Final exam GEO3-4301 Soil and Water Pollution
28 January 2010 13:00 – 16:00 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.
- The answers will be available on Blackboard directly after this exam.

1. Explain in brief (max. 50 words per answer)
   a. Why sulphate concentrations in runoff water from forested ecosystems have decreased between 1975 and 2000.
   b. Why ^{137}Cs deposition densities in soil are less on convex parts than on concave parts of a hillslope.
   c. Why the pH of lake water is generally higher during summer than during winter.
   d. Why chloride concentrations in shallow groundwater are generally larger near forest edges than in the centre of the forest.
   e. Why the metal content in the top 5 cm of soils in the floodplains of many European rivers are lower than at 30 cm depth.
   f. Why total phosphorus concentrations in streamwater are higher during storm events than during baseflow conditions.
   g. Why metal concentrations in soil are positively correlated with the aluminium content of the soil.
   h. Why dissolved iron is often absent in shallow groundwater in sandy areas.
   i. Why ammonium concentrations are relatively high in pore water of peat soils.
   j. Why drainage water from mine sites contains high levels of dissolved metals.

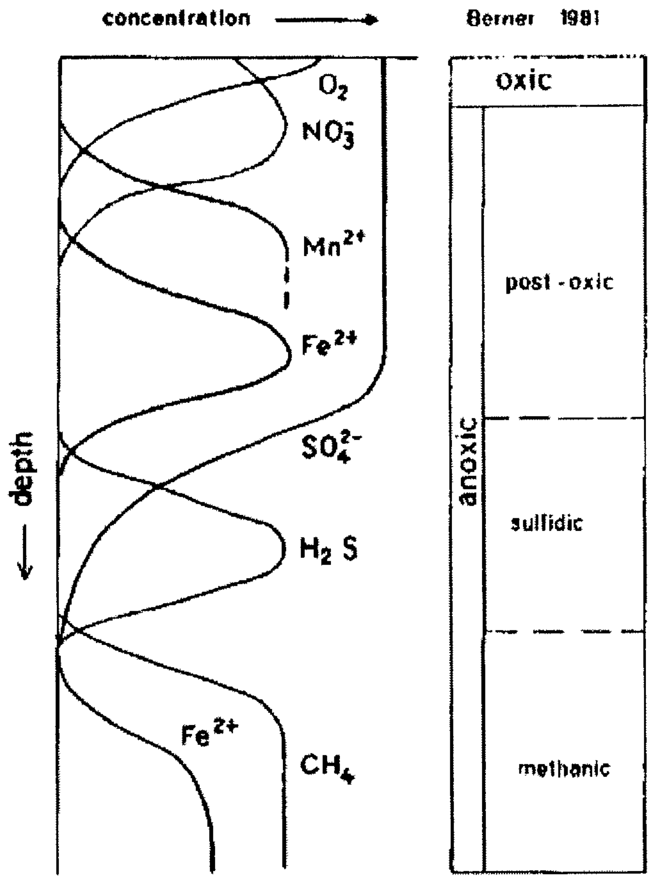
(20 points)

2. In sediments and groundwater, a clear zonation with respect to the chemical composition as depicted in the figure below can often be found.

a. What is the main driving process behind this zonation?

b. Give for each of the four zones (oxic, post-oxic, sulphidic, and methanic) the most important reactions in terms of reactants and reaction products (note that it is not necessary to give a closed reaction equation).

c. Why does the Fe^{2+} concentration decrease in the sulphidic zone?



(15 points)

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3. The figure below shows a so-called rating curve for the river Meuse at Keizersveer, the Netherlands, for the 2000-2006 period. The rating curve depicts the long-term relation between river discharge (Q; $m^3\ s^{-1}$) and the suspended sediment concentration (SSC; $mg\ l^{-1}$) and usually has the form $SSC = a\,Q^{\,b}$.

a. Give the most important reason why there is a positive relation between discharge and the suspended sediment concentration.

The individual SSC measurements display a considerable variation around the rating curve. This is mainly due to the fact that the Q-SSC relation for individual hydrologic events displays hysteresis

b. Give the major reason for the occurrence of the hysteresis effect.

c. Is the hysteresis most-often clockwise or anti-clockwise?

A floodplain section along the river Meuse near Keizersveer is inundated at a discharge of 375 $m^3\ s^{-1}$. The water flow velocity in the floodplain is 0.8 $m\ s^{-1}$ and the water depth is 2 m.

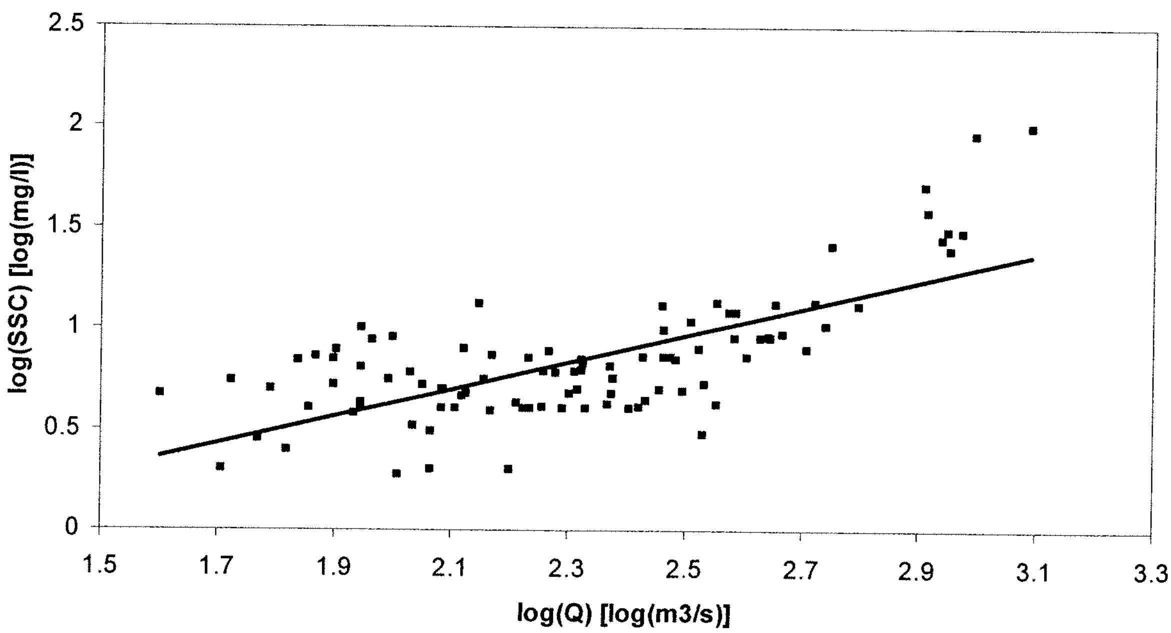
d. Calculate the distance needed to reduce the SSC in the floodplain to 5 $mg\ l^{-1}$ given the parameters of the rating curve $a = 0.22$ and $b = 0.675$, the effective settling velocity of the sediment (i.e. including the effect of shear stress) = 1.5 10^{-5} $m\ s^{-1}$, and:

$$\frac{d\,SSC}{dt} = -\frac{J}{H} \quad \text{and} \quad J = w_s\ SSC$$

Assume the SSC at the point of inflow is equal to the SSC according to the rating curve and neglect dispersion.

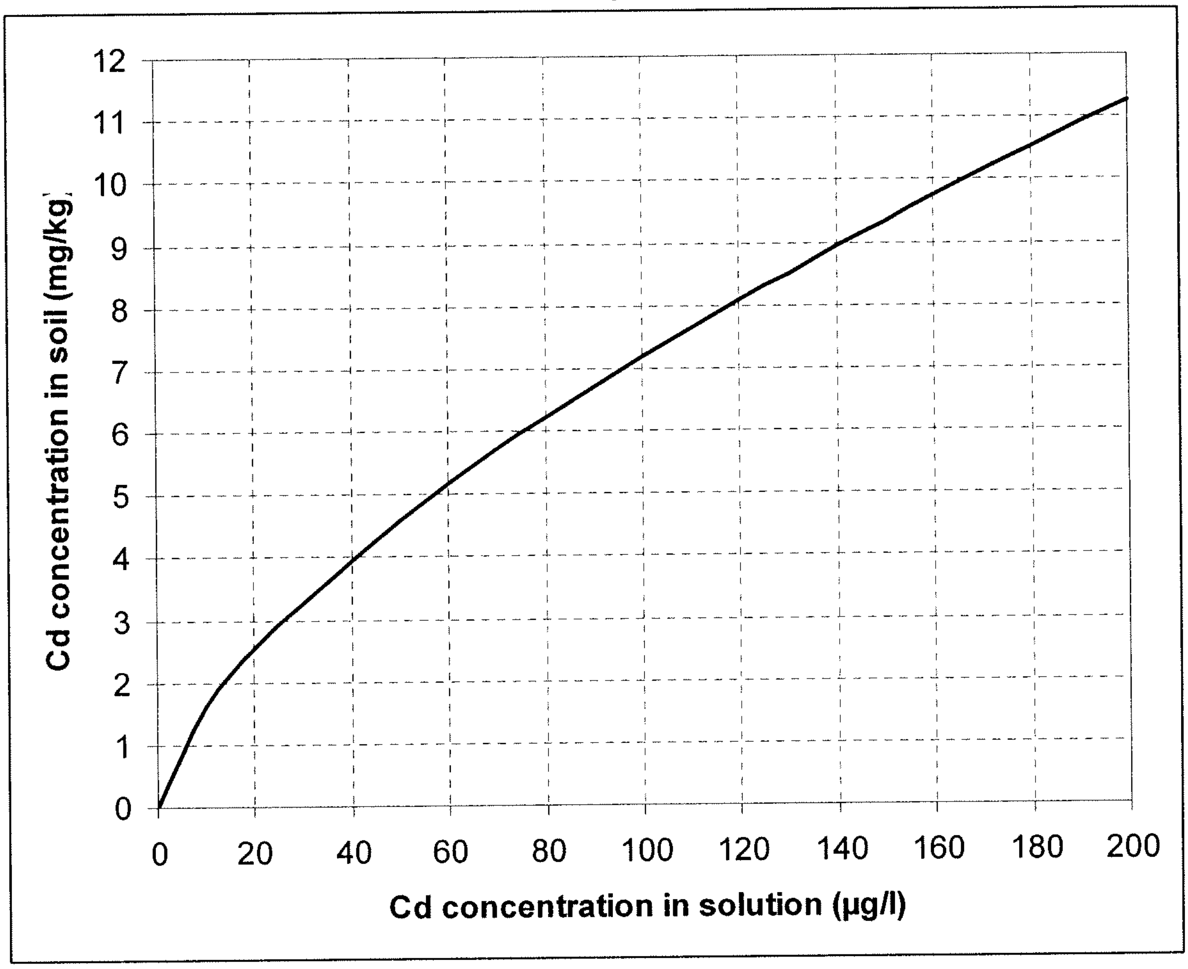
In this calculation the effect of hysteresis has not been taken into account.

e. Would this have caused an underestimation or an overestimation of the distance as calculated in exercise d? Explain your answer.



(22 points)

4. A pipe leakage underneath an industrial facility has discharged cadmium contaminated wastewater in small volumes into groundwater. The cadmium concentration in the waste water amounted 170 µg l^{-1}. Ten years after the beginning of the leakage, the leakage was discovered and repaired. To assess the dispersal of cadmium in the shallow sandy aquifer, the local hydrologic situation and the adsorption characteristics of the aquifer material were determined. The porosity of the aquifer material is 30% and the dry bulk density is 1650 kg m^{-3}. The horizontal groundwater flow velocity was determined to be 30 m per year. To determine the cadmium distribution coefficient a batch-experiment with the aquifer material was carried out, from which the cadmium isotherm shown in the figure below was derived.



a. Derive the cadmium distribution coefficient expressed in l kg^{-1} for the situation described above from the cadmium isotherm.
b. Calculate the maximum horizontal displacement of cadmium 10 years after the beginning of the leakage, given the retardation factor R_f ($=1+ K_d*\rho_b/n$) (neglect dispersion).

(10 points)

5. A small village discharges domestic waste water into a small river with a cross-sectional area of 5 m^2. The discharge of the waste water outfall amounts to 50 l s^{-1}. Analysis of water samples from the waste water and from the river just upstream and 1 km downstream of the waste water discharge gave the following results for chloride ammonium, and nitrate concentrations:

Location	**Cl^- (mg l^{-1})**	**NH_4^+ (mg l^{-1})**	**NO_3^- (mg l^{-1})**
Waste water	400	20	<< detection limit
River water upstream of outfall	10	<< detection limit	0.4
River water 1 km downstream of outfall	88	3.0	0.5

Assume steady state conditions and no additional inflows of tributaries or groundwater in the 1 km long river section downstream of the outfall.

a. Calculate the discharge of the river downstream of the waste water outfall.
b. Sketch a schematic diagram of the concentration profiles of ammonium, nitrate, and chloride as function of distance from the waste water discharge to 1 km downstream from the discharge. Explain in brief which processes are responsible for the shape of the profiles.
c. Calculate the first-order nitrification constant expressed in d^{-1}.

(23 points)