

Exercises II: organic micropollutant treatment I

Applied wastewater engineering

Exercise 1: Financing of new sewer pipe

Wastewater treatment plant (WWTP) A was designed (85th percentile) for 4'800 kg COD/d. It currently receives 3'000 kg COD/d (85th percentile) from inhabitants only.

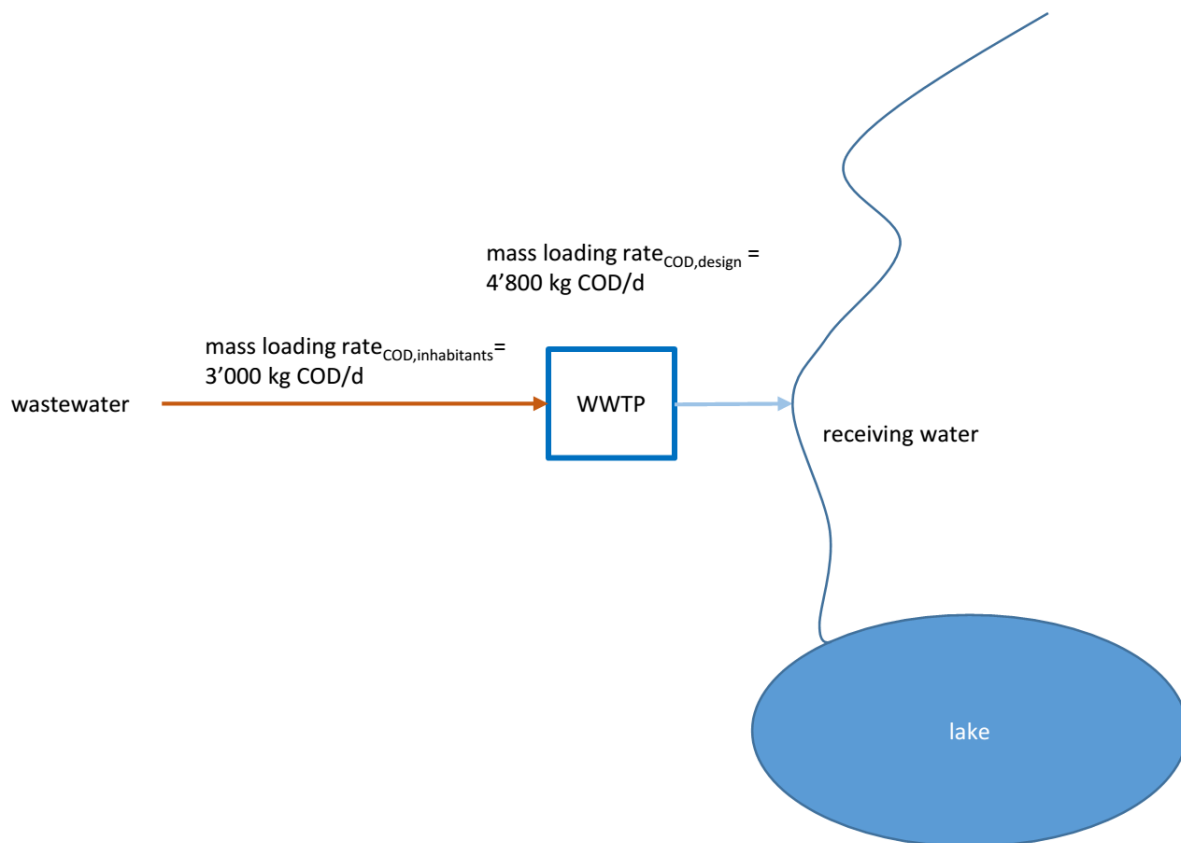


Figure 1: Scheme of exercise 1.

- a) For how many population equivalents was WWTP A designed for?

One population equivalent generates 120 g COD/d. Therefore, WWTP A has been designed for:

$$nPE = \frac{\text{mass loading rate}_{COD,design}}{PE_{COD}} = \frac{4'800 \text{ kg COD/d}}{120 \text{ g COD/PE}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = \mathbf{40'000 PE}$$

- b) The receiving water of WWTP A is a lake used for drinking water supply. Will WWTP A have to install an organic micropollutant treatment?

$$\begin{aligned} \text{inhabitants} &= \frac{\text{mass loading rate}_{COD,inhabitants}}{PE_{COD}} = \frac{\frac{3'000 \text{ kg COD}}{d}}{120 \text{ g COD/PE}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \\ &= \mathbf{25'000 inhabitants} \end{aligned}$$

Yes, WWTP A will have to install an organic micropollutant treatment. Wastewater treatment plants with more than 24'000 inhabitants upstream of a lake have to treat organic micropollutants.

- c) WWTP A could potentially be connected to a larger WWTP, which is equipped to treat organic micropollutants. How high are the maximum creditable costs for this new sewer pipe?

The creditable costs for the new sewer pipe are:

$$\begin{aligned} \text{creditable costs} &= 34'000 \times \sqrt{\text{size of WWTP(PE)}} = 34'000 \times \sqrt{40'000\text{PE}} \\ &= \mathbf{CHF\ 6.8\ million} \end{aligned}$$

- d) What is the maximal refund that the community of WWTP A can expect to receive from the Federal Office for the Environment (FOEN)?

The community of WWTP A can expect to receive at maximum 75 % of the creditable costs for the new sewer pipe from the FOEN.

$$\text{maximal refund} = 0.75 \times \text{creditable costs} = 0.75 \times 6.8 \text{ million} = \mathbf{CHF\ 5.1\ million}$$

Exercise 2: Presence of micropollutants

- a) Where do you expect to find the highest micropollutant concentrations of domestic origin: in Lake Geneva, certain small rivers of Canton de Vaud or in the Rhone River in Valais? Explain your answer.

I expect to find the highest micropollutant concentrations of domestic origin in certain rivers of Canton de Vaud. On slide 17 of the organic micropollutant removal lecture one can see many deep red coloured rivers in Canton de Vaud indicating that they contain a lot of (treated) wastewater. As the wastewater content in these river systems is high, the micropollutant concentrations can also be expected to be high as no micropollutant treatment has been installed so far in this region.

These rivers are relatively short and their catchment areas do not include glaciers, as it is the case for the Rhone River or Lake Geneva: their water flowrates depend on rain and their water levels decrease during dry periods (Q347: residual residence flow). Hence, the effluent of even small wastewater treatment plants may contribute strongly to the flowrate/organic micropollutant concentrations of such small rivers.

- b) During which periods of the year do you expect to find the highest organic micropollutant concentrations (of domestic origin)? Why?

I expect to find the highest concentrations of micropollutants of domestic origin during dry periods. Most organic micropollutant loads leaving wastewater treatment plants do not vary importantly during dry and wet weather conditions. Hence, during dry weather conditions the micropollutant concentrations of domestic origin are higher because there is less dilution due to lower river flowrates.

Exercise 3: industrial wastewaters with inorganic micropollutants (iMP)

An industry group is planning to construct a new production site in Canton de Vaud. They estimate that the new production site will produce 15 m³/day of wastewater with the following composition (iMP and oMP which are not given in the list will not be used at the future site):

Parameter	Estimated value
pH	5.0
Temperature	5 – 25 °C
Transparency	10 cm
Total suspended solids (TSS)	40 mg/L
Cobalt (Co)	0.3 mg/L
Copper (Cu)	5.0 mg/L
Nickel (Ni)	10.0 mg/L
Cyanide (CN ⁻)	0.01 mg/L CN ⁻ (free and easily releasable cyanide)
Volatile chlorinated hydrocarbons (VOCI)	0.3 mg/L

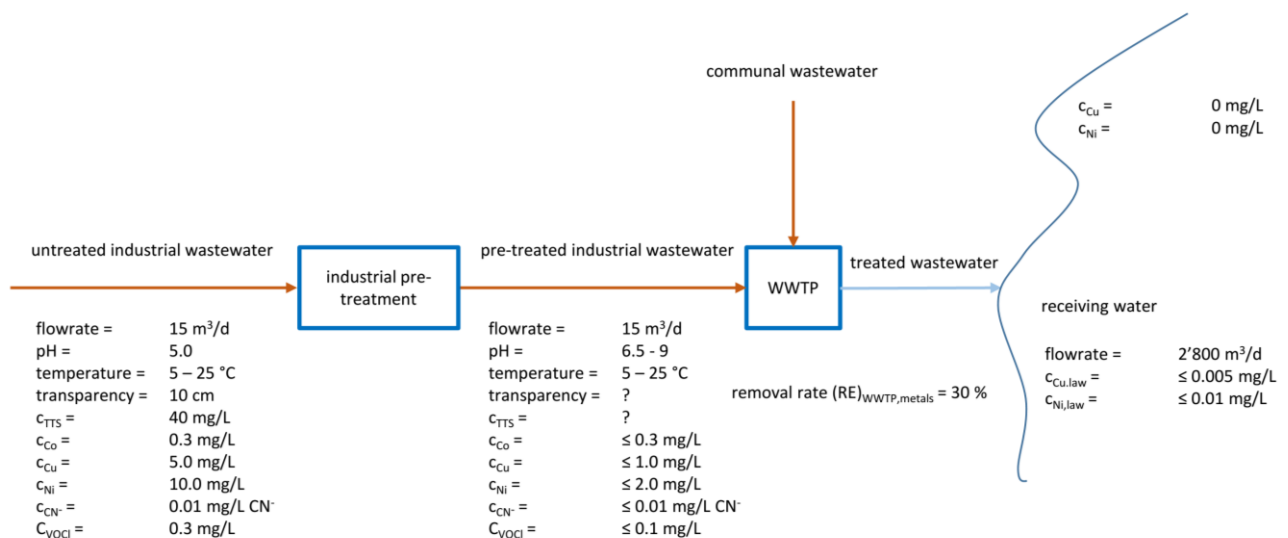


Figure 2: Scheme of exercise 3.

1. Will the new site have to install a wastewater pre-treatment to discharge the wastewater into the public sewer system (no special requirements apply for this industry)?
 - a. Which parameters/micropollutants will have to be treated?

The following parameters/micropollutants will have to be treated:

- pH
- inorganic micropollutants: copper and nickel
- organic micropollutants: volatile chlorinated hydrocarbons (VOCl)

- b. Based on the general requirements for industries what criteria for these parameters/micropollutants will the effluent have to respect?

The following table indicates the required pH values and the maximal acceptable effluent concentrations of the different micropollutants:

Parameter	Maximal effluent concentration/value
pH	6.5 – 9
Copper (Cu)	1 mg/L
Nickel (Ni)	2 mg/L
Volatile chlorinated hydrocarbons (VOCl)	0.1 mg/L

2. The communal wastewater treatment plant (WWTP) discharges into a small unpolluted river with a flowrate of 2'800 m³/day (including water of the WWTP). The communal WWTP removes 30 % of the metals by adsorption to activated sludge. Will the metal concentrations in the river respect the WPO or might the 'Direction générale de l'environnement' (DGE) impose a reinforcement of the industries' effluent concentrations?

The industrial wastewater pre-treatment will discharge the following maximal quantities of iMP after treatment:

$$\begin{aligned} \text{cooper discharge rate}_{\text{industrial pre-treatment}} &= \text{effluent concentration}_{\text{cooper}} \times \text{flow rate} \\ &= \frac{1\text{mgCu}}{\text{L}} \times \frac{15\text{m}^3}{\text{d}} \times \frac{1\text{g}}{1000\text{mg}} \times \frac{1000\text{L}}{1\text{m}^3} = 15.0\text{g/d} \end{aligned}$$

$$\begin{aligned} \text{nickel discharge rate}_{\text{industrial pre-treatment}} &= \text{effluent concentration}_{\text{nickel}} \times \text{flow rate} \\ &= \frac{2\text{mgNi}}{\text{L}} \times \frac{15\text{m}^3}{\text{d}} \times \frac{1\text{g}}{1000\text{mg}} \times \frac{1000\text{L}}{1\text{m}^3} = 30.0\text{g/d} \end{aligned}$$

The communal WWTP will discharge the following maximal quantities of iMP after treatment:

$$\begin{aligned} \text{cooper discharge rate}_{\text{communal WWTP}} &= \text{cooper discharge rate}_{\text{industrial pre-treatment}} \times \text{removal of WWTP} \\ &= 15\text{g/d} \times (100\% - 30\%) = 15\text{g/d} \times 0.7 = 10.5\text{g/d} \end{aligned}$$

$$\begin{aligned} \text{nickel discharge rate}_{\text{communal WWTP}} &= \text{nickel discharge rate}_{\text{industrial pre-treatment}} \times \text{removal of WWTP} \\ &= 30\text{g/d} \times (100\% - 30\%) = 30\text{g/d} \times 0.7 = 21.0\text{g/d} \end{aligned}$$

The concentrations in the river will be the following:

$$\begin{aligned} \text{concentration}_{\text{Cu,river}} &= \frac{\text{cooper discharge rate}_{\text{communal WWTP}}}{\text{flow rate}_{\text{river}}} = \\ &= \frac{10.5\text{g/d}}{2800\text{m}^3/\text{d}} \times \frac{1000\text{mg}}{1\text{g}} \times \frac{1\text{m}^3}{1000\text{L}} = \mathbf{0.0038\text{mg/L}} \end{aligned}$$

$$\begin{aligned} \text{concentration}_{\text{Ni,river}} &= \frac{\text{nickel discharge rate}_{\text{communal WWTP}}}{\text{flow rate}_{\text{river}}} = \\ &= \frac{21.0\text{g/d}}{2800\text{m}^3/\text{d}} \times \frac{1000\text{mg}}{1\text{g}} \times \frac{1\text{m}^3}{1000\text{L}} = \mathbf{0.0075\text{mg/L}} \end{aligned}$$

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The total concentrations of copper and nickel in the river will be below the general requirements for surface waters; copper (total): 0.005 mg/L and nickel (total): 0.01 mg/L. Hence, the DGE will most probably not reinforce the effluent concentrations for the industrial pre-treatment.