Write clearly; several questions consist of two or more subquestions.

1. Suspended Solids Removal

A sewage treatment plant (STP) treating the wastewater of 100,000 pop. eq. has to be extended with effluent filtration for suspended solids removal. It was decided to apply fixed bed filtration with a multi media filter bed.
The characteristics of the WWTP are:

- capacity: 100,000 p.e.
- average dry weather flow DWF_{avg} = 15,000 m³/day
- maximum dry weather flow DWF_{max} = 1,000 m³/h
- maximum storm weather flow SWF = $3 \cdot DWF_{max}$
- effluent suspended solids concentration 20 mg/L

Before the full scale filtration is designed pilot filters were tested. The characteristics and results of these tests are summarized in the table and graphs below. The results of the pilot tests can be considered as representative for full scale filters.

Table 1 Pilot filter tests

Pilot filter	Filtration Velocity m³/(m².h)	Anthracite height 75 cm	Sand height 75 cm
Filter a	5	1.6-2.5 mm	0.7-1.2 mm
Filter b	10	1.6-2.5 mm	0.7-1.2 mm
Filter c	20	1.6-2.5 mm	0.7-1.2 mm
Filter d	10	2.5-4.0 mm	1.5-2.0 mm
Filter e	20	2.5-4.0 mm	1.5-2.0 mm

The requirements for the effluent filter are:

- treatment of maximum dry weather flow
- suspended solids removal efficiency 80%
- maximum headloss 1.5 m water column
- maximum surface of a filtration unit approximately 25 m²

The filter is operated with a constant filtration rate with a variable head. The filter is cleaned by backwashing with filtrate according to the following procedure in table 2.

Table 2 Back wash procedure

Step	Duration (sec)	Back wash with	Back wash velocity (m³/m².h)
1	90	air	-
2	360	water	50

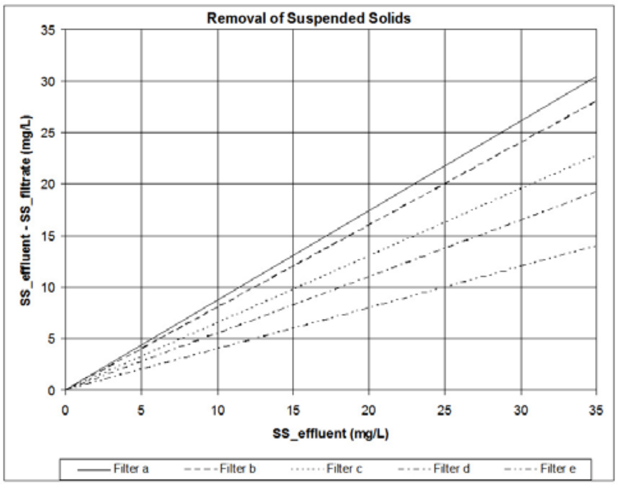


Figure 1 Suspended solids removal efficiency

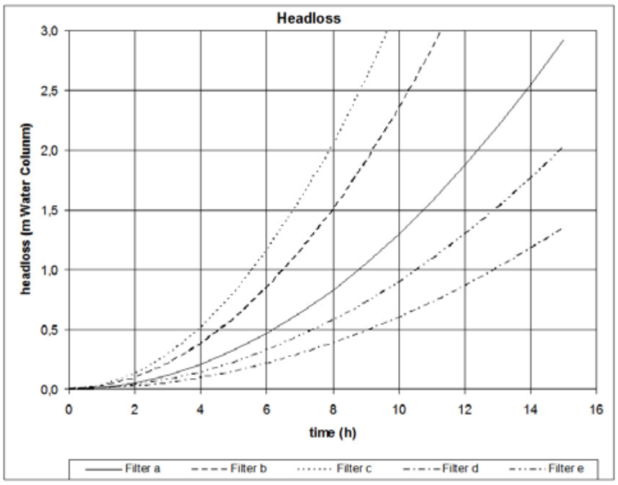


Figure 2 Headloss as function of filter run length

Questions:

1.1 Give the following dimensions of the effluent filtration:
  a. Total surface needed.
  b. Number of filtration units.
  c. Height of the filters (bed height + supernatant height).

1.2. a. What is the number of 'back washes' for each unit per day (24 hrs)?
  b. Calculate the daily volume of back wash water.

2. Advanced P removal

Sedimentation
A new wastewater treatment plant needs to be designed. The parameters required for the design are presented below:

- Dry weather flow = 1,200 m^3/h
- Rain weather flow = 4,200 m^3/h
- Qday = 18,000 m^3/d
- P = 10 mg/L
- Advanced pre-precipitation
- Sedimentation tank
- Surface load = 2.5 m^3/m^2h
- P effluent = 1 mg/L
- FeCl3 (41%)
- Me-dosage = 1.1 mol/mol

Questions:
2.1 Calculate the required surface of the sedimentation tank. Why would you built one or multiple sedimentation tanks?

2.2 The phosphorus removal during primary sedimentation can be increased by adding metal salt. Which phosphorus form will be mainly removed by metal salt addition? Calculate the required metal salt addition as g Fe^{3+}/m^3.

2.3 What conditions are required for a good phosphorus removal? How will you make sure that the circumstances are optimal?

3. Disinfection

Disinfection is referred to as the mechanism to dye-off pathogenic organisms in effluents

Give at least 3 mechanisms of disinfections and explain what chemical and/or physical measures you have to take for each mechanism?

4. Ultrafiltration of sewage treatment plant (STP) effluent

Membrane fouling is one of the key constraints of the membrane process during the filtration of wastewater treatment plant effluent.

4.1 Consider an ultrafiltration installation operating a constant flux. If fouling occurs on the membranes how could it be recognized by the operators?

4.2 To remove the occurred fouling, the membranes have to be hydraulically cleaned after a certain filtration period. Please note three types of hydraulic cleaning.

4.3 Sometimes hydraulic cleanings are not effective and the membrane have to be chemically cleaned. Please note the different types of chemical cleaning that can be applied and note also the type of fouling they remove.

4.4 Consider the below questions and answer with a simple YES or NO answer

a) Concentration polarization plays a dominant role during ultrafiltration of WWTP effluent.
b) Inside-outside filtration is not always dead-end filtration.
c) During ultrafiltration of STP effluents, the filterability is dominated by big particles (e.g. > 100 μm).
d) Capillary membranes have a smaller internal diameter than tubular membranes
e) Organic fouling is predominant during ultrafiltration of WWTP effluent.

5. Decentralised Sanitation / source separation

5.1 Give an indication of the volume and mass fractions of COD, N and P associates with fecal matter and urine.

5.2 What are the major incentives for the development of sanitation approaches that are based on the separation of household waste streams. Give at least 4 reasons.

5.3 If only separate collection of urine would be considered for over 50% of the Netherlands. What would be the main effect on the currently used centralized activated sludge plants?

6. Membrane bioreactors (MBRs) for wastewater treatment

6.1 Compare the effluent quality provided by an MBR and a Conventional Activated Sludge (CAS) system. What are the most striking differences?

6.2 Describe the mostly applied MBR process configurations indicating main advantages and disadvantages.

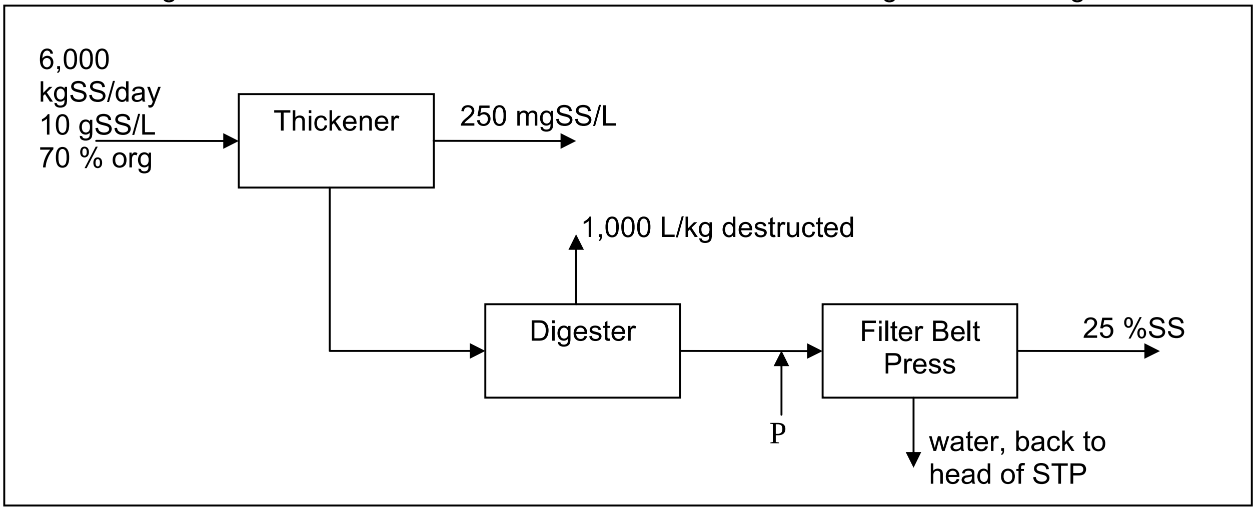
6.3 What is fouling and what are the main factors that determine it?

6.4 Why are fouling results, providing from different sources such as universities or water boards, difficult to compare?

6.5 Why are MBRs particularly suitable to treat industrial wastewater? Provide, at least, three reasons.

7. Sludge Treatment

The daily sludge production at a WWTP is 6,000 kg SS/day with a sludge concentration of 10 g SS/L. The organic content of the solids is 70% and the SVI of the sludge is <100 mL/g.



The sludge is treated according to the following scheme (see also the figure above):

1. Thickening by gravitation. The rejection water from the thickener has a suspended solids concentration of 250 mg SS/L.
2. Digestion with a biogas production of 1,000 L/kg destructed organic material.
3. Dewatering with a filter belt press to a dry solids content of 25%. To improve the dewaterability of the sludge a poly-electrolyte (PE) is dosed.

Questions:

7.1 Thickener:

a. Calculate surface and diameter assuming a maximum solids loading of 40 kg SS/(m^2.day)
b. What is the amount of sludge stored in the thickener

7.2 Digester:

a. Calculate the volume of the digester based on influent solids flow only.
b. What is the daily biogas production?

7.2 Filter belt press:

Calculate the daily consumption of PE assuming a consumption of 7 kg PE/ton SS.

8. Anaerobic treatment

A food industry discharges wastewater with a flow of 6000 m^3/day and a concentration of 5000 mg COD/l. The biodegradability of the wastewater was estimated to be 90%. The industry is evaluating anaerobic treatment and is interested in using the biogas for energy supply.

8.1 Calculate the required volume of the anaerobic reactor, applying an organic loading rate of 30 kg COD/m^3.day. Do you propose a UASB reactor or an expanded bed high-rate reactor for this loading?

8.2. The reactor is dimensioned for an upflow velocity of 6 m/h. Calculate the height and diameter of the anaerobic reactor.

8.3 Calculate the daily methane production and the electric energy recovery assuming that all biodegradable COD is converted and a 40% efficiency combined heat power (CHP) generator is used.

- oxidation of methane: $CH_4 + 2\ O_2 \rightarrow 2CO_2 + 2\ H_2O$
- 1 mol gas = 22.4 l at standard temperature and pressure;
- C, H, and O have a molar weight of 12, 1 and 16, respectively
- theoretical energy content of 1 m^3 CH_4 equals 10,95 kWh.

8.4 What will be the daily benefit calculating with an energy price of 0.09 €/kWh and assuming that the energy requirement of 1 kWh/kg COD of the alternative activated sludge plant is saved.

8.5 Explain what happens with the biogas production if suddenly the influent also contains 1 kg SO_4 /m^3? Calculate the impact on the daily biogas production assuming that no SO_4 will be in the effluent of the anaerobic reactor and 2 moles of COD is needed to fully reduce SO_4 (molecular weight of S = 32).

8.6 When the operator returns in the morning at the anaerobic reactor he is confronted with a very low pH of the anaerobic reactor. Give at least 2 possible reasons why such pH drop may occur?