CE 5364 Groundwater Transport Phenomena July 28, 2020

Last Homework due August 3

1. The following data for concentration of TCE were taken at a single monitoring well. Use the Mann-Kendall test to determine whether the concentration has an upward or downward trend.

Date	TCE (ppb)
9/92	8
12/92	19
3/93	21
6/93	13
9/93	39
12/93	24
3/94	28
6/94	25

2. Problem 11-1.
3. Problem 11-2.
4. Problem 11-4.
5. A fuel mixture includes benzene, toluene, and ethylbenzene at mole fractions of 0.075, 0.065, and 0.035, respectively. The mixture is allowed to come to equilibrium with the atmosphere at 25°C. Find the concentrations of these VOCs in the air in mg/L and $\mu g/m^3$. Figure 4.13 and Table 7.1 will be helpful.

Problem 5

Mann-Kendall Analysis of Plume

	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Sum #No-#Yes
Concentration	8	19	21	13	39	24	28	25			
Event 1>Event n?		No	No	No	No	No	No	No			7-0=7
Event 2>Event n?			No	Yes	No	No	No	No			5-1=4
Event 3>Event n?				Yes	No	No	No	No			4-1=3
Event 4>Event n?					No	No	No	No			4-0=4
Event 5>Event n?						Yes	Yes	Yes			0-3=-3
Event 6>Event n?							No	No			2-0=2
Event 7>Event n?								Yes			0-1=-1
Event 8>Event n?											
Event 9>Event n?											
							Mann-Kendall Statistic Total				16

$S = +16$ $N = 8$ $\Rightarrow$ Increasing Trend

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Fig 12.7 or 12.9 for $N=8$ Trend is indicated for $|S| \geq 12$

11-1 Given: Contaminated region 100 ft × 150 ft × 15 ft.
TPH on soil = 10000 mg/kg

Find: (a) Total mass of contaminants in kg. $\rho_{soil} = 128$ lb/ft³
(b) Total volume of TPH, assume 50% lost to volatilization, etc; in gal. $SG_{HC} = 0.8$
(c) Residual saturation in soil, n = 0.35.

(a) Total mass $M_{HC} = C_{HC} M_{soil}$

$$= \left(10000 \frac{mg}{kg}\right)(100 ft)(150 ft)(15 ft)\left(128 \frac{lb}{ft^3}\right)\left(\frac{454 g}{lb}\right)\left(\frac{1 kg}{1000 g}\right)$$

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$$= (1.31 \times 10^{11} mg)\left(\frac{1 kg}{10^6 mg}\right)$$

$$\boxed{M_{HC} = 131{,}000 \text{ kg}}$$

(b) Total volume of TPH if 50% lost

$$V_{HC\,released} = \frac{2 M_{HC}}{\rho_{HC}} = \frac{2(131{,}000 kg)}{0.8 (1 kg/L)} =$$

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$$= (327{,}000 L)\left(\frac{1 gal}{3.785 L}\right)$$

$$\boxed{V_{HC} = 86{,}500 \text{ gal}}$$

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(c) Residual saturation n = 0.35

$$V_{voids} = n V_{soil}$$

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$$= 0.35 (100 ft)(150 ft)(15 ft)\left(\frac{7.48 gal}{ft^3}\right)$$

$$= 589{,}000 \text{ gal}$$

$$S_{HC} = \frac{V_{HC}}{V_{voids}}$$

$$= \frac{\frac{1}{2}(86500) gal}{589{,}000 gal}$$

$$\boxed{S_{HC} = 0.073}$$

11.2 | Given: DNAPL source • Pool of free phase $A = 200 ft^2$, $d = 5 ft$
• Residual DNAPL $A = 100 ft^2$, 5 ft in unsaturated zone, 15 ft in saturated zone

• $S_{UZ} = 0.10$
• $S_{SZ} = 0.35$
• $S_{FP} = 0.70$

Find: (a) Total Volume of DNAPL
(b) Amount pumpable on theoretical basis, $n = 0.3$.

(a) Total volume $V_T = V_{UZ} + V_{SZ} + V_{FP}$

$V_{UZ} = S_{UZ} V_{UZ\,voids} = 0.10(0.30)(100 ft^2)(5 ft)$

$V_{UZ} = 15 ft^3$

8 $V_{SZ} = S_{SZ} V_{SZ\,voids} = 0.35(0.30)(100 ft^2)(15 ft)$

$V_{SZ} = 158 ft^3$

$V_{FP} = S_{FP} V_{FP\,voids} = 0.70(0.30)(200 ft^2)(5 ft)$

$V_{FP} = 210 ft^3$

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$V_T = 15 ft^3 + 158 ft^3 + 210 ft^3$

$V_T = 383 ft^3$

(b) Pumpable Amount $= V_{SZ} + V_{FP}$
$= 158 ft^3 + 210 ft^3$

2 Pumpable Amount $= 368 ft^3$

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11.4 Given: Gasoline in monitoring well, $S_g = 0.8$.
$h_w = 6$ ft.

Find: Find h_f

$$h_f = h_w \frac{\rho_w - \rho_{water}}{\rho_{water}} = h_w \frac{SG_w - SG_g}{SG_g}$$

$$= 6\text{ft} \frac{(1-0.8)}{0.8}$$

$$\boxed{h_f = 1.5 \text{ ft}}$$

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4 Given: Fuel Mixture $x_{benzene} = 0.075$, $x_{toluene} = 0.065$, $x_{ethylbenzene} = 0.035$ Equilibrium w/ air @ 25°C

Find: Concentrations in air in mg/L & µg/m³

$$C\left(\frac{mg}{L}\right) = \frac{x_a P_o^a MW_a}{RT}$$

$T = 273°K + 25°C = 298°K$
$R = 0.0821 \frac{L\,atm}{mole\,°K}$

Chemical	x_a	P_o^a mmHg	MW_a g/mole	C mg/L	C µg/m³
Benzene	0.075	60	78.11	18.9	18.9×10^6
Toluene	0.065	22	92.1	7.1	7.1×10^6
Ethylbenzene	0.035	7	106.17	1.4	1.4×10^6

$$C\left(\frac{mg}{L}\right) = \frac{x_a (P_o^a \text{ mmHg}) \left(\frac{1 \text{ atm}}{760 \text{ mmHg}}\right)\left(MW_a \frac{g}{mole}\right)\left(\frac{1000 \text{ mg}}{g}\right)}{\left(0.0821 \frac{L\,atm}{mole\,°K}\right)(298°K)}$$

$$= 5.38 \times 10^{-2}\; x_a (P_o^a \text{ mmHg})\left(MW_a \frac{g}{mole}\right)$$

$$C\left(\frac{mg}{L}\right)\left(\frac{1000\,\mu g}{mg}\right)\left(\frac{1000\,L}{m^3}\right) = C\,\frac{mg}{L} \times 10^6$$