ENV 504
Remediation of soils and groundwater
Final exam
May 10th 2022
9:15am-11:15am
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Name

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Instructions:
This is an open book examination. You are allowed the course notes but not the homework problems or solutions. To get partial credit, be sure to show your work and to justify your answers. Sign the Honor code pledge. Please work in the blank pages provided.

I will abide by the EPFL Honor code

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Total : 80 points

Question 1 : _____ / 25 points
Question 2 : _____ / 20 points
Question 3 : _____ / 35 points

Total number of pages: 8

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Problem 1: SVE (25 points)

As a result of leakage of an aboveground fuel tank, extensive soil contamination by benzene was detected at the Andrews Air Force Base in Maryland, US. The proposed remediation approach is SVE. The soil contamination extends into a volume equivalent to a cylinder 50 m in diameter and 100 m tall. The total mass of benzene released into the soil was estimated at 100,000 kg.
The target BTEX concentration following remediation is 25 mg/kg of dry soil.

1. Calculate the initial equilibrium concentration of benzene in the different phases.
2. Give the mathematical equation for the change in the total amount of benzene over time during SVE assuming instantaneous equilibration between all phases. (Hint: consider that the total mass of TPH changes as it is removed by SVE)
3. Using this relationship, how long would it take for the remediation to be completed?
4. Biodegradation of benzene is also possible. Given a first-order rate constant of k=0.005 d^{-1}, how long would the degradation of benzene take in the absence of SVE (under conditions where plenty of O_2 is available)?
5. Do you think SVE is a reasonable approach or do you recommend another?

ρ_{wb}= 2,000 kg/m^3
K_D=0.003 m^3/kg
K_H=2.08[-]
Soil porosity ε=0.3
Soil moisture content θ= 5%
Q= gas flow rate= 100m^3/s

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Problem 2: Electrical resistive heating (20 points)

Groundwater is contaminated with petroleum hydrocarbons and electrical resistive heating is used coupled to biodegradation. A temperature of 60ºC must be reached to allow the desorption of 80% of the TPH (total petroleum hydrocarbon) and its mass transfer to the aqueous phase. (Hint: solid-aqueous equilibrium is impacted by temperature).
Given a TPH initial concentration of 2,000 mg/kg sediment and a target concentration of 500 mg/kg sediment, how long will it take from the time that the desired temperature is reached until the target concentration is achieved if the process is not O_2 limited and the degradation rate is 0.01 d^{-1}?

The wet bulk density of the sediment is 1,400 kg/m^3. K_D=0.03 m^3/kg at 25 ºC; K_H=2.08 [-]

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Problem 3: Desorption/degradation vs. bioventing (35 points)

A soil is contaminated with toluene (28,125 kg) and the contamination is sufficiently shallow and limited in space that excavation followed by slurry phase desorption and degradation or bioventing are deemed feasible options. Alessia, the environmental engineer in charge of remediating the site is attempting to evaluate the preferable approach given a final target concentration of 30 mg/kg dry soil. The volume of soil to be treated is 50,000 m^3 (wet soil) with a soil moisture content of θ= 10 %.

Desorption/degradation

1- The slurry is mixed to a concentration of 10 kg dry soil per m^3 of slurry. Calculate the concentration of toluene in the aqueous phase of the slurry, assuming equilibrium.
2- The slurry is amended to a CSTR that is 2,000 m^3 in volume. Calculate the residence time required for the degradation of the toluene to the target concentration.
3- Estimate the amount of time required to treat the entire contaminated soil by a slurry phase process.

Bioventing

4- Bioventing of the entire contaminated area through injection of air is also considered. Calculate the volume of liquid and gas in the soil. What is the initial concentration of toluene in the aqueous phase of the soil?
5- How much O_2 must be delivered to the subsurface to allow oxidation of toluene to the target concentration?
6- Assuming a toluene-related oxygen utilization rate of 0.5 min^{-1} and no O_2 limitation, what is the minimum amount of time it will it take to reach the target concentration assuming toluene is oxidized to CO_2?

Comparison

7- Please compare the two options. Which would you recommend and why?

K_D=0.02 m^3/kg
$k_{toluene}$= 0.5 h^{-1}
Dry solid density ρ_s=2,500 kg/m^3
Dry soil bulk density ρ_b=1,875 kg/m^3
Soil moisture content in situ θ= 10 %
Soil porosity ε=0.25
K_H=0.41 [-]
MW O_2 =32 g/mol
MW toluene= 92.14 g/mol
Toluene = C_7H_8

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