HYDROGEOLOGICAL TRANSPORT PHENOMENA

Final Exam **30/01/2015**

You are only allowed to use the Summary Lecture Notes and Analytical Solutions Handout.
Make sure to give all relevant formulas, steps of computations, and units.
Some given parameter values may not be needed and some quantities values are not specified. In the latter case, you should assume reasonable values.

Problem 1

Whisky contains 40% ethylic alcohol by volume. Consider two different bottles each partially filled with whisky. In one bottle, the headspace was filled with air under atmospheric pressure. In the other bottle, all air was extracted before putting whisky in there. Both bottles are at room temperature. See the table below for properties of water and alcohol.

Calculate the ethylic alcohol mole fraction and mass concentration in the headspace of each bottle. *(20+5 points)*

	Mass density (g/cm^3)	Mol. Weight (g/mole)	Vapor pressure (Pa)
Water	1.00	18	2300
Alcohol	0.79	46	6000

Problem 2

As a result of a pipe rupture in a factory, a large volume of a solution containing an organic solute enters an unpaved ditch and quickly penetrates the soil and the groundwater. This creates an instantaneous source of pollution over a length of 20 m and the whole depth of the aquifer. The total volume of lost liquid was 10 m^3 containing the solute at a concentration of 250 mg/L.

The aquifer is fully saturated with a thickness of 5 m. It consists of homogeneous sandy material. Groundwater flow is uniform and perpendicular to the pollution source plane.

The depths to the groundwater table was measured in two wells, 50m apart in the flow direction and with the same wellhead elevation, to be 3.50m and 3.60m. The hydraulic conductivity was estimated to be 50 m/day. Soil bulk density is assumed to be 1.75 g/cm^3. For determining transport properties of the aquifer material, laboratory experiments were carried out on a number of undisturbed soil samples from the site, as explained below.

Question 2a: First, a soil column of 60 cm long with a diameter of 4 cm was prepared. A salt solution was injected for a period of 15 hours at a rate of 0.001 *L/min*. The salt concentration was measured at a location 50 cm from the inlet. The results are given in the table below. Use this data to calculate porosity and longitudinal dispersivity. *(15 points)*

Time (min)	Relative Concentration (C/C_0)	Time (min)	Relative Concentration (C/C_0)
100	0.021	250	0.750
150	0.205	300	0.882
175	0.352	350	0.955
200	0.500	400	0.982
225	0.640	450	0.993

Question 2b: Next, breakthrough experiments were carried out with water containing the solute. The flow rate was again 0.001 *l/min* for a period of 15 hours, but this time the solute was introduced for a period of one hour only, at a concentration of 150 *mg/l*. The solute concentrations measured at a location 50 cm from the inlet are given in the table below. Use this data to determine the distribution coefficient of the solute. (*5 points)*

Time (min)	Solute Conc. (*mg/L)*	Time (min)	Solute Conc. (*mg/L)*
200	0	1,100	9.824
500	1.067	1,200	8.716
700	6.041	1,300	7.365
800	8.535	1,600	3.660
900	10.022	1,700	2.775
1,000	10.375	1,800	2.073

Question 2c: Assume that the pollution can be modelled as a planar source. Write the governing equation as well as initial and boundary conditions for the field problem and provide the analytical solution. Give all relevant assumptions.

(*5 points)*

Question 2d: There is a water well 50 m down gradient from the spill. What will be the maximum solute concentration at the well and when will it be reached? Assume that laboratory-determined dispersivity and distribution coefficient values (calculated in parts **a** and **b)** should be modified by a factor 10 for rough flied calculations. If you could not calculate parameter values in parts **a** and/or **b**, just assume some reasonable values for this part. (*15 points)*

Problem 3

A series of batch experiments have been carried out to study the sorption of phosphorous to a glacial outwash. Nine suspensions were prepared in nine different flasks, each containing 10 gm of the sediment and 100 mL of water with different concentrations of dissolved disodium phosphate. The flasks were shaken for one day on an autoshaker. The samples were then filtered and phosphate concentrations were measured in the filtrate (i.e. water). The initial and the corresponding equilibrium concentrations of phosphate are given in the table below.

Initial conc. (mg/L)	35	70	130	170	250	320
Equilibrium conc. (mg/L)	10	20	39	51	75	100

It was known that the sediments already had some adsorbed phosphate in their natural state. Thus, a solution of HCl was used to extract the adsorbed phosphate and it was found that the amount of phosphorus sorbed to the sediment prior to the test was 16 µg/g.

Question 3a: Plot the adsorption isotherm (s vs C) for the phosphate and observe the form of the curve. (*15 points*)

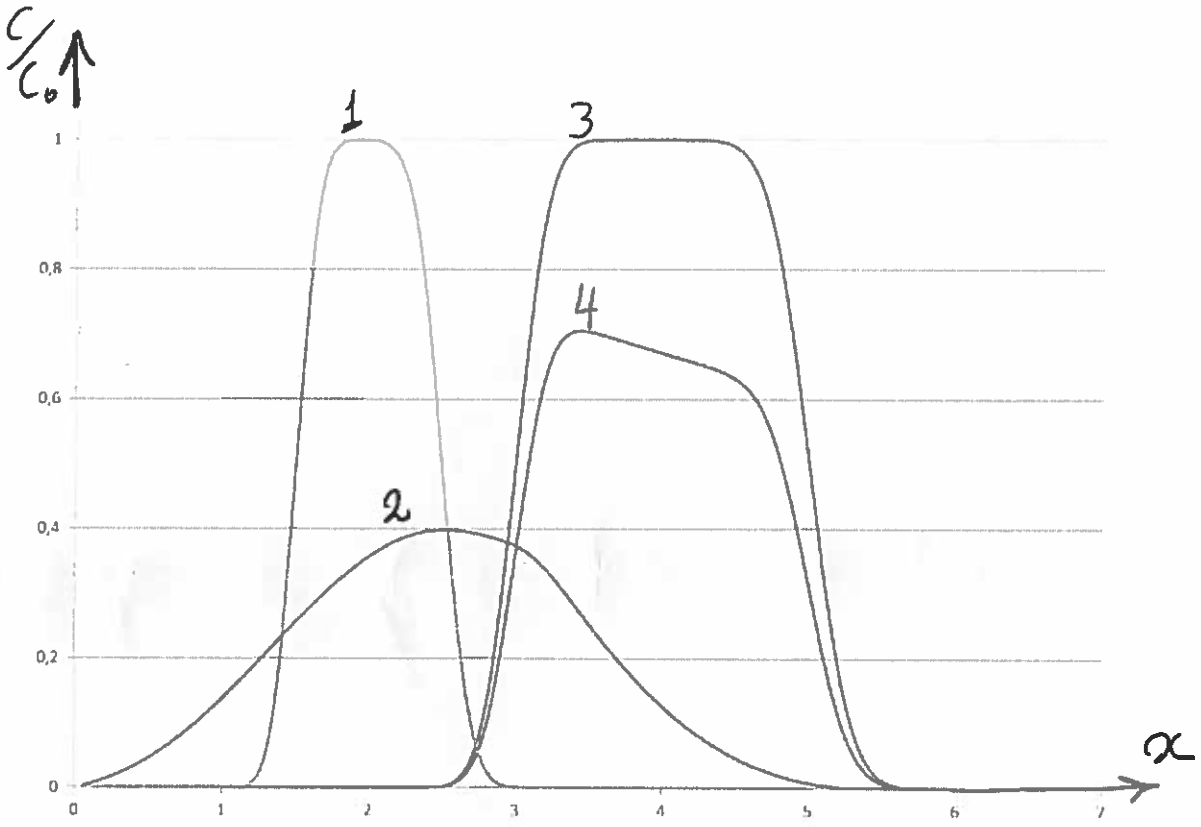
Question 3b: What kind of isotherm does it suggest? Give the corresponding adsorption formula and calculate the adsorption parameter(s). (*5 points*)

Problem 4

A set of solute transport experiments in a one-dimensional laboratory column has been carried out. In this experiment, first, steady-state flow was established. Then, four different solutes were injected into the column for a finite duration. The solutes are known to be of four different types: one is conservative, one is decaying, one undergoes equilibrium adorsption, and one undergoes kinetic adsorption. Results of measurements of solute concentrations after 500 minutes are shown in the figure below.

a) Identify the curves of different solute types. (*15 points*)

b) Determine the (approximate) flow velocity and the duration of injection of solutes. (*15 points*)



finite duration injection