National Exams - December 2017

04-Geol-B1 Contaminant Hydrogeology

Duration: 3 hours

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.

4. Each question is of equal value.

5. Clarity and organization of the answer are important. Please show your work.

6. Unless otherwise specified, use water density = 998 kg/m^3, water viscosity = 0.001 kg/m-sec, g = 9.81 m/s^2, 1 atm = 101300 Pa, and R = 8.314 Pa-m^3/gmol-K = 0.082 atm-L/mol-K.

Marking Scheme:

1.	(a) 7 marks;	(b) 5 marks;	(c) 8 marks
2.	(a) 7 marks;	(b) 6 marks;	(c) 7 marks
3.	(a) 10 marks;	(b) 5 marks;	(c) 5 marks
4.	(a) 4 marks;	(b) 8 marks;	(c) 8 marks
5.	(a) 6 marks;	(b) 7 marks;	(c) 7 marks

Question 1

a) A landfill is leaking leachate into an underlying aquifer such that the concentration of chloride in the aquifer below the landfill is 100 mg/L. The Darcy velocity in the aquifer is 0.35 m/day, the aquifer porosity is 0.35, and the dispersivity in the aquifer is 10 m. Assuming that a one-dimensional solution is appropriate for this scenario, determine the concentrations of chloride in the aquifer 1000 m from the landfill in the direction of groundwater flow after 900 and 1100 days. The effective diffusion coefficient for chloride in the aquifer is 10^{-10} m^2/sec. Discuss the conditions under which a one-dimensional solution would be appropriate for this system. **(7 marks)**

b) Determine the time required for 90 % of a chemical to degrade in water assuming a degradation rate coefficient of 0.001 day^{-1}. **(5 marks)**

c) A train derailment led to the almost instantaneous release of hydrochloric acid into a shallow aquifer. The concentration of chloride in the release was 3500 mg/L and the area over which the release infiltrated the ground was 100 m^2. The aquifer Darcy velocity was 0.1 m/day, porosity was 0.36, longitudinal dispersivity was 15 m, transverse dispersivity was 2 m, and the effective diffusion coefficient for chloride in the aquifer was 10^{-10} m^2/sec. If the transport can be considered to be two-dimensional (horizontal transport), determine the maximum concentration of chloride in the aquifer after 100 days, and the location of this concentration. Also determine the concentration of chloride 100 m from the centre of the spill location after 100 days. Assume that no reactions occur to influence the chloride concentration. **(8 marks)**

Question 2

a) A sand has a porosity of 0.33, bulk density of 1.8 g/cm^3, and organic carbon fraction of 0.007. Perchloroethylene (PCE) ($\log K_{ow} = 0.29$) absorption to this sand has been found to be linear. The sand is placed in a 5 cm diameter, 80 cm long column, and water containing 50 mg/L of PCE has been added to the column at one end at a rate of 5.2 mL/min. Determine the concentration of PCE in the effluent from the column after 4 days if the column has a dispersivity of 5 cm and an effective diffusion coefficient of 10^{-6} cm^2/s. **(7 marks)**

b) At 20 °C there is 1m^3 of gas and 42g TCE in the gas phase. If the molecular weight of TCE is 131 g/mol, find the partial pressure of TCE and aqueous concentration of TCE. Henry's coefficient for TCE is 0.42, the vapour pressure at 20 °C of TCE is 8590 Pa and the solubility of TCE is 1100 mg/L. **(6 marks)**

c) It was discovered that PCE seeping from a landfill site to an aquifer (the aquifer had soil properties similar to the ones that have been described in Q 2(a)), was being biodegraded in the aquifer, subject to first order decay with a half-life of 600 days. Assuming that the one-dimensional equation for contaminant transport with a Type I boundary condition could be applied to the movement of PCE along the centerline of the plume, with the additional impact of first order decay, determine the concentration of PCE 30 m from the landfill boundary after 1000 days. **(7 marks)**

Question 3

A leaking underground storage tank at a chemical manufacturing facility has led to a pool of benzene (H = 0.0055 atm-m^3/mol, log K_{ow} = 2.13 at 20 C) and toluene (H = 0.0066 atm-m^3/mol, log K_{ow} = 2.77 at 20 C) resting on the water table. A lab analysis indicates that the total (dissolved, vapour, and sorbed) concentrations of benzene and toluene are 1,500 and 2,200 mg/kg, respectively. The soil has a porosity of 0.4, a bulk density of 1.8 g/cm^3, and a f_{oc} of 0.03. The soil temperature is 20 °C, the water saturation is 0.3, and the gas saturation is 0.7 (no NAPL phase).

a) Determine the water phase concentrations of benzene and toluene in the porewater in the contaminated zone. **(10 marks)**

b) Determine the gas phase concentrations of benzene and toluene in the pore gas in the contaminated zone. **(5 marks)**

c) Determine the concentrations of benzene and toluene in the soil phase in the contaminated zone. **(5 marks)**

Question 4

a) A capillary tube of diameter 0.1 mm was placed in a pan containing a fluid with a density of 1400 kg/m^3. The fluid moved up the capillary tube to a height of 4 cm. If the air-fluid contact angle was 10 degrees, determine the air-liquid interfacial tension. **(4 marks)**

b) A droplet of mercury (Hg) is held between two glass plates. The plates are 10 microns apart and the mercury droplet has a volume of 0.7 mL. Assuming that the mercury is nonwetting with respect to air on the glass, and that the mercury droplet is approximately cylindrical in shape, determine the weight of the upper plate. The air-Hg interfacial tension is 480 dynes/cm. **(8 marks)**

c) Given TCE vapour concentration is 100 mg/L, in a soil with soil distribution coefficient of 2 L/kg, porosity of 0.4, bulk density of 2 kg/L and the water and gas saturations of 0.3 and 0.7 respectively. Find the total mass of TCE per m^3 of soil. (H = 0.42). **(8 marks)**

Question 5

a) A soil has a permeability of 10^{-12} m^2, and a porosity of 0.4. The Brooks-Corey parameters for the soil are $\lambda = 3.0$, $p_d = 40$ cm, $S_{wr} = 0.1$, $S_{max} = 1.0$. Determine the moisture content in the soil at the ground surface if under conditions of zero vertical flux the water table is 2 m below the ground surface. If under new conditions, the relative humidity at the ground surface is 50%, and there is no vertical flux, determine the depth to the water table. **(6 marks)**

b) Measurements of soil moisture at a field site made using time domain reflectometry indicate that the water saturation at the ground surface is 0.1. At 1 m below the ground surface the saturation is 0.5. Tensiometer measurements indicate that the water pressures are -2 m at the ground surface and -1.0 m at the depth of 1 m below the ground surface. If the irreducible water saturation is 0.05, the maximum saturation is 1.0, and the soil can be characterized using the Brooks-Corey relationship determine p_d and λ, and depth to the water table if there is no water flow. The soil porosity is 0.4 and the soil hydraulic conductivity is 10^{-3} cm/sec. **(7 marks)**

c) If the soil in Q5(b) was initially at a uniform water saturation of 0.05 to a depth of 10 m, and rainfall produced an infiltrating water pulse with a saturation of 0.9, determine how long it would take for the water pulse to move 30 cm below the ground surface using an appropriate method. **(7 marks)**

TABLE G.2 The Error Functions

X	erf(X)	erfc(X)
0.00	0.000000	1.000000
0.05	0.056372	0.943628
0.10	0.112463	0.887537
0.15	0.167996	0.832044
0.20	0.222703	0.777297
0.25	0.276326	0.723674
0.30	0.328627	0.671373
0.35	0.379382	0.620618
0.40	0.428392	0.571608
0.45	0.475482	0.524518
0.50	0.520500	0.479500
0.55	0.563323	0.436677
0.60	0.603856	0.396144
0.65	0.642029	0.357971
0.70	0.677801	0.322199
0.75	0.711156	0.288844
0.80	0.742101	0.257899
0.85	0.770668	0.229332
0.90	0.796908	0.203092
0.95	0.820891	0.179109
1.00	0.842701	0.157299
1.10	0.880205	0.119795
1.20	0.910314	0.089686
1.30	0.934008	0.065992
1.40	0.952285	0.047715
1.50	0.966105	0.033895
1.60	0.976348	0.023652
1.70	0.983790	0.016210
1.80	0.989091	0.010909
1.90	0.992790	0.007210
2.00	0.995322	0.004678
2.10	0.997021	0.002979
2.20	0.998137	0.001863
2.30	0.998857	0.001143
2.40	0.999311	0.000689
2.50	0.999593	0.000407
2.60	0.999764	0.000236
2.70	0.999866	0.000134
2.80	0.999925	0.000075
2.90	0.999959	0.000041
3.00	0.999978	0.000022