ENV 504
Remediation of soils and groundwater
Final exam
May 8th 2018
9:15am-11:15am
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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.

I will abide by the EPFL Honor code ______________________________

Total : 100 points

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

Total number of pages : 8

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Problem 1: Soil Vapor Extraction (40 points)

A site contaminated with a contaminant is considered for soil vapor extraction. The average concentration of the contaminant in the soil is 50 mg contaminant /kg dry soil. The extraction well has a diameter of 20 cm, a screened height of 6 m, and a pressure of 0.7 atm. Air is drawn at a flow rate of Q (m^3/d). A monitoring well at 10 meters from the extraction well has a pressure of 0.99 atm.
Given that the contamination covers a surface area of 1200 m^2 and a depth of 3m, how many SVE wells need to be put in? How long will it take to remediate the site (90% removal)?

1. Calculate the gas phase concentration of the contaminant.
2. Calculate the radius of influence.
3. Calculate the flow rate needed per well.
4. Calculate the number of wells needed to cover the surface area.
5. Calculate how long it will take to remove 90% of the contaminant.

Please state your assumptions explicitly.

Soil porosity=0.35
Soil wet bulk density=1.8 g/cm^3
Soil dry bulk density= 1.6 g/cm^3
Molecular weight of the contaminant= 78.1 g/mol
Henry's law's constant= 0.23 [-]
Octanol-water partitioning coefficient= 300
Soil gas permeability= $9*10^{-8}$ cm^2
Viscosity of air= $1.8 * 10^{-4}$ $N/(m^2.s)$
Mass fraction organic matter in soil= 0.05
1 atm= $1.013 *10^5$ N/m^2

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Problem 2: Soil washing (30 points)

A soil in California has been contaminated with an emerging contaminant at a concentration of 300 mg/kg dry soil. The State Health Department permits a maximum of 10 mg/kg contaminant in dry soil. To meet the State's requirement, it is proposed to use soil washing to transfer the contaminant into the aqueous phase which can then be treated by activated carbon adsorption. The contamination covers a surface area of 150 m^2 and a depth of 3m.

Given the specifications below and assuming equilibrium, how many consecutive batch reactor runs are needed to remove the contaminant from the soil.

Using off-the-shelf GAC barrels described below, design an activated carbon treatment for the water from the soil washing 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

$\Gamma = 25\ C^{0.36}$

where Γ =sorbed concentration (mg sorbed per g activated carbon) and C= equilibrium aqueous 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.
Soil:
K_D for contaminant= 10^{-4} m^3/g
Total reactor volume= 800 m^3
Solid phase concentration in slurry= 10 kg/m^3
Soil wet bulk density=1.8 g/cm^3
Soil moisture content= 0.15
Residence time in reactor= 1 day (assume equilibrium is reached in that amount of time)

GAC barrels:
Size= 2m high by 0.8m diameter
Bulk density of GAC= 485 kg/m^3
Surface loading rate= 300 $L/(min{*}m^2)$

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Problem 3: Partitioning (30 points)

Some organic contaminants (non-aqueous phase liquids, NAPL) form a separate phase in aquifers and it is difficult to evaluate how much of this contaminant is trapped in this phase in the aquifer. Environmental engineers have developed tracers to evaluate the mass of contaminant in this NAPL phase in order to better characterize the contamination. One such tracer –sulfurhodamine B (SRB)– is used by introducing it to the subsurface and measuring the aqueous concentration and back-calculating the mass of NAPL using a NAPL/water partitioning coefficient (K_{NW}) defined below. SRB partitioning to the gas phase is negligible but that to the aqueous, solid, and NAPL phases is significant. The aqueous concentration of SRB in water after dosing the aquifer with 2 kg of SRB is 3.289 μg/L. Only the contaminated region (which received 2,000 kg of NAPL) in the aquifer is being considered here.

1. Using the partitioning of SRB in the three relevant phases, calculate the mass of NAPL present as a separate phase in the aquifer.
2. Calculate the aqueous concentration of NAPL in the groundwater. Include the gas phase in your calculation for the NAPL.

Volume of water in the aquifer (V_L)= 498 m^3
Volume of gas in aquifer (V_G)=2 m^3
Mass of soil in the aquifer (M_S)=20,000 kg
K_H (NAPL)[-]= 0.6
K_D (NAPL)=0.09 cm^3/g
K_D(SRB)= 5.5*10^{-6} m^3/g
K_{NW}(SRB) [-]= 0.06
density of NAPL=1,100 kg/m^3

$$K_{NW}\,[-] = \frac{C_{i,NAPL}\ \text{(mol in NAPL phase/L NAPL phase)}}{C_{i,aq}\ \text{(mol in solution /L liquid)}}$$

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