Final exam GEO3-4301 Soil and Water Pollution
2 February 2006 14:00 – 17:00 h

General remarks:

- This exam contains five questions.
- Please answer concisely.
- Answers in English or in Dutch are allowed.
- At the end of the examination hand in all your answer sheets.
- Write down your name or student number on all answer sheets.

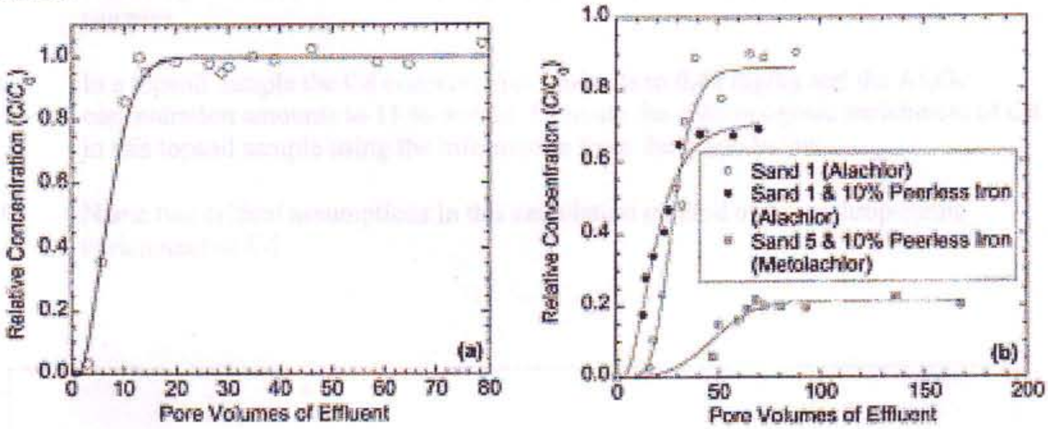
1. Explain in brief (max. 20 words per answer)
   a. why the pH in soil pore water is generally lower near a forest edge than in the centre of a forest.
   b. why the peak concentration of an instantaneous contaminant release into a river decreases in downstream direction.
   c. why hysteresis occurs in the relationship between river discharge and suspended solids concentrations during single flood events.
   d. why heavy metals are generally more mobile in sandy soils than in loamy soils.
   e. why chloride concentrations in groundwater are generally lower below heather than below forests.
   f. why groundwater of peatlands contains no nitrate.
   g. why dissolved iron disappears in the sulphate reduction zone in groundwater.
   h. why the nitrification rate is larger at the edge of an ammonium plume than in the centre of the plume.
   i. why a TCE is more mobile in an aquifer with low organic carbon content than in an aquifer with high carbon content.
   j. why the $Na^+ : K^+$ ratio increases from the centre to the edge of a landfill leachate contaminated plume.

(30 points)

2. The decomposition of organic matter in bed sediments or aquifer sediments causes a lowering of the redox potential in a number of consecutive steps. In soil and groundwater these different steps are reflected in different layers or zones characterised by a predominant redox reaction. Describe five of these layers in terms of the predominant oxidant and the reaction products.

(15 points)

3. A column experiment with metolachlor and alachlor, both widely used herbicides in agriculture, in sands of different composition yields typical breakthrough curves a shown in the figure below (Lee and Benson, 2004; J Environm. Qual. 33:1682-1693). Figure (a) shows the breakthrough curve for metolachlor in a silica sand and figure (b) shows the breakthrough curves for metolachlor and alachlor in so-called green sand, an industrial by product containing zero-valent (metallic) iron, which can degrade both herbicides. On the x-axes, the time is expressed in the number of pore volumes of effluent, i.e. the amount of aqueous solution present in the column. This allows to directly derive the retardation factor from the curves.



a. Explain the shape of the breakthrough curve shown in figure (a).

b. Estimate the distribution coefficient (in l kg^{-1}) for metolachlor in the silica sand (figure (a)) given the sediment parameters:
Bulk density = 1680 kg m^{-3}
Porosity = 0.36
and:

$$R_f = 1 + \frac{\rho_b}{n} K_d$$

c. Describe and explain the main features of the breakthrough curves displayed in figure (b) in comparison with figure (a).

(15 points)

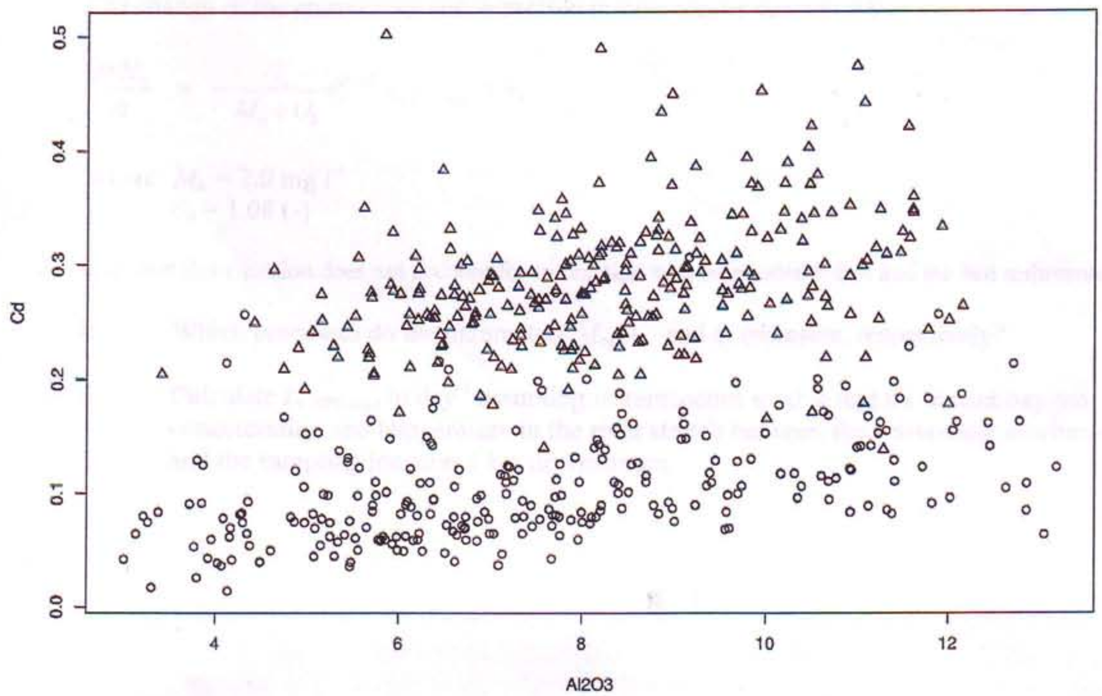
4. For a study to diffuse soil contamination in the Province of Zeeland, soil samples were collected from both the subsoil (about 1 m below soil surface) and the top soil. These samples were analysed for a number of parameters, amongst which Cd and Al_2O_3. In the graph below the Cd concentrations (in mg kg^{-1}) are plotted against the Al_2O_3 concentrations (in % weight) for both the subsoil samples (○) and topsoil samples (Δ).

a. Explain the relation between the Cd and Al_2O_3 concentrations

b. What is probably the reason why the topsoil samples contain more Cd than the subsoil samples

c. In a topsoil sample the Cd concentration amounts to 0.43 mg/kg and the Al_2O_3 concentration amounts to 11 % weight. Estimate the anthropogenic enrichment of Cd in this topsoil sample using the information from the graph below.

d. Name two critical assumptions in this calculation method of the anthropogenic enrichment of Cd.



(15 points)

5. In a river with a cross-sectional area of 6 m^2, wastewater effluent is discharged at a constant rate. To monitor the river quality, samples were collected from the river just upstream and 1 km downstream from the from the wastewater discharge. The effluent water was also sampled. Furthermore, a discharge measurement was performed at the sampling location 1 km downstream from the wastewater discharge. The analysis and measurement results are shown in the table below.

	Upstream from the wastewater discharge	Wastewater effluent	1 km downstream from the wastewater discharge	
Q	-	-	0.3	m^3/s
Cl^-	4	100	10.4	mg/l
NH_4^+	0	22.5	1.2	mg/l
NO_3^-	0.5	3	1.5	mg/l
O_2	5		5	mg/l
T	17	17	17	°C

a. Calculate the discharge of the wastewater effluent in $l\ s^{-1}$.

The change of the ammonium concentration in time can be described by

$$\frac{dNH_4}{dt} = -\frac{O_2}{M_n + O_2}\theta_n^{T-20}\, k_{n,20°C,max}\, NH_4$$

Where $M_n = 2.0\ mg\ l^{-1}$
$\theta_n = 1.08$ (-)

Note that this equation does not account for interaction with suspended solids and the bed sediments.

b. Which processes do the parameters M_n, θ_n and k_n represent, respectively?

c. Calculate $k_{n,20°C,max}$ in day^{-1} assuming instantaneous mixing and a constant oxygen concentration and temperature in the river stretch between the wastewater discharge and the sampling location 1 km downstream.