ENV 504
Remediation of soils and groundwater
Final exam
May 7, 2019
9:15am-11:15am
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Name

Camipro #

Instructions:
This is an open book examination. 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.

For each problem, please write all the equations without any numerical values and calculate the numbers only at the end of each problem.

I will abide by the EPFL Honor code

Total : 100 points

Question 1 : _____ / 30 points
Question 2 : _____ / 40 points
Question 3 : _____ / 30 points

Total number of pages: 8

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Problem 1: Permeable reactive barrier (30 points)

The groundwater at a site in Carouge is contaminated with hexavalent chromium (Cr(VI)). The total amount of the contaminant released into the aquifer sediment is 50 kg. The plume is a cylinder 20 m in diameter and 12 meters long. A zerovalent iron (ZVI) permeable reactive barrier (PRB) is being considered for this site. The bedrock is 15m deep. The legal limit for Cr(VI) is groundwater is 5 ppb (5 µg/L).
Calculate the aquifer dry bulk density.
What is the optimal design for this PRB (width)? What is the mass of ZVI needed?

Please state your assumptions explicitly.

Aquifer porosity=0.35
Aquifer wet bulk density=1.8 g/cm^3
Molecular weight of Cr(VI)= 194 g/mol
K_D for Cr(VI)= 0.2 mL/g
Porosity in PRB: 0.5 [-]
Hydraulic gradient: 1.2 [-]
Hydraulic conductivity of PRB: 0.5 m/d
Safety factor: 3.5
Bulk density ZVI: 2.3 g/cm^3
Cr(VI) reduction rate: 5 h^{-1}

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Problem 2: Air stripping (40 points)

A groundwater in California has been contaminated with TCE at a concentration of 2,300 µg/L. The State Health Department permits a maximum of 100 µg/L. To meet the State's requirement, it is proposed to use air stripping to transfer the contaminant into the gaseous phase which can then be treated by activated carbon adsorption.

Part 1:
Given the specifications below, what gas flow rate should be utilized to keep a reasonable total height of stripping tower? Hint: Assume a ratio of air to water volumetric flow rate for the calculations and determine if the total height is reasonable.

Air stripping tower:
Diameter= 0.8 m
Henry's constant (dimensionless): 0.415
Water flow rate Q_w= 30 L/sec
TCE molecular weight= 131.4 g/mol
TCE molar volume= 256 cm^3/mol

Use the simplified empirical calculation for the overall mass transfer coefficient (K_La) with α=0.5 and n=0.2.

Part 2:
Using off-the-shelf GAC barrels described below, design an activated carbon treatment for the gas from the air stripping process (how many drums, what configuration, how long before exchange drums). The equilibrium isotherm for adsorption of the contaminant on activated carbon is given by
$\Gamma=475\ C^{0.83}$
where Γ =sorbed concentration (mg sorbed per g activated carbon) and C= equilibrium gaseous concentration (mg/L). The activated carbon treatment is to be achieved flow through reactor packed with granulated activated carbon (GAC).

Please state your assumptions explicitly.

GAC barrels:
Size= 2.5m high by 0.7m diameter
Bulk density of GAC= 500 kg/m^3
Surface loading rate= 150 $L/(s*m^2)$

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Problem 3: chemical oxidation (30 points)

A soil contaminated with TCA ($C_2H_3Cl_3$) is to be treated by chemical oxidation. Instead of treating the soil *in situ*, it is excavated and spread in a land treatment facility and the chemical oxidant (sodium persulfate, $Na_2S_2O_8$) added in solid form and mixed in by tilling. The solid phase will dissolve and oxidize TCA in the aqueous phase.
The facility is 40 m long by 25 m wide.

How many batches of soil land farming will need to be treated? How much time will it take to degrade TCA to a concentration below the regulatory limit for the entire excavated soil? How much sodium persulfate will be needed? Hint: in persulfate, the oxidation state of S is +6 and that of two of the O is -1 (for the rest of O, it is -2)).

Assumptions:

Persulfate is degraded to sulfate.
TCA is oxidized to CO_2.
Sodium persulfate will dissolve completely.

Relevant data:
Total amount of TCA in soil: 10 m^3
Total volume of soil excavated: 7,000 m^3
Depth of contaminated soil in land farming facility: 30 cm
Soil wet bulk density: 1,800 kg/m^3
Regulatory limit of TCA in soil: 50 mg/kg
Rate constant for oxidation of TCA with persulfate (first order) k= 0.1 d^{-1}
Molecular weight of sodium persulfate: 238 g/mol
Atomic weight of sodium: 23 g/mol
TCA molecular weight: 133.4 g/mol
Density of TCA: 1,325 kg/m^3
Henry's law constant TCA: 0.56 [-]
Octanol-water coefficient: $10^{-2.5}$
Soil porosity: 0.25
Soil moisture content: 0.10 m^3/m^3
K_D= 10^{-5} m^3/g

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