Exercises III: organic micropollutant treatment II

Applied wastewater engineering

Exercise 1: Ozone contactor

The wastewater treatment plant of Terre Sainte is mandating you to design an ozone contactor to treat their secondary clarified wastewater. The current plant treats a maximum flowrate during rainy weather of 229 L/s. The average flow rate in 2015 was 6’000 m^3/day.

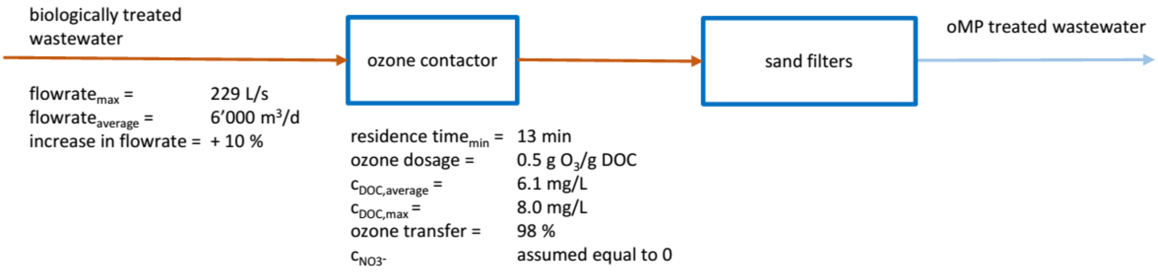

Figure 1: Scheme of exercise 1.

a) What is the required volume of the ozone contactor for a minimal residence time of 15 minutes?

Volume required for the ozone contactor is:

$$V_{ozone\ contactor} = Q_{RW} \cdot contact\ time_{min} = \frac{229L}{s} \cdot 15\ min \frac{60s}{1min} \frac{m^3}{1000L} = \mathbf{206\ m^3}$$

b) The community would like to know how much ozone the installation would use per day (kgO_3/d) for average and design DOC levels and average flow in 2020. Use the values of 2015 and assume an increase of 10 % of the average flowrate value. You decide that the ozone should be dosed at 0.5 g O_3/ g DOC. The ozone transfer efficiency will be 98 %. For a first estimation, you neglect the ozone consumption of nitrites.

Table 1: Average pollutant concentrations of the secondary clarified wastewater of the wastewater treatment plant of Terre Sainte, 2015.

pollutant	unit	concentration
TSS	mg/L	5.5
COD	mg/L	16.0
DOC	mg/L	6.1

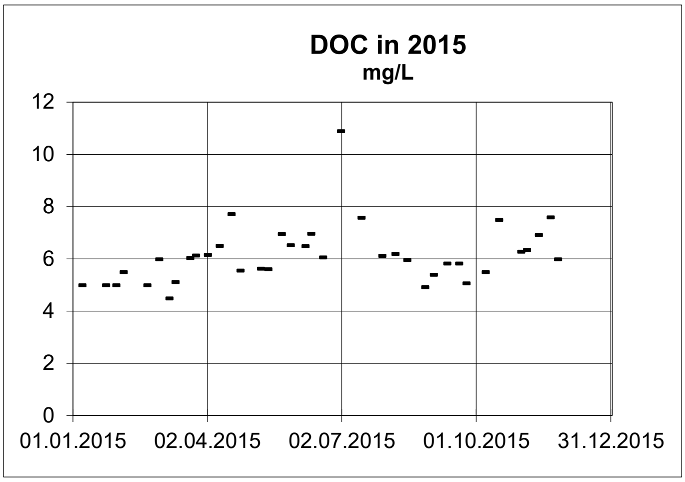

Figure 2: Measured DOC content of the secondary clarified wastewater of the wastewater treatment plant of Terre Sainte, 2015.

$$\boldsymbol{quantity_{ozone,average,d}} = flowrate \cdot flow\ rate\ increase \cdot c_{DOC,average} \cdot \frac{ozone\ dosage}{ozone\ transfer}$$

$$= 6'000m^3/d \cdot 1.1 \cdot 6.1gDOC/m^3 \cdot \frac{0.5gO_3/gDOC}{0.98}\frac{1kg}{1'000g} = \mathbf{21\ kgO_3/d}$$

The highest COD value observed in 2015 is about 11 mg COD/L. However, this is one single value and it does not make sense to design with extreme values. Therefore, I chose the maximum effluent COD concentration of 7.5 mg/L for the design (which corresponds roughly to percentile 85 %):

$$\boldsymbol{quantity_{ozone,\max DOC,d}} = flowrate \cdot flow\ rate\ increase \cdot c_{DOC,max} \cdot ozone\ dosage$$

$$= 6'000m^3/d \cdot 1.1 \cdot 7.5gDOC/m^3 \cdot \frac{0.5gO_3/gDOC}{0.98}\frac{1kg}{1'000g} = \mathbf{25\ kgO_3/d}$$

The average ozone consumption in 2020 will be 21 kg/d. Furthermore, for an elevated COD concentration observed in 2015 (7.5 mg/L corresponds roughly to percentile 85 %) and an estimated average flowrate of 2020, the ozone consumption will be 25 kg/d.

Exercise 2: The legislation about micropollutants

a) What are the main differences between the old (before 2016) and the new legislation concerning organic micropollutants?

- *The old legislation did only include certain organic micropollutants: pesticides, certain hydrocarbons (aliphatic, aromatic, halogenated), whereas the new legislation includes various organic micropollutants (only certain have to be measured to evaluate the efficiency of the treatment)*
- *The old legislation concerned only industrial wastewater treatment and not communal wastewater, the new legislation also concerns communal wastewater treatment.*
- *The old legislation gave only concentrations levels (e.g. in industrial wastewater, surface waters, ground water used for drinking water production), whereas the new legislation also includes a treatment to be achieved in certain wastewater treatment plants (80 % removal).*

- *Furthermore, for certain organic micropollutants (not only sum-parameters: e.g. pesticides) maximal concentrations are defined for surface waters since 2021.*

b) By what means does the Swiss law reduce the introduction of inorganic micropollutants into the environment?

- *Mainly by restricting the effluent concentrations of inorganic micropollutants by industries*
- *Furthermore, maximal concentrations have to be respected in surface water systems and groundwater systems used for drinking water production. Hence, Cantons can reinforce the treatment efficiency required for certain installations in order to respect these laws.*

Exercise 3: Activated carbon dosage

A wastewater treatment plant treating the wastewater of 25’000 PE is planning to construct an organic micropollutant treatment using powdered activated carbon. In average, each PE evacuates 150 L of wastewater per day. Furthermore, the wastewater contains 40 % infiltration water. The average DOC concentration after biological treatment is 7 mg/L.

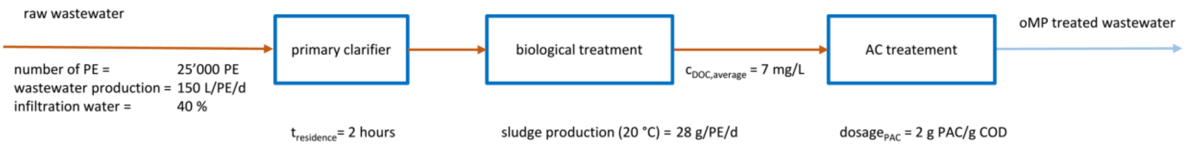

Figure 3: Scheme of exercise 3.

a) The community contracts you to compute how much activated carbon they will use per day and per year. You estimated that they will require a maximum of 2 mg of powdered activated carbon/mg DOC.

Wastewater production excluding infiltration water:

$Q_{average,excluding\ infiltration\ water} = nPE \cdot \frac{wastewater\ production}{PE \cdot d} = 25'000PE \frac{150L}{PE \cdot d} \frac{m^3}{1'000L} =$ 3750 m^3/d

Total wastewater production (including infiltration water):

$$Q_{average,total} = \frac{Q_{average,excl.infiltration\ water}}{(1.0 - fraction_{infiltration\ water})} = \frac{3'750m^3/d}{(1.0 - 0.4)} = 6'250\ m^3/d$$

Activated carbon consumption:

$$quantity_{PAC,d} = Q_{average,total} C_{COD} dose_{PAC} = 6'250 m^3/d \cdot 7 gCOD/m^3 \frac{2gPAC}{gCOD} \frac{1kg}{1'000g} = \mathbf{88\ kgPAC/d}$$

$$quantity_{PAC,year} = 88 kg/d \frac{365d}{1year} = \mathbf{32 tPAC/year}$$

The activated carbon consumption is 88 kg per day and 32 t per year.

b) Furthermore, they would like to know how much additional sludge (expressed in %) would be generated in average due to powdered activated carbon treatment in summer (water temperature 20°C). Use the following table to estimate the actual sludge production (the residence time in the primary clarifier is 2.0 hours):

Table 2: Sludge production [g/(PE·d)] for a nitrifying activated sludge plant with a sludge age of 10 day.

nitrifying activated sludge plant (minimal sludge age 10 days)					
residence time in primary clarifier	temperature	sludge production		volatile solids fraction	
		85th percentile	50th percentile	85th percentile	50th percentile
[h]	[°C]	[g/(PE·d)]	[g/(PE·d)]	[%]	[%]
0.5	10	49	37	73	73
0.5	20	43	34	70	70
1.0	10	43	33	73	72
1.0	20	39	31	70	70
2.0	10	29	29	72	71
2.0	20	28	28	69	71

$$WAS\ production = nPE \times \frac{m_{WAS,50th\ percentile}}{PE \times d} = 25'000PE \times \frac{28g}{PE \times d} \times \frac{kg}{1'000g} = 700\ kg/d$$

$$additional\ sludge\ production\ due\ to\ PAC\ dosage = \frac{quantity_{PAC,d}}{WAS\ production} = \frac{88\ kg/d}{700\ kg/d} \cdot 100\% = \mathbf{12.5}\ \%$$

The sludge production due to PAC addition is an additional 12.5 %.