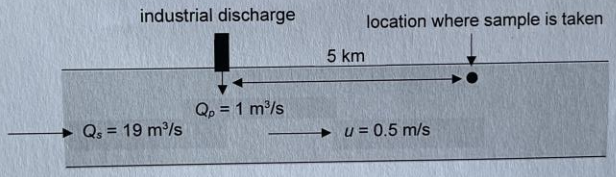
5. **Pharmaceuticals in water (4)**
   a. Give at least two problems related to pharmaceuticals in natural water systems. (2)
   b. Give at least two measures on how the emission of human pharmaceuticals to natural waters can be reduced. (2)

6. **Water quality standards (4)**
   a. For mercury 38 NOEC (in μg/l) values are available. The average value of the log(NOEC) values is 0.8 and the standard deviation is 0.89 (Crommentuijn et al. 1997). Calculate the MPA. (2)
   b. Mercury is a priority pollutant for the EU Water Framework Directive and therefore the standard applies to all water bodies in Europe. Explain briefly why you think this is fair/not fair. (2)

e. Give the mass balance (differential equation) of this problem. (You do not have to solve it.) (2)
f. Draw again the concentration in the wetland as a function of time in the same graph as for 3.c. Indicate clearly what line is with and without degradation. (2)
g. How would the graph change if adsorption is not instantaneous but should be described as a non-equilibrium process. Indicate clearly in the same figure. (2)

4. BOD discharge to a stream (11)

Organic material is discharged into a stream with wastewater from an industrial point source. The discharge of the point sources (Q_p) is 1 m^3/s with a BOD of 20 mg/l. The discharge of the stream (Q_s) upstream of the point source is 19 m^3/s and the BOD is negligible. The velocity (u) of the stream is 0.5 m/s. The half-life for first-order degradation of the quickly degradable organic matter is 0.5 day. 5 km downstream from the point source a sample is taken to measure the BOD concentration.



a. What does the abbreviation BOD stand for and what does it mean? (2)

Assume as chemical composition for the organic material $C_6H_{10}O_5$.

b. Give the reaction for the complete aerobic biodegradation of $C_6H_{10}O_5$. (2)

Assume the point source and stream are immediately and completely mixed.

c. Calculate the BOD of the stream right after the point source. (2)
d. Estimate the BOD at the sample location assuming piston displacement (advection) and decay. (If you do not have an answer to question 4.c use 20 mg/l.) (2)
e. In reality, the measured BOD at the sampling location appears higher than calculated in 4.d. What is the most likely reason for this? (1)
f. Give two policy measures that can be taken to force industry to reduce emissions to the environment. (2)

Exam Water Quality

Master Civil Engineering and Management

1. **EU-Water Framework Directive (6)**
   a. Give two reasons for what hinders the achievement of the WFD goals. (2)
   b. Give two principles that were considered when designing the WFD. (2)
   c. Why is a good chemical status not sufficient to represent a good ecological status? (2)

2. **Removal of nitrate at a wastewater treatment plant (6)**
   a. Why is the removal of nitrate in a wastewater treatment plant important? (1)

   In wastewater treatment plants nitrate is (NO_3^-) is removed by uptake by activated sludge, a biological floc composed of bacteria and protozoa and by denitrification.

   Assume that the chemical composition of activated sludge can be written as: $C_{106}H_{212}O_{106}N_{16}P$

   a. Calculate how much nitrate (in gram) is taken up for the production of 1 gram of activated sludge. (2)
   b. What is done with the activated sludge? (1)
   c. When does denitrification take place? (1)
   d. What form of nitrogen is produced during denitrification? (1)

3. **Pollution of a shallow lake (14)**
   Assume a shallow lake with a volume of 10^5 m^3. Initially the lake is free of contaminants. At t = 0 water enters with a discharge of 1 m^3/s that contains a constant concentration of an organic contaminant of 10 µg/l. Water leaves the lake with the same discharge so the volume of water in the lake remains constant. The organic contaminant adsorbs to the top layer of the sediment which corresponds to $5 \cdot 10^6$ kg of sediment. The equilibrium adsorption coefficient is 0.3 m^3/kg. Assume no degradation or volatilization of the contaminant.
   a. Give the mass balance (differential equation) of this problem (2)
   b. Solve the equation. (2)
   c. Draw the concentration in the wetland as a function of time. Use quantitative axes. (2)
   d. How much mass of the contaminant is stored in the sediment when equilibrium is reached? (2)

   Assume now that the contaminant is degraded with a half-life of 5 days.

UNIVERSITY OF TWENTE.

Exam Water Quality

Master Civil Engineering and Management

Course code:	202300107
Date:	October 27, 2025
Location:	NH 115
Time:	13:45-16:45 *(17:30 for students with right of extra time (25%))*
Lecturer:	D.C.M. Augustijn

Type exam: Closed book

Appendix: Information sheet Water Quality

Instructions:

- This exam consists of six (6) questions. The total number of points that can be earned is 45 points. The number of points is indicated per question and sub-question. A partly correct answer is awarded part of the allocated points.
- Write the answers on the provided answer sheets. Write your name on each separate sheet. The blank pages in the middle can be used as scrap paper.
- You have 3 hours for the entire exam. Plan your exam well.
- This is a closed book exam, so you are not allowed to use any books or notes, except the information sheet which is handed out at the beginning of the exam.
- Please do not write on the information sheet so it can be reused.
- You may use dictionaries (no digital versions).
- You may use a (graphical) calculator.
- Answer the questions in English (language errors are not lowering your grade).
- In answering the questions, be concise and clear.
- Hand in the answer sheets, information sheet and these questions, the scrap paper you can take home.

Good Luck!