Lecture Notes week 10

Slide 35 – In-situ chemical oxidation

How much potassium permanganate is needed to oxidize all the tetrachloroethylene in the aquifer with the following characteristics?
Areal extent of the plume: 20 m^2
Thickness of the plume: 2 m
Average PCE concentration: $C_{PCE,aq}$ = 400 mg/L
Aquifer porosity: ϵ = 0.35
Organic content fraction: f_{oc} = 0.02
Dry bulk density: ρ_b = 1.6 g/cm^3

$$K_{oc} = 1.55 * 10^2 \frac{L}{kg} \rightarrow K_D = f_{oc} * K_{oc} = 3.1 \frac{L}{kg} = 3.1 \frac{L}{kg} \frac{1\,m^3}{1{,}000\,L} = 3.1 * 10^{-3} \frac{m^3}{kg}$$

1) **How much PCE in the plume?**

$$V_L = V_T \epsilon = 20\,m^2 * 2\,m * 0.35 = 14\,\mathrm{m}^3$$

$$M_S = \rho_b * V_T = 1{,}600 \frac{kg}{m^3} * 20\,m^2 * 2\,m = 64{,}000\,\mathrm{kg}$$

$$m_{PCE} = C_{PCE,aq} V_L + C_{PCE,s} M_S = C_{PCE,aq}(V_L + K_D M_S)$$

$$= 400 \frac{g}{m^3}\left(14\,m^3 + 3.1 * 10^{-3} \frac{m^3}{kg} * 64{,}000\,kg\right) = 85\,\mathrm{kg}$$

2) **Oxidation reaction**

Half-reactions:

$$C_2Cl_4 + 4H_2O \rightarrow 2CO_2 + 4Cl^- + 8H^+ + 4e^-$$

$$MnO_4^- + 3e^- + 4H^+ \rightarrow MnO_2 + 2H_2O$$

Complete reaction :

$$3C_2Cl_4 + 4H_2O + 4MnO_4^- \rightarrow 6CO_2 + 12Cl^- + 8H^+ + 4MnO_2$$

We need 4 moles of potassium permanganate for 3 moles of tetrachloroethylene.

In the soil, there is:

$$n_{PCE} = \frac{85\,kg}{166 \frac{\mathrm{g}}{\mathrm{mol}}} = 511\,\mathrm{mol}$$

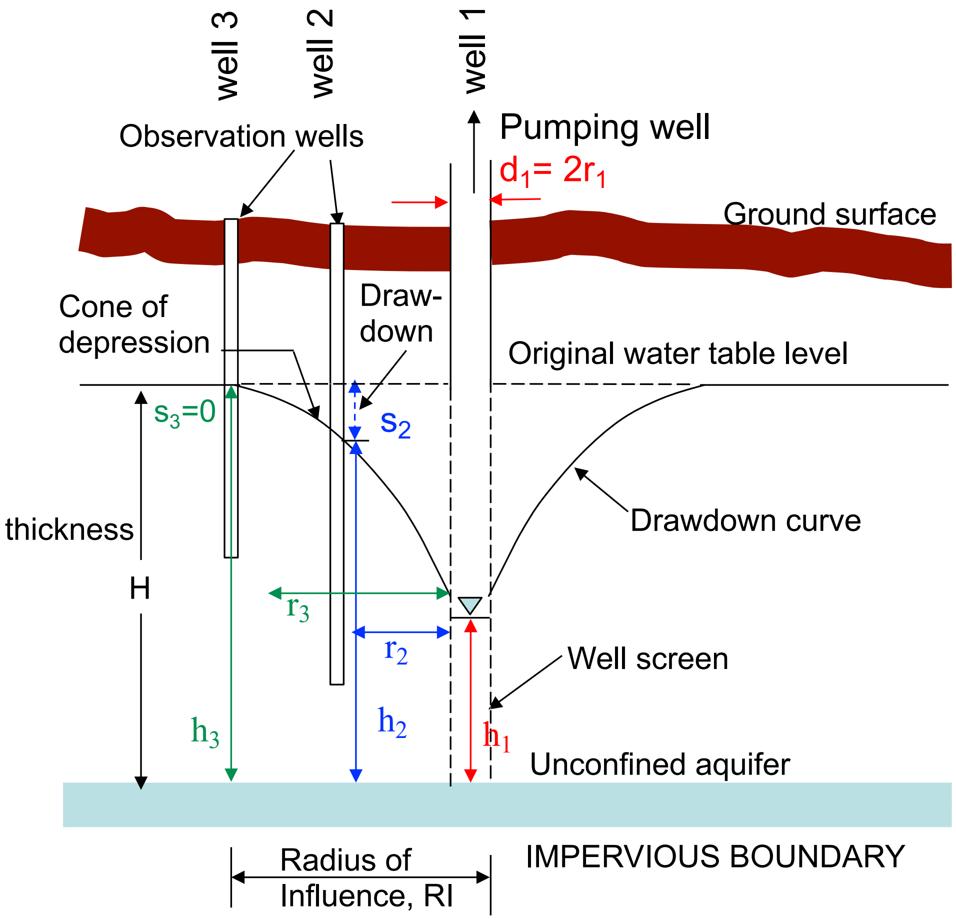
So we need:

$$n_{KMnO_4} = 682\,\mathrm{mol}$$

$$m_{KMnO_4} = 682\,\mathrm{mol} * 158 \frac{\mathrm{g}}{\mathrm{mol}} = 108\,\mathrm{kg}$$

This is the minimum amount of oxidant needed. Depending on the organic matter content, the amount will need to be multiplied by 2-10 to be effective.

Slide 50 – Pump and Treat



Aquifer thickness: H=12.2 m
Well diameter: d_1 = 0.1 → r_1 = 0.05 m
Q = 0.15 m^3/min= 0.15 m^3/min *1440 min/day= 216 m^3/day
K = 8.2 m/day
r_2 = 3 m
s_2= 1.5 m
h_2 = aquifer thickness- drawdown= 12.2 – 1.5 = 10.7 m

1) The drawdown at the well 3m away is 1.5m. What is the drawdown at the pumping well (s_1)?

$$h_1 = \sqrt{Q * \frac{\log\left(\frac{r_2}{r_1}\right)}{\pi K} + h_1^2} = \sqrt{\frac{216 \frac{m^3}{day} \ln\left(\frac{3}{0.05}\right)}{8.2 \frac{m}{day} * \pi} + 10.7^2} = 8.96\, m = 9\, m$$

$$s_1 = 12.2 - 9 = 3.2\, m$$

2) What is the radius of influence of the pumping well (r_3=RI)?

We are looking for h_3 = 12.2 m (i.e, no impact on the water level at the radius of influence, s_3=0):

$$\ln\left(\frac{r_3}{r_2}\right) = \pi * K * \frac{h_3^2 - h_2^2}{Q} = \pi * 8.2\,\frac{m}{day} * \frac{12.2^2 m^2 - 10.7^2 m^2}{216\,\frac{m^3}{day}} = 4.1$$

$$r_3 / r_2 = e^{4.1} = 60.1$$

$$r_3 = 60.1 * \ 3m \ = 180.4\ m$$