

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 $Q = 0.3 \text{ m}^3/\text{h}$, the influent concentration $C_i = 560 \text{ } \mu\text{g/L}$. Monod kinetics: $k = 120.3 \text{ mg toluene/g cell/min}$ and $K_s = 17.4 \text{ mg/L air}$. The operational biomass concentration is $X = 1 \text{ g cells/L air flow}$.

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

Target effluent concentration: $35 \text{ } \mu\text{g/L}$

Liquid flow rate $Q_w = 643.45 \text{ L/min}$

Column diameter = 0.915 m

Packing = $2.5 \text{ cm polyethylene Raschig rings}$

$D_L = 6 \times 10^{-6} \text{ cm}^2/\text{s}$

$D_G = 0.09404 \text{ cm}^2/\text{s}$

Air to water ratio: $100:1$

$K_H' = 0.27$

$T = 20 \text{ }^\circ\text{C}$.

Problem 3:

A leaking underground storage tank has discharged 10 m^3 of 1,1,1-TCA to a sandy clay soil. The contaminated soil is found to extend over a diameter of approximately 30m and a depth of 10m, beginning 2m below the surface. A short SVE program at $3 \text{ m}^3/\text{min}$ or $4.5 \text{ m}^3/\text{min}$ was run to select the design extraction rate and the data are shown below. The extraction rate selected was $Q = 3 \text{ m}^3/\text{min}$.

Estimate the time necessary to remove 95% of TCA.

Characteristics of 1,1,1-TCA:

vapor pressure $P_v = 0.13 \text{ atm at } 20^\circ\text{C}$

$MW = 133.4 \text{ g/mol}$

$\rho_{\text{TCA}} = 1,325 \text{ kg/m}^3$

$K_H' = 0.56 \text{ at } 20^\circ\text{C}$

$K_{OW} = 10^{-2.5}$

Soil characteristics:

Wet bulk density: $\rho_{wb} = 2,090 \text{ kg/m}^3$

$K_D = 10^{-5} \text{ m}^3/\text{g}$ (for 1,1,1-TCA)

$$\theta = 0.10 \text{ m}^3/\text{m}^3$$

$$\varepsilon = 0.25$$

$$T_{\text{soil}} = 20^\circ\text{C}$$

$$\rho_{\text{air}} = 1.28 \text{ kg}/\text{m}^3$$

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: $60 \text{ m}^3/\text{day}$

For extraction: $120 \text{ m}^3/\text{day}$

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 $500 \text{ mg TPH}/\text{kg soil}$ and assumed to be homogeneously distributed. The target concentration is $50 \text{ mg TPH}/\text{kg soil}$. The dry bulk density of the sediment is $1,400 \text{ kg}/\text{m}^3$. $K_D = 0.03 \text{ m}^3/\text{kg}$ and $K_H = 2.08 [-]$, soil porosity $\varepsilon = 0.3$, soil moisture content $\theta = 0.05$; 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 6 m of the contaminated soil depth.

The percent volume of O_2 in air is $C_{\text{O}_2} = 21\% \text{ m}^3 \text{ O}_2/\text{m}^3 \text{ air}$

Part 1: Bioventing

- 1- What is the oxygen utilization rate (in $\% \text{ m}^3 \text{ O}_2/(\text{m}^3 \text{ air} \cdot \text{day})$) that is reached with this air flow rate?
- 2- What is the corresponding biodegradation rate of TPH (in $\text{mg TPH}/(\text{kg soil} \cdot \text{day})$)?
- 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 ($C_{\text{TPH,g}}$)?
- 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.