Tentamen: Environmental Geochemistry
date: January 30 , 2003
time: 9.00 – 12.00 a.m.
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This test consists of 8 assignments. Write your answers immediately below the questions. If necessary continue on the back of each page.

1.a) Which soil forming factor is responsible for the difference between a "haarpodzol" (e.g. in the heathland near Kootwijk) and a "veldpodzol" (e.g. in the moist forest near Voorst) ?

b) Explain how and why the depth of plant roots differs between these two soil types.

c) An "enkeerdgrond" (e.g. the old agricultural field near Beekbergen) is characterized by a relatively high P-content of the A-horizon. How would you explain this ?

d) Arrange the next four soil materials from low to high base saturation (% BS):

the A-horizon of:

- a haarpodzol
- an ooivaaggrond in young sediment of the river Rhine
- an enkeerdgrond in agriculture

the A/C-horizon of a "kattekleigrond" (acid sulphate soil)

2. Given is the following equation for the unit layer of a smectite

$$Al_{0.24}Ca_x[Si_{7.5}Al_{0.5}]Al_{3.7}Mg_{0.3}O_{20}(OH)_4$$

and the molar mass values Al: 27.0 Ca: 40.1 Si: 28.1 Mg 24.3 O: 16.0 H: 1.0

a) Calculate the value of x in this equation.
b) Where is most of the surface charge generated: in the octahedral layers or in the tetrahedral layer ?
c) Calculate the CEC of this smectite (in $mmol_c/kg$).
d) What is the percentage base saturation ?

3. A sand and a clay have CEC-values of respectively 0.1 and 1 mol_c/kg.
Ca^{2+} and Zn^{2+} are the only ions adsorbed on the CEC.
For both soils is given that:

   - exchange equilibrium exists
   - the amount of Zn^{2+} adsorbed on the exchange complex is 0.05 mol_c/kg
   - the Ca^{2+}-concentration in the porewater is 0.3 $mmol/dm^3$
   - the selectivity coefficient K_s is 5, with preference for Zn^{2+} over Ca^{2+}

   Calculate the ratio of the zinc-concentrations in the porewater of the sand and the clay. In which soil exists the greatest environmental risk with respect to zinc?

4. Given are the proton dissociation constants of the $Al(OH)_3$ (s) surface:

$>Al\text{-}OH_2^+ \leftrightarrow >Al\text{-}OH + H^+$ $\quad\quad$ $\log K_1 = -5.3$

$>Al\text{-}OH \leftrightarrow >Al\text{-}O^- + H^+$ $\quad\quad$ $\log K_2 = -8.1$

a) What is the ratio of $(>Al\text{-}O^-)/(>Al\text{-}OH_2^+)$ at pH 6.2 ?

b) What is the PZC of $Al(OH)_3$ (s)

5. Given the formulae of respectively selenite and selenate:

SeO_3^{2-} and SeO_4^{2-}

Derive from the "shared charge" concept:

a) which of these two species might be expected to form a stronger bond with variable-charge minerals ?

b) which of the two acids is weaker: $HSeO_3^-$ or $HSeO_4^-$?

6. a) For an acid, mineral soil the exchangeable reserve acidity may be indicated by AlX_3 (s). X stands for an adsorption site on the exchange complex. Give the equation for the expected reaction when this soil is limed with $CaCO_3$.

b) Give the reaction equation for nitrification of ammonia. How many mol H^+ are produced by nitrification of 100 kg NH_4^+/ha (molar mass N: 14; H: 1) ?

7. At trace concentrations the adsorption isotherm of Cs^+ in a given soil is approximately linear:

$$m_{Cs} = 100\ [Cs^+]$$

where m_{Cs} is adsorption in mol/kg
$[Cs^+]$ is concentration in mol/dm^3

The soil has a bulk density of 1.5 kg/dm^3 and a volumetric moisture content of 20 %. The groundwater table is at 75 cm depth and the average percolation velocity of water in the soil is 150 cm/year.

Given the retardation factor: $R = 1+(\rho/\theta)\ K_d$
where ρ = bulk density
θ = volume fraction moisture
K_d = distribution coefficient

How long does it take for a Cs^+-contamination at the soil surface to reach the groundwater table ?

Question 8: Exam Environmental Geochemistry

Organic pollutants can be grouped according to their physical and chemical properties. Give at least four properties that can be used to characterize organic pollutants.

Adsorption can have a physical and/or chemical nature. Give at least four important differences between physical and chemical adsorption. Which type of isotherm do you expect for physical adsorption? Explain.

Consider a biodegradable organic pollutant X. The sorption isotherm follows Langmuir, with a desorption rate constant k_1=0.1 mmol g^{-1} h^{-1} and an adsorption rate constant k_2=1.2 cm^3 g^{-1} h^{-1}. The (bulk) density of the soil under consideration ρ=1.5 g cm^{-3}. You may assume that ρ represents the amount of free adsorption sites.

Calculate the equilibrium adsorption constant K_1. Calculate the rate of desorption assuming that the amount of free adsorption sites is negligible compared to the amount of occupied sites (you may do this when adsorption is far below saturation).

In a biodegradation study, the initial rate of degradation is calculated to be 10 mmol g^{-1} h^{-1}. Discuss what factor is limiting the biodegradation rate. At the end of the experiment, the aqueous concentration went down to 0.4 mmol cm^{-3} while the biodegradation rate equals 0.15 mmol g^{-1} h^{-1}. Explain this new situation.