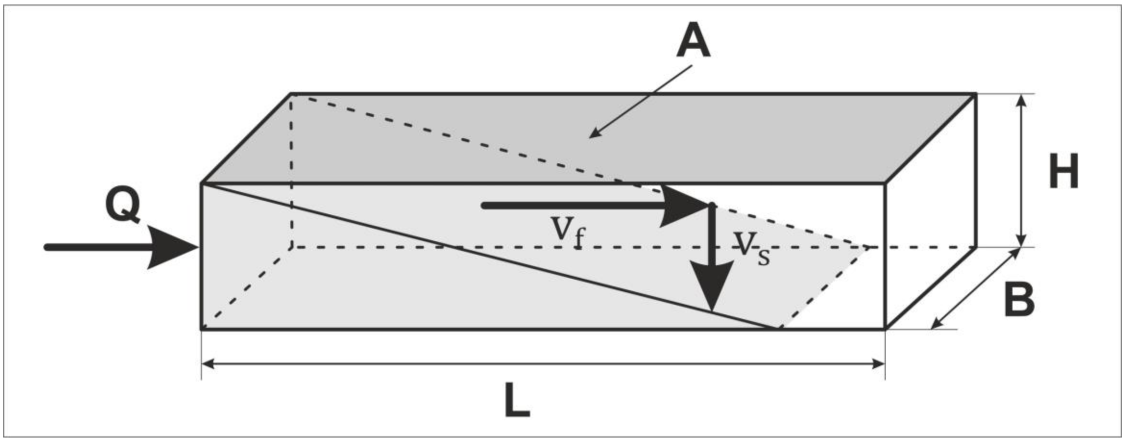
   - Total Nitrogen (TN),
   - Total Organic Nitrogen (TON),
   - Total Inorganic Nitrogen (TIN),

   when again gaseous nitrogen should be ignored?

4. How much is the removal of Nitrogen in percent in the WWTP of questions 2 and 3?
5. Why we normally find neither nitrates nor nitrites in the influent of a WWTP after the sewage passed a longer sewer network?
6. What is the foul-smelling gaseous substance that can be released from a sewer or sewage treatment plant if there is a lack of oxygen?

Exercise to Lecture 3

1. A primary sedimentation tank is planned as a rectangular one, a width B of 8.0 m, depth H of 3.0 m and a length L of 35.0 m. Maximum dry weather influent of the WWTP is 1700 m³/h. In case of stormy weather the combined sewer releases up to 5100 m³/h into the WWTP. Is the sedimentation tank big enough to properly treat these volumetric flow rates when the sedimentation velocity is 1.0 cm/s?



2. What should be the minimum length L of a rectangular sedimentation tank when sedimentation velocity is 1.0 cm/s, the maximum dry weather volumetric flow rate is 3200 m³/h and the width B of the tank is planned to be 5.0 m?
3. The following table represents the average concentration of influent and effluent of a sewage treatment plant:

Parameter	influent	effluent	elimination rate
COD	732 mg/l	51 mg/l	93,03%
BOD	409 mg/l	5 mg/l	98,78%
Total N	78 mg/l	9 mg/l	88,46%
NO_3-N	0 mg/l	8 mg/l	
TSS	322 mg/l	13 mg/l	95,96%

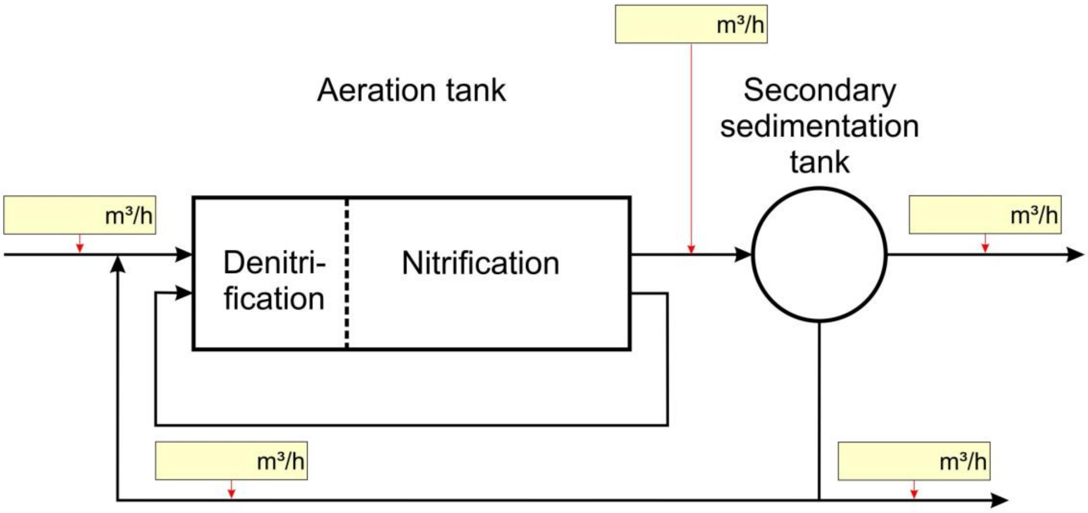
   Calculate the elimination rate in % for each of the parameters above!
   Why do nitrates occur in the outlet of the WWTP although no nitrates were in the influent?
4. How long is the hydraulic retention time of
   - maximum dry weather sewage flow of 52000 m³/d
   - and
   - maximum stormy weather sewage flow of 156000 m³/d

   in the primary sedimentation tanks of WWTP Stahnsdorf where the volume is 2500 m³?

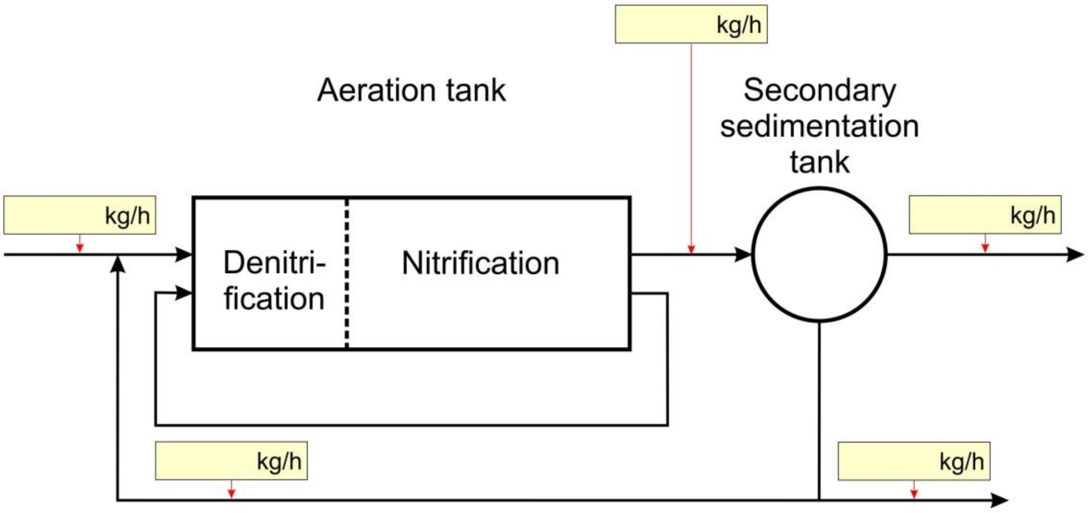
5. How much of the organic load and of the solids load can be removed in the mechanical step of a WWTP (as rule of thumb)?
6. What happens about the nitrogen and phosphorus in primary sedimentation?
7. Explain why the processes of artificial biological wastewater treatment are copies of the self-cleaning in natural rivers!
8. The organic pollutants in the inflow of a wastewater treatment plant are converted by biological metabolism and thus removed. Which substances are created in this process?

Exercise to Lecture 4

1. The following is known of the biological treatment of a WWTP:
   Q_{In} (Influent flow) = 2100 m³/h
   Q_{WAS} (Waste activated sludge) = 768 m³/d
   RR (RAS Recycle ratio) = 0.8
   Complete the flow balance sheet seen below!



2. In addition, there is known about the biological treatment of the sewage treatment plant from task 1:
   $MLSS$ (Mixed liquor suspended solids) = 3800 mg/l
   $X_{TS,In}$ (Influent suspended solids) = 240 mg/l
   $X_{TS,Out}$ (Effluent suspended solids) = 15 mg/l
   Complete the mass balance sheet seen below!



Exercise to Lecture 5

1. The following is known of the biological treatment of a WWTP:
   TS_{RAS} (Total Solids of recycle activated sludge) = 8.8 g/l
   RR (RAS Recycle ratio) = 1.2
   How much are expected the Mixed Liquor Suspended Solids $MLSS$ within the aeration tank?

2. For a sewage treatment plant have been calculated:
   $MLSS$ (Mixed liquor suspended solids) = 3800 mg/l
   $Total\ V_{AT}$ (Total volume of the aeration tank) = 2400 m³
   Q_{WAS} (WAS flow) = 32 m³/h
   TS_{RAS} (Concentration of Suspended Solids in RAS) = 7 g/l
   Calculate the Sludge Retention Time SRT_{AT}!

   Interpret the result, considering that the growth rate of the autotrophs at 12° C is about 0.36 per day!

Exercise to Lecture 6

In the design of sewage treatment plant with upstream denitrification the following was determined:

Q_d	Inlet flow to the aeration tank	= 60,000 m^3/d
$C_{COD,In}$	Inlet concentration of COD in the aeration tank	= 350 mg/l
$S_{COD,inert,Out}$	Inert soluble COD which leaves the secondary settlement tank	= 25 mg/l
$X_{COD,WAS}$	COD removed by WAS	= 90 mg/l
$S_{NO3,D}$	Concentration of nitrates which are to be denitrificated	= 40 mg/l
$S_{NO3,In}$	Influent concentration of nitrates	= 0 mg/l
$S_{NO3,Out}$	Effluent concentration of nitrates	= 12 mg/l
f_C	Impact factor of oxygen consumption for carbon elimination	= 1.2
f_N	Impact factor of oxygen consumption for nitrification	= 1.5
$T_{des.,high}$	Upper design temperature of the water in °C	= 19 °C
c_x	Set point of oxygen concentration in the aeration tank	= 2.0 mg/l
η	Average of oxygen uptake by microorganisms	= 35%
α	Quotient of the oxygen supply in activated sludge and in pure water	= 0.7

Calculate the required supply of air for the aeration of the nitrification step of the activated sludge tank $V_{Air,OC}$ in m^3/h! To determine $OD_{d,C}$ in kg O_2/d (daily oxygen demand for elimination of carbonaceous substances) use calculation via oxygen balance!

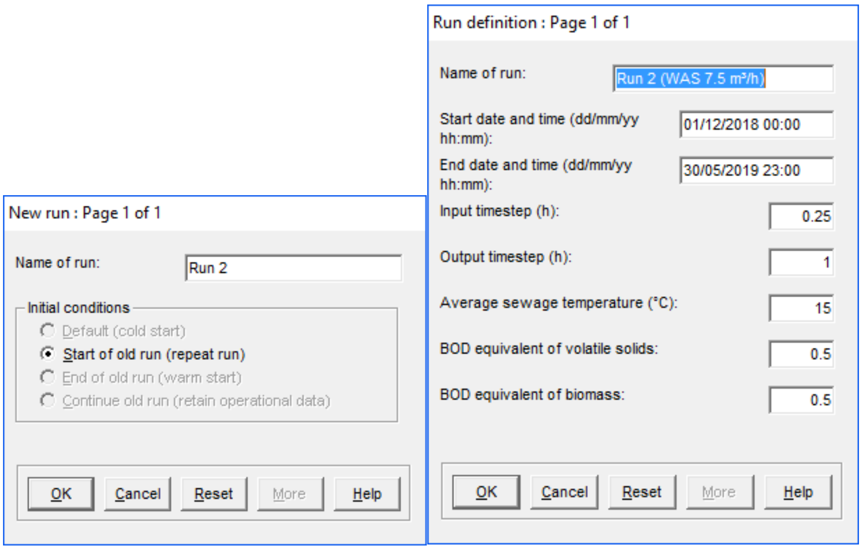
For the design of a WWTP the following was given or has been calculated:

Q_d	Inlet flow to the aeration tank	= 18,000 m^3/d
DR	Result of calculation of the internal recirculation ratio for denitrification	= 6
RR	RAS recycle ratio	= 1.5

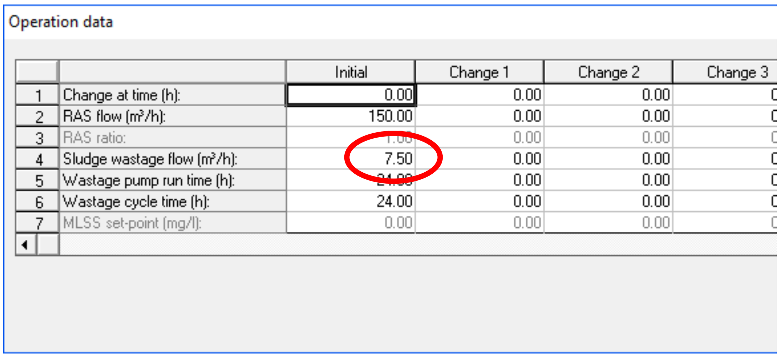
Calculate the flow of internal recirculation for denitrification Q_{IRD}!

Exercise to Lecture 7

1. Open STOAT and the model you built in the lecture.
   Commands: File → New run (Repeat run 1)

   Overwrite the run settings according to the above screenshot.
   Open the operation data of the secondary sedimentation tank (right mouse click on the SST bit, Input data → Operation). Change the excess sludge removal from 5 m³/h to 7.5 m³/h (increase of 50% compared to the previous run) according to the screenshot below:

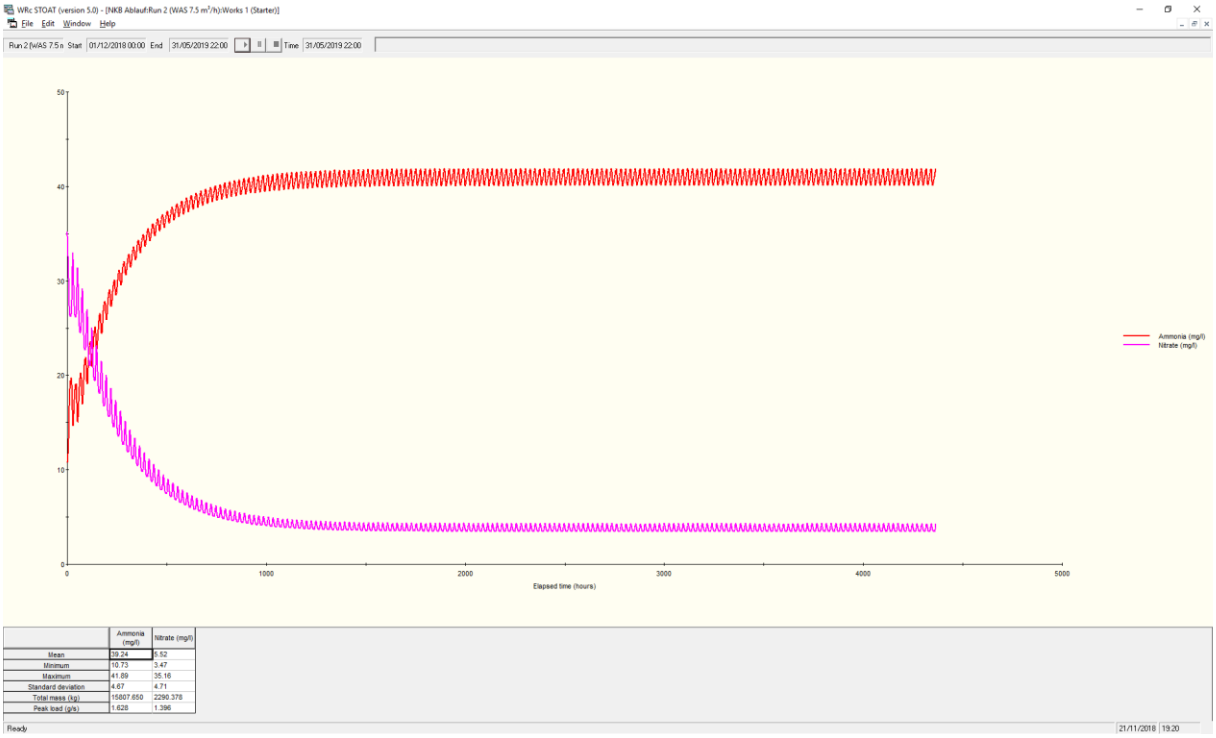
   

   Operation data

		Initial	Change 1	Change 2	Change 3
1	Change at time (h):	0.00	0.00	0.00	
2	RAS flow (m³/h):	150.00	0.00	0.00	
3	RAS ratio:	1.00	0.00	0.00	
4	Sludge wastage flow (m³/h):	7.50	0.00	0.00	
5	Wastage pump run time (h):	24.00	0.00	0.00	
6	Wastage cycle time (h):	24.00	0.00	0.00	
7	MLSS set-point (mg/l):	0.00	0.00	0.00	

   Click the "OK" button, leave all other settings as before and start the run.
2. Open the results, particularly for ammonia and nitrate. What happened compared to the very first run? Try to explain it!

Answer:



Now we see that ammonia goes high and nitrate goes down. That means a very bad nitrification. Why? We increased the waste activated sludge by 50%. Therefore the microorganisms within the system will be washed out. This applies first of all for the autotrophs because they have the longest generation time. The autotrophs are responsible for nitrification (= ammonia oxidation) and this cannot work properly when too little autotrophs are in the aeration tank.

Exercise to Lecture 8

1. Explain the function of a throttle upstream the inlet to a sewage plant which is connected to a combined wastewater system (in the STOAT model “WWTP Stahnsdorf #1” represented by the overflow!
2. Explain the particularities of Sankey diagrams compared to other graphical representations!
3. In case nitrification doesn’t work properly, which settings the operator of a WWTP should change?
4. When nitrification fails in a STOAT simulation, why it may be meaningful to change the calibration settings for autotrophs (assuming that the iron calibration rule is not violated)?
5. Why does better sedimentation in the secondary tank improve the effluent values of BOD and COD?
6. Wastewater treatment is the best water protection - why?
7. Describe in outline the solids balance of an activated sludge plant with upstream denitrification (ie ways, conversion and retention of solids)! Name all processes of wastewater treatment that have an influence on the solids (elimination or formation of solids)!
8. Why do wastewater treatment plants that operate on the principle of upstream denitrification require an internal recirculation? What does the feedback ratio for internal recirculation depend on?

The so called "iron rule" of calibration:

> Only change the growth rates and / or coefficients of the "Activated Sludge Models" if you are sure that deviations between model forecast and measured values are not due to faulty or incomplete inputs.
>
> Leave the settings in case of doubt with the default values!

Answer to #6:

Whether a body of water can fulfil all the purposes depends directly on the quality of the water, because almost all uses are linked to a good condition (drinking water supply, service water supply, drinking and irrigation water supply, fishing, recreation, etc.).

By fulfilling the legal requirements of wastewater treatment, the quality of the waters is preserved because the pollutants are eliminated before discharge into the water to tolerable residual contents. Thus, the self-cleaning power of the waters is secured at a high level, so that even in case of cases, reserves are still available. Thus, all uses can be realized without extensive pre-treatment (eg drinking water treatment does not have to be converted into a repair operation for wastewater treatment, but can be carried out using comparatively natural methods).

In addition, the removal of pollutants at the site of wastewater arising is always significantly more economical than the removal of pollutants from raw water, which was taken from contaminated water (because here are the pollutants due to repeated mixing and dilution always in much lower concentration).

Exercise to Lecture 9

1. **STOAT**:
   Open model "WWTP Stahnsdorf #1 (basic model)",
   Do the runs "**Run 2** (repeat run 1, calib. autotrophs)", "**Run 3** (repeat run 2, stormy weather)" and "**Run 4** (repeat run 3, calib. SST)"
   Compare the results of all 4 runs with this model!
2. **STOAT**:
   Explain the mode of action of the STOAT bit PLC (Programmable Logic Controller resp. Ladder Logic Controller) using the example of "PLC Precipitation of phosphate"!
3. For a new WWTP the water authority allowed discharge of 75 mg COD/l, 2 mg NH_4-N/l and 1 mg P/l. The average influent concentrations are expected to be 650 mg COD/l, 40 mg NH_4-N/l and 12 mg P/l. Buffers for security should be taken into account for properly operating the WWTP. These buffers are 30% for COD, 50% for NH_4-N and 25% for P. Which rates of elimination of COD, NH_4-N and P the design of the treatment steps should be based on?

Answers

Zu 3:

$$\eta = \frac{C_{influent} - C_{effluent}}{C_{influent}}$$

$$C_{design} = C_{effluent} * (1 - buffer\ for\ security)$$

$$\eta_{design} = \frac{C_{influent} - C_{design}}{C_{influent}} = \frac{C_{influent} - C_{effluent} * (1 - buffer\ for\ security)}{C_{influent}}$$

COD

$$\eta_{design,COD} = \frac{650 - 75 * (1 - 0.3)}{650} \approx 91.9\%$$

NH4-N

$$\eta_{design,NH4-N} = \frac{40 - 2 * (1 - 0.5)}{40} \approx 97.5\%$$

P

$$\eta_{design,P} = \frac{12 - 1 * (1 - 0.25)}{12} \approx 93.8\%$$