Final exam GEO3-4301 Soil and Water Pollution
29 January 2009 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.
- The answers will be available on WebCT after this exam.

1. Explain in brief (max. 40 words per answer)
   a. Why chloride concentrations in groundwater are generally higher underneath forests than underneath grassland.
   b. Why calcium concentrations in surface water are often in higher during baseflow than during periods of high discharge.
   c. Why nitrate concentration in stream water is generally lower during summer than during winter.
   d. Why positive clockwise hysteresis often occurs in the relationship between river discharge and the suspended sediment concentrations during single flood events.
   e. Why heavy metal concentrations in soil correlate positively with soil aluminium content.
   f. Why drainage water from mine wastes is often extremely acid.
   g. Why dissolved metal concentrations in surface water decrease downstream from mine wastes.
   h. Why ammonium concentrations in surface water decrease downstream from discharges of sewage treatment works.
   i. Why cadmium concentrations are higher in the topsoil than in the subsoil of agricultural areas.
   j. Why the topsoil of floodplains along the river Rhine is less contaminated a locations with high deposition rates than at locations with low deposition rates.

(20 points)

2. a. Explain why the nitrate concentrations in the shallow groundwater are generally low in catchments where the water tables are permanently high.

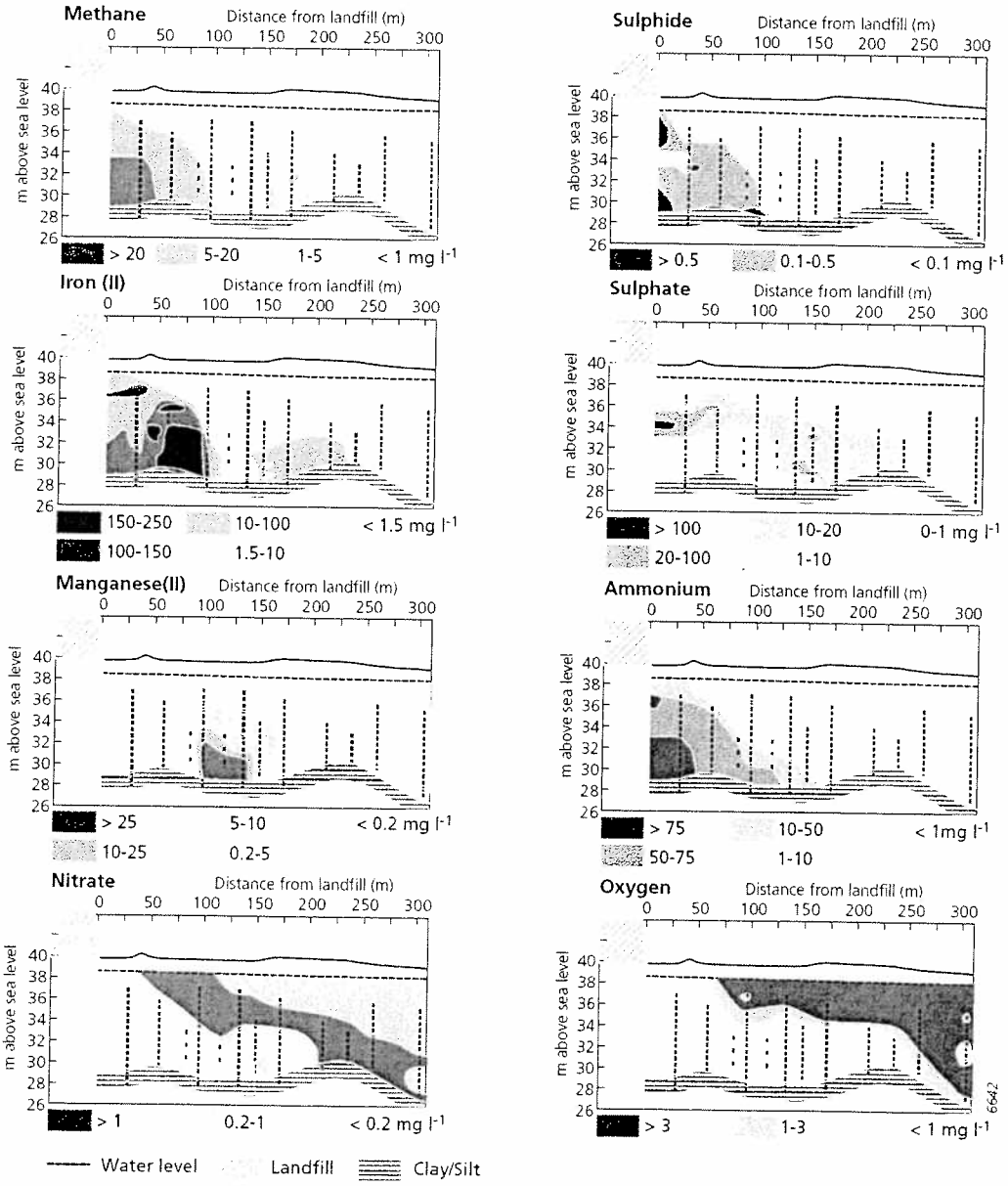
   In contrast, the nitrate concentrations in streams draining agricultural catchments are often higher during wet conditions, i.e. periods when the water tables are high.
   b. Explain this phenomenon in terms of the underlying processes

(10 points)

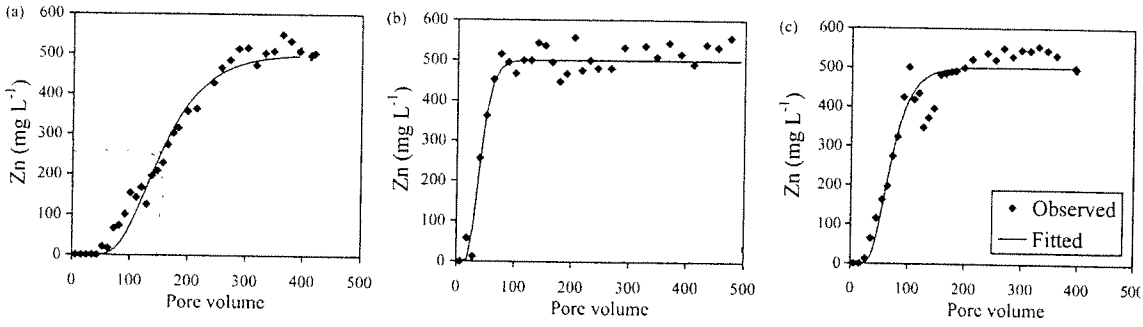
3. The figure below shows the concentrations profiles of several dissolved substances in groundwater downgradient from the Grindsted landfill site in Denmark (source: Bjerg et al., 1995).

a. What is the main driving process that is responsible for the observed patterns of the observed concentrations?
b. Explain why the oxygen concentrations increase in downgradient direction.
c. What is the source of methane directly downgradient from the landfill site?
d. Explain the high ammonium concentrations and low nitrate concentrations directly downgradient from the landfill site.
e. Explain why the highest iron and manganese concentrations occur further downgradient from the landfill site.

(20 points)



4. The figure below shows the results of a series of column experiments to investigate the transport and sorption of zinc in a marine clay soil (source: Antoniades *et al.* (2007) *Journal of Environmental Quality* 36:53-60). Zinc was infiltrated to the column at a concentration of 500 mg l^{-1}. Figure (a) shows the breakthrough curve of zinc. This experiment was repeated with 500 mg Zn l^{-1} in combination with 500 mg l^{-1} of other metals (copper and nickel). Figure (b) shows the breakthrough curve for 500 mg Zn l^{-1} and 500 mg Cu l^{-1} and figure (c) shows the breakthrough curve for 500 mg Znl^{-1} and 500 mg Ni l^{-1}. 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 derive the retardation factor from the curves directly.



a. Explain the shape of the breakthrough curve shown in figure (a).
b. Estimate the distribution coefficient (in l kg^{-1}) for zinc in the single-element experiment (figure (a)) given the sediment parameters:
Bulk density = 1440 kg m^{-3}
Porosity = 0.45
and:

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

The breakthrough curves shown in figures (b) and (c) demonstrate that the transport and sorption of zinc is considerably affected by the presence of other metals in solution.
c. Discuss in brief the effects of the presence of the other metals in solution and give a likely explanation for the observed breakthrough curves as shown in figures (b) and (c) in comparison to the curve shown in figure (a).

(20 points)

5. In a shallow, closed pond, ammonium is released from the lake bed sediment. This ammonium release is the only source of nitrogen species in the pond water. Because the ammonium release rate and water temperature remain constant and the water level does not change, the concentrations of the nitrogen species reach equilibrium. Given the information given below:

a. Calculate the ammonium concentration in mg l^{-1} in the pond.

b. Calculate the nitrate concentration in mg l^{-1} in the pond.

Surface area of the pond = 1200 m^2
Water depth = 1.5 m
Ammonium release rate = 15 mg m^{-2} d^{-1}
Denitrification rate constant = 0.5 d^{-1}
Nitrification rate constant = 0.4 d^{-1}
Atomic weight of nitrogen = 14
Atomic weight of oxygen = 16
Atomic weight of hydrogen = 1

$$\frac{dC}{dt} = \frac{J}{H} - kC$$

c. What happens to the ammonium concentration if the water temperature increases?

Similarly to ammonium in the above situation, phosphate is released from bottom sediments in ponds, lakes and rivers.

d. Explain why the rate phosphate release is often much higher in deep lakes than in shallow lakes, especially during summer.

(20 points)