

National Exams May 2003

98-Geol-B1, Contaminant Hydrogeology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made;
2. Any non-communicating calculator is permitted. This is an Open Book exam. Note to candidates, you must indicate the type of calculator being used. ie. write the name and model designation of the calculator, on the first inside left hand side sheet, of the exam work book.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value.

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1. A 5 cm diameter, 50 cm long column contains sand with a porosity of 0.35, a bulk density of 2.0 g/cm^3 , and a f_{oc} of 0.01. A solution containing 100 mg/L of benzene ($\log K_{oc} = 1.92$) is pumped through the column at $20 \text{ cm}^3/\text{sec}$. The sand has a dispersivity of 1 cm, and an effective diffusion coefficient of $10^{-6} \text{ cm}^2/\text{sec}$. Determine the concentration of benzene at the column outlet after 4 pore volumes of water have passed through the column. You may assume that the concentration at the inlet increased instantaneously to 100 mg/L when the benzene solution was added to the column.
2. Water containing 100 mg/L of tritium is introduced into a 1 m long column of 10 cm diameter at a flow rate of 1 mL/min. The longitudinal dispersivity of the sand in the column is 0.05 m, the porosity of the sand is 0.4, and the sand bulk density is 1.6 g/cm^3 . The effective diffusion coefficient for tritium in the sand is $1.0 \times 10^{-10} \text{ m}^2/\text{sec}$. The tritium undergoes radioactive decay with a half-life of 1 day. Determine the concentration of tritium leaving the column after 30 hours.
3.
 - a) Groundwater contains 200 mg/L of Na^+ , 80 mg/L of K^+ , 150 mg/L of Ca^{2+} , 100 mg/L of Mg^{2+} , 500 mg/L of $\text{SO}_4^{=}$, and 480 mg/L of Cl^- . Determine if the water is saturated with respect to gypsum ($\text{CaSO}_4 \cdot \text{H}_2\text{O}$, $K_{s0} = 2.5 \times 10^{-5}$), including activity corrections in your calculations. Neglect the formation of ion pairs between the ionic species.
 - b) A water sample has $[\text{Fe}^{2+}] = 0.1 \text{ mM}$, and $[\text{Fe}^{3+}] = 0.001 \text{ mM}$. Determine the $p\text{E}$ of the groundwater ($\text{Fe}^{3+} + \text{e}^- = \text{Fe}^{2+}$, $\log K = 13.0$ at 25°C).
 - c) Does dissolution of calcite in groundwater cause the pH of the groundwater to increase or decrease? Explain your answer.
4.
 - a) Explain what the meteoric water line is and how it can be used in hydrologic investigations, giving example applications.
 - b) Explain how tritium measurements can be used to date groundwater.
 - c) Explain why ^{14}C measurements of groundwater samples may overestimate groundwater age.
5. 100 L of water containing 5,000 mg/L of arsenic are rapidly spilled into a 5 m deep aquifer, creating a cylindrical contaminated zone of uniform concentration over the entire 5 m depth of the aquifer. The aquifer porosity is 0.4, and the groundwater linear porewater velocity is 0.1 m/day. The longitudinal dispersivity for the aquifer is 1.0 m, and the transverse dispersivity is 0.1 m. The effective diffusion coefficient for arsenic in the aquifer is $1.0 \times 10^{-10} \text{ m}^2/\text{sec}$. Arsenic has a distribution coefficient (K_d) in the aquifer of 10.0 mL/g, and the aquifer soil bulk density is 1.6 g/m^3 . Determine the position of the maximum concentration of arsenic in the aquifer after 1 year, and the maximum concentration at this point. Determine the maximum distance from the original spillage point where arsenic concentrations would be 0.1% of the maximum concentrations at a time of 1 year. Assume that the aquifer can be treated as a two-dimensional horizontal system.

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6. The vadose zone at a site is contaminated with tetrachloroethene. The soil has a porosity of 0.35, a bulk density of 1.8 g/cm^3 , a f_{oc} of 0.01, a water phase saturation of 0.3, and a gas phase saturation of 0.7. Tetrachloroethene has a molecular weight of 166 g/gmol, a $\log K_{oc}$ of approximately 2.6, a solubility in water of 150 mg/L, a vapour pressure of 2400 Pa, and a Henry's Law constant of $1600 \text{ Pa}\cdot\text{m}^3/\text{mol}$.
 - a) If the soil gas concentration of tetrachloroethene was 10 mg/L at 10°C , determine the concentrations of PCE in the water and soil phases in the system.
 - b) Consider a 1 m by 1 m by 1 m block of the vadose zone at the site. If air was flushed through this block at a rate of 100 L/sec, determine the time required for the concentration in the soil gas to be reduced to 1 mg/L, assuming equilibrium between all phases, and a completely mixed system.

7. A phase one investigation at an electronics manufacturing facility reveals that trichloroethylene (TCE) was used as a cleaning solvent for many years in the 1950's and that many barrels of TCE were dumped in a pit on the site. The site consists of a sandy aquifer overlaying a thick clay aquitard at 30 m below the ground surface. The water table at the site is 5 m below the ground surface. TCE has a liquid density of 1460 kg/m^3 , a water phase solubility of 1100 mg/L, and a vapour pressure of 9800 Pa at 25°C .
 - a) Describe the expected movement of TCE NAPL at this site, and steps you would take to determine the location of the TCE NAPL.
 - b) Discuss the processes that will influence the transport of TCE dissolved in the water phase at the site.
 - c) Discuss two technologies of your choice for remediating this site, indicating their advantages and disadvantages.

Values of erf (β) and erfc (β) for
positive values of β

| β | erf (β) | erfc (β) |
|---------|-----------------|------------------|
| 0 | 0 | 1.0 |
| 0.05 | 0.056372 | 0.943628 |
| 0.1 | 0.112463 | 0.887537 |
| 0.15 | 0.167996 | 0.832004 |
| 0.2 | 0.222703 | 0.777297 |
| 0.25 | 0.276326 | 0.723674 |
| 0.3 | 0.328627 | 0.671373 |
| 0.35 | 0.379382 | 0.620618 |
| 0.4 | 0.428392 | 0.571608 |
| 0.45 | 0.475482 | 0.524518 |
| 0.5 | 0.520500 | 0.479500 |
| 0.55 | 0.563323 | 0.436677 |
| 0.6 | 0.603856 | 0.396144 |
| 0.65 | 0.642029 | 0.357971 |
| 0.7 | 0.677801 | 0.322199 |
| 0.75 | 0.711156 | 0.288844 |
| 0.8 | 0.742101 | 0.257899 |
| 0.85 | 0.770668 | 0.229332 |
| 0.9 | 0.796908 | 0.203092 |
| 0.95 | 0.820891 | 0.179109 |
| 1.0 | 0.842701 | 0.157299 |
| 1.1 | 0.880205 | 0.119795 |
| 1.2 | 0.910314 | 0.089686 |
| 1.3 | 0.934008 | 0.065992 |
| 1.4 | 0.952285 | 0.047715 |
| 1.5 | 0.966105 | 0.033895 |
| 1.6 | 0.976348 | 0.023652 |
| 1.7 | 0.983790 | 0.016210 |
| 1.8 | 0.989091 | 0.010909 |
| 1.9 | 0.992790 | 0.007210 |
| 2.0 | 0.995322 | 0.004678 |
| 2.1 | 0.997021 | 0.002979 |
| 2.2 | 0.998137 | 0.001863 |
| 2.3 | 0.998857 | 0.001143 |
| 2.4 | 0.999311 | 0.000689 |
| 2.5 | 0.999593 | 0.000407 |
| 2.6 | 0.999764 | 0.000236 |
| 2.7 | 0.999866 | 0.000134 |
| 2.8 | 0.999925 | 0.000075 |
| 2.9 | 0.999959 | 0.000041 |
| 3.0 | 0.999978 | 0.000022 |

20 marks QUESTION 7:

Worker safety is a valid concern for any site investigation field work. Briefly describe the approach to worker safety and types of personal protective equipment that you would adopt if responsible for worker safety on the following projects.

- (4) a. A groundwater drilling program in an active quarry operation with daily blasting activities.
- (4) b. Investigation of a suspected fuel spill in a crawl space area below a warehouse floor slab.
- (4) c. Surface water sampling of springs emanating from land adjacent to a municipal landfill.
- (4) d. Sampling of buried drums of unknown materials in an old industrial park.
- (4) e. Shallow soil drilling on the shoulder of a busy urban expressway for design of additional traffic lanes.

20 marks QUESTION 8:

Identify four different geophysical methods used in site investigations. Answer the following questions for each method.

- (12) a. Briefly describe the geophysical method and its operating principle. Use a simple sketch if this will assist your description.
 - (8) b. What is the general usefulness of each method for identifying:
 - i. Subsurface stratigraphy
 - ii. Buried objects and structures
 - iii. Organic or inorganic contaminants.
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