

Remediation of soil and groundwater
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Problem set #0: dry/wet density

Problem 1

1. Volume of voids

$$V_{voids} = V_T - V_S$$

$$V_T = \frac{\pi D^2 h}{4}$$

$$V_S = \frac{m_{dry}}{\rho_s}$$

$$m_{dry} = m_{wet} - m_{water} = m_{wet} - \omega m_{dry}$$

$$\Rightarrow m_{dry} = \frac{m_{wet}}{1 + \omega}$$

So the porosity volume is:

$$V_{voids} = \frac{\pi D^2 h}{4} - \frac{m_{wet}}{1 + \omega} \frac{1}{\rho_s} = 572 - 312 = 260 \text{ cm}^3$$

2. Volume of water initially present in the soil

$$V_L = \frac{M_L}{\rho_{eau}} = \frac{\omega m_{dry}}{\rho_{eau}} = \frac{\omega}{\rho_{eau}} \frac{m_{wet}}{1 + \omega} = 17 \text{ cm}^3$$

3. Water to add to reach 90% saturation

$$\frac{V_L}{V_{voids}} = 90\%$$

$$\Rightarrow V_L = 234 \text{ cm}^3$$

So the water volume to add to the soil is: $234 - 17 = 217 \text{ cm}^3$

Problem 2

Toluene contamination in aquifer:

$$K_{OC} = 182 \frac{L}{kg}$$

$$f_{OC} = 0.02$$

$$C_{i,aq} = 20 \frac{mg_{tol}}{L}$$

$$\varepsilon = 0.35$$

In an aquifer (= saturated) there is only two phases: solid and liquid.

Part 1 – Dry bulk density: 1.6 g/cm^3

$$K_D = K_{OC} * f_{OC} = 3.64 \frac{L}{kg} \frac{1 kg}{1000 g} \frac{1 m^3}{1000 L} = 3.64 * 10^{-6} \frac{m^3}{g}$$

$$K_D = \frac{C_{i,s}}{C_{i,aq}}$$

$$\rightarrow C_{i,s} = K_D C_{i,aq} = 3.64 * 10^{-6} \frac{m^3}{g} 20 \frac{mg_{tol}}{L} \frac{1000 L}{m^3} = 0.0728 \frac{mg_{tol}}{g} \frac{1000 g}{1 kg} = 72.8 \frac{mg_{tol}}{kg}$$

We consider 1 m^3 of aquifer (here aquifer refers to the bulk volume, not 1 m^3 of solid volume)

$$M_S = V_T \rho_b = 1 \text{ m}^3 1.6 \frac{g}{cm^3} \frac{10^6 cm^3}{m^3} \frac{1 kg}{1000 g} = 1,600 \text{ kg}$$

$$m_{i,s} = C_{i,s} M_S = 72.8 \frac{mg_{tol}}{kg} 1,600 \text{ kg} = 116.48 \text{ g}_{tol}$$

Part 2 – Wet bulk density: 1.6 g/cm^3

We need to recalculate the mass of dry solid in a cubic meter of aquifer.

$$M_S + M_L = V_T \rho_{wb}$$

$$M_L = V_L \rho_{water} = 0.35 * 1 \text{ m}^3 * 997 \frac{kg}{m^3} = 349 \text{ kg}$$

$$M_S = 1,600 - 349 = 1,251 \text{ kg}$$

$$m_{i,s} = C_{i,s} M_S = 72.8 * 1,251 = 91 \text{ g}_{tol}$$

Less toluene is sorbed on the solid phase because there is less solid phase in the cubic meter of aquifer.