Remediation of soil and groundwater
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Problem set # 4: vapor phase processes

Problem 1:
A biofilter is used to remove toluene from the gas phase. The gas flow rate is Q= 0.3 $m^3.h^{-1}$, the influent concentration C_i= 560 μg.L^{-1}. Monod kinetics: k=120.3 mg toluene.(g cell.min)$^{-1}$ and K_S=17.4 mg.L^{-1} air. The operational biomass concentration is X= 1g cells.L^{-1} air flow.
What is the effluent concentration of toluene assuming a height of 1m?

Problem 2:
Please calculate the height of an air-stripping tower to remove ethylbenzene from groundwater given the following information.

Influent concentration of ethylbenzene: 1 mg.L^{-1}
Target effluent concentration: 35 μg.L^{-1}
Liquid flow rate Q_W= 643.45 L.min^{-1}
Column diameter= 0.915m
Packing= 2.5 cm polyethylene Raschig rings
$K_L a$ =0.016 s^{-1}
Air to water flow ratio: 100:1
K_H'= 0.27
T= 20 ºC.

Problem 3:
A leaking underground storage tank has discharged 10 m^3 of 1,1,1-TCA (1,1,1-trichloroethane) to a sandy clay soil. The contaminated soil is found to extend over a cylinder of diameter of approximately 30m and a depth of 10m, beginning 2m below the surface. The extraction rate selected was Q=3 $m^3.min^{-1}$.
Estimate the time necessary to remove 95% of TCA.

Characteristics of 1,1,1-TCA:
vapor pressure P_v= 0.13 atm at 20ºC
MW= 133.4 g.mol^{-1}
ρ_{TCA}=1,325 kg.m^{-3}
K_H'=0.56 at 20ºC
K_{OW}=$10^{-2.5}$

Soil characteristics:

Wet bulk density: ρ_{wb}= 2,090 kg.m^{-3}
K_D= 10^{-5} m^3.g^{-1} (for 1,1,1-TCA)
θ= 0.10 [-]
ε=0.25
T_{soil}=20ºC
ρ_{air}=1.28 kg.m^{-3}

Problem 4:
A soil is contaminated with petroleum hydrocarbons and injection bioventing (with no gas phase treatment) or soil vapor extraction are being considered as treatment approaches. Due to the cost, only a single well at the center of the contamination area is planned and the injection and the extraction flow rates are set:
For injection: 3.5 m^3/min
For extraction: 5 m^3/day
The question for the environmental engineer in charge of the site to solve is which treatment would be most rapid in this situation?

The contamination area is cylindrical and 6 meters deep and covers a surface area of 20 m^2.
The concentration of total petroleum hydrocarbon (TPH) is 500 mg TPH/kg soil and assumed to be homogeneously distributed. The target concentration is 50 mg TPH/kg soil. The dry bulk density of the sediment is 1,400 kg/m^3. K_D=0.03 m^3/kg and K_H'=2.08[-], soil porosity ε=0.3, soil moisture content θ = 0.05; 1 g O_2 is required to degrade 0.3 g of TPH carbon. As a reminder, the molar volume of gas is 22.4 L per mole under these conditions. The well is screened along the entire 6m of the contaminated soil depth.
The fractional volume of O_2 in air is C_{O2}=0.21 m^3 O_2/m^3 air

Part 1: Bioventing

1- What is the oxygen utilization rate (in m^3 O_2/(m^3 air.day)) that is reached with this air flow rate?
2- What is the corresponding biodegradation rate of TPH (in g TPH/(kg soil.day))?
3- Assuming the biodegradation rate follows first order kinetics, how long will the remediation take to reach the target with this method?

Part 2: SVE

4- What is the concentration of TPH in the gas phase initially ($C_{TPH,g}$)?
5- How long will it take to reach the regulatory goal? (hint: consider that the total mass of TPH changes as it is removed by SVE)

Finally, please indicate what you think is the best approach here and why.