National Exams - May 2018

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) 4 marks;	(b) 4 marks;	(c) 4 marks;	(d) 4 marks;	(e) 4 marks
2.	(a) 6 marks;	(b) 8 marks;	(c) 6 marks		
3.	(a) 8 marks;	(b) 12 marks			
4.	(a) 8 marks;	(b) 6 marks;	(c) 6 marks		
5.	(a) 3 marks;	(b) 5 marks;	(c) 6 marks;	(d) 6 marks	

Question 1

a) The approximate coefficient of diffusion for Cl^- in water is 2×10^{-5} cm^2/s. Estimate the effective diffusion coefficient of Cl^- in a saturated porous medium having a porosity of 0.3 and tortuosity of 1.22. **(4 marks)**

b) Determine the time required for 99 % of a chemical to hydrolize in water assuming a hydrolysis rate coefficient of 0.001 day^{-1}. **(4 marks)**

c) A capillary tube of radius 0.25 mm is inserted into a beaker of water. If the air-water interfacial tension is 72 dynes/cm, determine height of the water in the tube. Assume water is completely wetting to the tube material. **(4 marks)**

d) The groundwater in a porous medium travels with a linear (porewater) velocity of 16 cm/day. Determine the transport velocity of an organic contaminant having a K_d of 6.6 mL/g in the medium with porosity of 0.37 and solids density of 2.64 g/cm^3. **(4 marks)**

e) Distinguish between the processes (both the physical and chemical) that simply retard the movement of contaminant from those that are capable of reducing its mass concentrations. **(4 marks)**

Question 2

a) Water containing 110 mg/L of chloride is introduced into a 1 m long column of 10 cm diameter at a flow rate of 6 mL/min. If the longitudinal dispersivity of the sand in the column is 0.08 m, the porosity of the sand is 0.37, and the sand bulk density is 1.6 g/cm^3, determine the concentration of chloride leaving the column after 11 hours. The effective diffusion coefficient for chloride in the sand is 1.0×10^{-10} m^2/sec. **(6 marks)**

b) A buried pipe leaked 1000 kg of an organic compound over the full depth of a 10 m thick confined aquifer over a very short period of time. The groundwater Darcy velocity in the aquifer was 0.05 m/day and the porosity of the aquifer was 0.3. The dispersivity of the aquifer was found to be 10 m in the horizontal directions parallel to the direction of groundwater flow and perpendicular to groundwater flow. (i) Determine the maximum concentration of organic compound in the aquifer after 1 year, and the location of this maximum concentration. (ii) Determine the concentration of the organic compound at a location 1 km directly downgradient from the original spill site after 10 years. **(8 marks)**

c) Briefly discuss three principle components required for the development of the conceptual site model. **(6 marks)**

Question 3

a) A soil sample has been found to have TCE vapour concentration of 100 mg/L. The distribution coefficient of TCE in soil is 2 L/kg. The soil sample has 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 kg of the soil. (H = 0.42) **(8 marks)**

b) A soil is known to contain a NAPL mixture of toluene and benzene at 10 °C. The water phase concentration of toluene in the NAPL zone is 125 mg/L. The soil f_{oc} is 0.015 and the bulk density is 1.85 g/cm^3. Toluene solubility is 500 mg/L and benzene solubility is 1700 mg/L. At 10 °C the toluene Henry's constant is 0.124, the benzene Henry's constant is 0.114, toluene K_{oc} is 180 L/kg and benzene K_{oc} is 72 L/kg. (i) Determine the NAPL phase composition (mole fractions) and water phase concentration of benzene. (ii) Determine the gas phase concentrations (mg/L) of benzene and toluene. (iii) Calculate the soil phase concentrations (mg/kg) of benzene and toluene. **(12 marks)**

Question 4

a) The water table of an unconfined aquifer is 2.5 m below the ground surface. The vadose zone above the water table consists of two layers. The upper layer is clay (2 m thick), while the lower layer is coarse sand (0.6 m thick). The hydraulic gradient in the sand is 0.05 (positive is up), while the hydraulic gradient in the clay is 0.26. The clay and sand can be described by the Brooks-Corey relationships (for sand P_d is 0.05 m water, S_{wr} is 0.1, $\lambda = 6.0$, for the clay P_d is 0.5 m water, S_{wr} is 0.25, $\lambda = 2.0$). Find the water saturations in the clay and sand layers at the clay-sand interface and the water saturation at the ground surface. **(8 marks)**

b) If the water saturation at the ground surface is 0.26, and the soil properties and hydraulic gradients are the same as in Question 4 (a,) find the depth to the capillary fringe and the new depth to the water table. **(6 marks)**

c) If the humidity in the clay in Question 4 (a) is 15 % at the ground surface, find the water saturation, and hydraulic head at the ground surface. The soil temperature is 10 °C. **(6 marks)**

Question 5

a) It has been proposed that underground waste disposal vaults located in the unsaturated zone be surrounded by layers of very coarse material to keep out water. Explain the reasoning behind this proposal. **(3 marks)**

b) If a soil is initially at a saturation of 15%, and rainfall produces a saturation at the ground surface of 84%, determine the time for the wetting front to move 1 m into the soil and determine the velocity at which the front is moving at this time. The soil properties can be described by the Brooks-Corey relationships with p_d = 0.2 m, and λ= 3.0, S_{wr} = 0.05, S_m= 1.0, n = 0.4, and K = 10^{-3} cm/sec. **(5 marks)**

c) Discuss the advantages and disadvantages of three remediation techniques that might be considered for remediation of DNAPL contaminated fractured clay soil. **(6 marks)**

d) A field study is required to determine the suitability of a proposed site for municipal waste disposal. Discuss the important variables that would be required to be measured at the site, why they are important, and describe how the variables would be measured. **(6 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