HYDROGEOLOGICAL TRANSPORT PHENOMENA

Final Exam **30/01/2004**
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1. Under normal conditions (p = 1 *atm*, T = 20°*C*), 368 grams of kitchen salt can be dissolved in 1 liter of distilled water. This results in a saturated salt solution. The solid salt mass density is 2 *kg/l* and pure water mass density is 1 kg/m^3. Assume that *the volume of the solution is equal to the sum of volumes of solid salt and water*.
   a) Calculate the salt mass concentration.
   b) Calculate the solution mass density
   c) Calculate the salt mass fraction.

2. A landfill has a clay underlining to prevent the pollution of the aquifer below the landfill. The clay has a permeability of 10^{-16} m^2, a porosity of 0.385 and a thickness of one meter. Piezometric measurements show that pressure heads on top and bottom of the clay layer are 5*m* and 5.5*m*, respectively. The concentration of pollutants on top of the clay lining is around 800 *mg/l* and remains constant.
   Additional information: Molecular diffusion coefficient in water, D_{mol}, = $10^{-8} m^2/s$; tortuosity = 3.3; dispersivity = 0.01*m*; viscosity, μ = 10^{-3} *kg/m.s*; water density, ρ= 10^3 kg/m^3; g = 9.8 m/s^2
   Hint: It's more convenient to work with year as the time unit.
   a) Calculate the average pore velocity.
   b) How long does it take for the concentration of pollutants in the groundwater just below clay to reach 400 *mg/l*?
   c) Calculate the concentration under the clay layer after 20 years and 40 years.

3. The following set of experiments has been carried out for determining distribution coefficient of an adsorbing solute in a sandy soil. Five batches of soil suspension were prepared by pouring 500 *g* of dry sand into 900 *ml* of distilled water. To each batch, a solution of 100 *ml* containing the solute at a concentration C_i was added. The suspension was gently stirred for a few hours until it was believed that adsorption equilibrium was reached. Then, water was sampled and the solute concentration was measured. The results are given in the following table. Use this data to calculate the distribution coefficient.

C_i (*g/l*)	20	30	40	60	80
C_{eq} (*g/l*)	0.79	1.21	1.62	2.38	3.25

4. A column experiment was carried out with undisturbed samples of the same sandy soil as in problem 3. The soil grain density is 2500 *g/l*. A solution containing common salt and the same adsorbing solute as in problem 3 were fed to the column continuously at a flow rate of 13.3 $ml/hr/cm^2$. The breakthrough of salt and adsorbing solute were measured at a distance of 40cm from the inlet. The same

relative concentrations for salt and solute are measured but at different times. The data are given in the following table.

t (hr) for salt	0.5	0.6	0.7	0.8	0.9	1.03	1.1	1.2	1.4	1.8
C/Co	0.001	0.01	0.07	0.18	0.38	0.54	0.70	0.82	0.94	0.99
t (hr) for adsorbing solute	3	3.6	4.2	4.8	5.4	6.18	6.6	7.2	8.4	10.8

Assuming that the solute's adsorption may be modelled as linear equilibrium, calculate the soil porosity, dispersivity, and distribution coefficient.
How is the value of distribution coefficient calculated here different from the value calculated in problem 3? Why is there such a difference?

The solute concentration in a column with continuous injection of the solute may be approximate by the following formula:

$$C(x,t) = \frac{1}{2} C_0 erfc\left(\frac{x - vt}{2\sqrt{D_x t}} \right)$$

The derivative of this solution is given by:

$$\frac{\partial C}{\partial t} = \frac{C_0 (x + vt)}{4t\sqrt{\pi D_x t}} e^{-(x-vt)^2 / 2D_x t}$$

Tables of Error Function and Complementary Error Function
$\left(erfc(-\beta) = 2 - erfc(\beta)\right)$

β	erf (β)	erfc (β)
0	0	1.0
0.05	0.056372	0.943628
0.1	0.112463	0.887537
0.15	0.167996	0.832004
0.2	0.222703	0.777297
0.25	0.276326	0.723674
0.3	0.328627	0.671373
0.35	0.379382	0.620618
0.4	0.428392	0.571608
0.45	0.475482	0.524518
0.5	0.520500	0.479500
0.55	0.563323	0.436677
0.6	0.603856	0.396144
0.65	0.642029	0.357971
0.7	0.677801	0.322199
0.75	0.711156	0.288844
0.8	0.742101	0.257899
0.85	0.770668	0.229332
0.9	0.796908	0.203092
0.95	0.820891	0.179109
1.0	0.842701	0.157299
1.1	0.880205	0.119795
1.2	0.910314	0.089686
1.3	0.934008	0.065992
1.4	0.952285	0.047715
1.5	0.966105	0.033895
1.6	0.976348	0.023652
1.7	0.983790	0.016210
1.8	0.989091	0.010909
1.9	0.992790	0.007210
2.0	0.995322	0.004678
2.1	0.997021	0.002979
2.2	0.998137	0.001863
2.3	0.998857	0.001143
2.4	0.999311	0.000689
2.5	0.999593	0.000407
2.6	0.999764	0.000236
2.7	0.999866	0.000134
2.8	0.999925	0.000075
2.9	0.999959	0.000041
3.0	0.999978	0.000022