

Final exam GEO3-4301 Soil and Water Pollution

28 January 2016 17:00 – 20:00 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. 50 words per answer)
- Why dissolved iron disappears in the sulphate reduction zone in groundwater.
 - Why the K^+/Cl^- ratio in groundwater increases with time downgradient from a surface discharge of waste water.
 - Why the pH of lake water is generally higher during summer than during winter.
 - Why chloride concentrations in shallow groundwater are generally larger near forest edges than in the centre of the forest.
 - Why chloride concentrations in shallow groundwater are generally larger beneath forests than beneath natural grasslands.
 - Why total suspended sediment concentrations in streamwater are higher during storm events than during baseflow conditions.
 - Why metal concentrations in soil are positively correlated with the aluminium content of the soil.
 - Why bicarbonate concentrations in stream water is often higher during baseflow than during periods of high discharge.
 - Why ammonium concentrations are relatively high in pore water of peat soils.
 - Why dissolved phosphate concentrations in shallow groundwater are larger in the marine areas than in the sandy areas of the Netherlands.

(20 points)

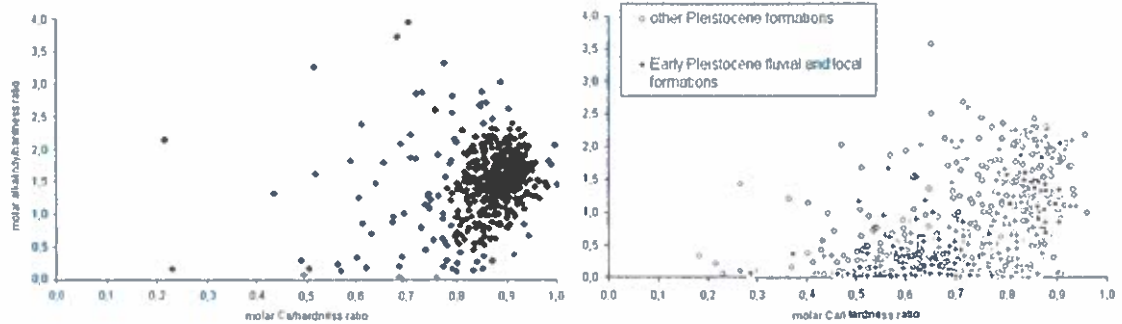
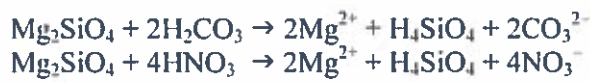
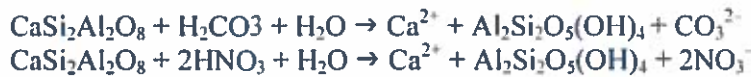
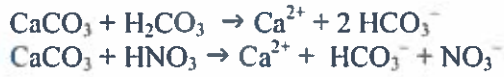
2. A flow reactor with a cross-sectional area of 0.8 m^2 is filled with sandy sediment with a dispersivity α of 0.012 m . The sediment is fully saturated with water with a Cl^- concentration of 0 mg l^{-1} . The flow velocity is set to 0.75 m d^{-1} , a mass of 1 g of Cl^- is released instantaneously at time $t = 0$.
- Calculate the dispersion coefficient
 - Does this coefficient refer to longitudinal or to transverse dispersion? Give reasons for your answer.
 - Explain the major mechanisms that cause dispersion in the flow reactor.
 - Calculate the maximum concentration after 1 day given

$$C(x,t) = \frac{M}{2A\sqrt{\pi D_x t}} e^{-(x-ut)^2 / 4D_x t}$$

- Calculate the maximum concentration at $x = 1.0 \text{ m}$.

(20 points)

3. Griffioen *et al.* (2013) studied the groundwater composition in various aquifer types across the Netherlands. They plotted the ratio between the alkalinity concentration and the hardness (i.e. the sum of the molar Ca and Mg concentrations) against the ratio between the molar Ca concentration and the hardness for two distinct aquifers: 1) The Late Pleistocene sandy formations in the central/eastern part of the Netherlands (see left figure below) and 2) The Early to Late Pleistocene formations in the southern part of the Netherlands (see right figure below). They related the differences between the graphs to the differences in weathering processes occurring in the aquifer. The reaction equations of the main weathering processes are:



1) Central/eastern part of the Netherlands

2) Southern part of the Netherlands

- What is the main source of carbonic acid in groundwater?
- Name two sources of nitric acid in groundwater.
- Copy the below table on your answer sheet and give the molar alkalinity / hardness ratio resulting from carbonate dissolution and silicate weathering by carbonic acid and nitric acid.

Weathering process	Weathering by carbonic acid	Weathering by nitric acid
Carbonate dissolution		
Silicate weathering		

- Interpret the differences between the above figures in terms of the major weathering processes that occur in the studied aquifers in the central/eastern and in the eastern part of the Netherlands.

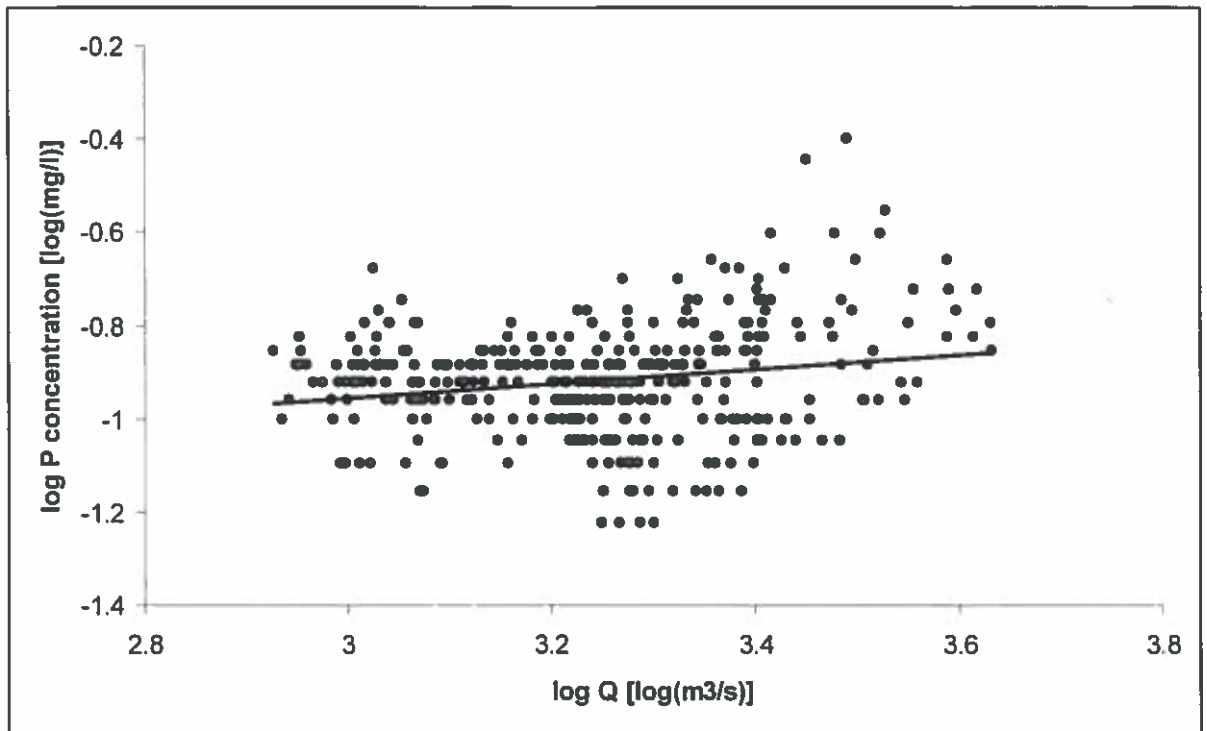
(20 points)

4. The figure below shows a so-called concentration rating curve for daily total phosphorus measurements in the River Rhine at Lobith, the Netherlands, for the year 2009. The rating curve depicts the relation between river discharge (Q ; $\text{m}^3 \text{s}^{-1}$) and the phosphorus concentration (P ; mg l^{-1}) and usually has the form $P = a Q^b$.

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

The individual SSC measurements display a considerable variation around the rating curve.

b. Give two major reasons for the occurrence of this variation and describe in brief the processes responsible for this.



The change of the phosphorus concentrations as function of time can be described by a combination of a zero-order phosphorus release from the bed sediments and a first-order removal:

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

During a period of high discharge a 10 ha large and 0.5 km long floodplain section is inundated. The water depth in the inundated floodplain section is 5 m. At the point of inflow the phosphorus concentration was measured to be 0.12 mg l^{-1} . The phosphorus concentration at the outlet remained unchanged at 0.12 mg l^{-1} . The phosphorus release flux rate from the floodplain soil was measured to be $360 \text{ mg m}^{-2} \text{ d}^{-1}$.

c. Calculate the first-order phosphorus removal rate constant in d^{-1} .

(20 points)

5. At a fixed location in a river, weekly measurements are performed to determine mean flow velocity (U), discharge (Q), and a number of water quality parameters including temperature (T) and nitrate concentration (NO_3). In 2015, the following monthly averages were determined:

Month	U (m s^{-1})	Q ($\text{m}^3 \text{s}^{-1}$)	T ($^{\circ}\text{C}$)	NO_3 (mg l^{-1})
January	1.04	183	3.0	12.2
February	1.28	289	3.5	11.3
March	1.08	200	8.0	13.5
April	1.22	260	11.0	13.0
May	1.26	277	13.5	11.3
June	1.27	286	17.5	9.5
July	1.14	222	19.0	9.2
August	1.01	172	20.0	9.6
September	0.99	164	18.5	10.4
October	0.79	100	15.5	11.3
November	0.82	108	9.5	14.2
December	0.93	141	8.0	14.6

The following data are given:

- denitrification rate constant at 20°C $k_d = 1.0 \text{ d}^{-1}$;
 - temperature coefficient for denitrification $\theta = 1.04$;
 - ammonium and nitrite concentrations are negligible;
 - An industrial discharge is located at 10 km downstream of the measurement location. The constant discharge amounts to $1.5 \text{ m}^3 \cdot \text{s}^{-1}$ and the nitrate concentration amounts to $85 \text{ mg} \cdot \text{l}^{-1}$.
- a. Name two factors that explain the seasonal variation in nitrate concentrations.
 - b. Estimate the average nitrate load in g/month for April 2015.
 - c. Calculate the nitrate concentration in the river directly downstream of the industrial discharge for September 2015. Assume instantaneous mixing of the industrial discharge across the entire river cross section.