Remediation of soil and groundwater
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Problem set # 8: *in situ* physicochemical processes and barriers

Problem 1:
A sandy soil with a porosity of 0.3 is contaminated with a wide range of organic and inorganic contaminants to a depth of 3 meters. This site is a candidate for *in situ* vitrification. Calculate the surface subsidence expected at the completion of vitrification (based on 1 m^2 of surface).

Problem 2:
Stabilization of sludge from a wastewater treatment plant is being considered. The plant treats $1.14*10^6$ L/day with a suspended solids concentration of 220 mg/L in the influent wastewater. The treatment plant has a suspended solids removal efficiency of 90%. From bench scale studies, adequate stabilization can be achieved by adding 8% lime by weight. Lime stabilization costs are $80 per metric ton of sludge including materials, labor and equipment. What is the annual cost? How much lime is needed per year?

Problem 3:
Calculate the expected pumping rate for a single extraction well with a drawdown of 6m when the drawdown at a monitoring well that is 18m away is 0.2 m. Both wells have a radius of 0.2m. The aquifer can be assumed to be homogeneous and isotropic. It is 12 m deep with a hydraulic conductivity of $4.2 * 10^{-4}$ m/s.

Problem 4:
An oily waste was stabilized by mixing with fly ash. The waste was analyzed and found to contain 14% oil and grease, 2.2% total organic carbon, 72% volatile solids including 180 mg/kg 1,1,1-trichloroethane, 71 mg/kg butylbenzylphtalate, 15 mg/kg cadmium, 150 mg/kg copper, 20 mg/kg lead and 15 mg/kg zinc. The waste required 1.2 parts fly ash to 1 part waste per weight. After stabilization, the material analyzed was found to contain 89% total solids and 14% volatile solids including 1.5 mg/kg 1,1,1-trichloroethane, 1,1 mg/kg 4-methyl-2-pentone, 12 mg/kg toluene, 14 mg/kg ethyl benzene and 15 mg/kg total xylenes.
Calculate the reduction in contaminant concentrations due to the dilution only.

Problem 5:
A former dry-cleaning site in Reine, Germany is contaminated with 20 mg/L PCE. A continuous wall treatment is planned for this site with ZVI. The PRB was designed to be 25 meters long and 10 meters deep. Given that the target concentration of PCE is 100 μg/L and the hydraulic conductivity in the PRB 0.5 m/d, what is the width of the PRB? How much ZVI will be needed (in metric tons) if 100 % ZVI is used? How about if use 60% sand and 40% ZVI by volume?
PCE degradation half-life (first order kinetics): 3 hours
Porosity in PRB: 0.6 [-]

Hydraulic gradient: 1.2 [-]
Safety factor: 3.5
Density ZVI: 2.3 g/cm^3
Density sand: 1.6 g/cm^3

Problem 6:
An underground storage tank is leaking PCE into the groundwater at the rate of 4 mL/day from a dry-cleaning operation. The dry-cleaning facility operators and the Environmental Protection Agency (EPA) both know about the leak, but the EPA cannot forcibly shut down the dry-cleaning facility until the PCE concentration in the groundwater exceeds the maximum contaminant limit (MCL) allowable. How long will it take for the concentration of PCE in the water to exceed the MCL of 5ppb (parts per billion)?
The EPA scientist in charge of this case has determined that clay lenses limit the possible contamination zone to a cylinder 2 meters deep and 50 meters in diameter in the saturated zone. The wet bulk density (weight of saturated aquifer material/volume of saturated aquifer material) of the aquifer sediments is ρ_{wb}= 1,500 kg/m^3. The porosity of the aquifer material is ε=0.4.
PCE: K_H'= 0.75 [-]; K_D= $1.3*10^{-5}$ m^3/g; MW= 166 g/mol; density 1.6 kg/L.

Finally, after nine months, the EPA was able to shut down the dry-cleaning operation (see above), remove the leaky tank from the ground and initiate the remediation process. The engineers in charge of the clean-up are considering a pure zerovalent iron permeable reactive barrier (ZVI PRB). The goal of this problem is to design the PRB.

a- Calculate the concentration of PCE in the water after nine months of release of PCE (assuming no loss).
b- Estimate the PRB thickness required to remove PCE from the water in the aquifer down to 5ppb.

Groundwater velocity in PRB = 2 m/d; Safety factor in PRB design SF=3.5; PCE degradation half-life (first order kinetics): 3 hours