

## Final exam. Geoenvironmental Engineering

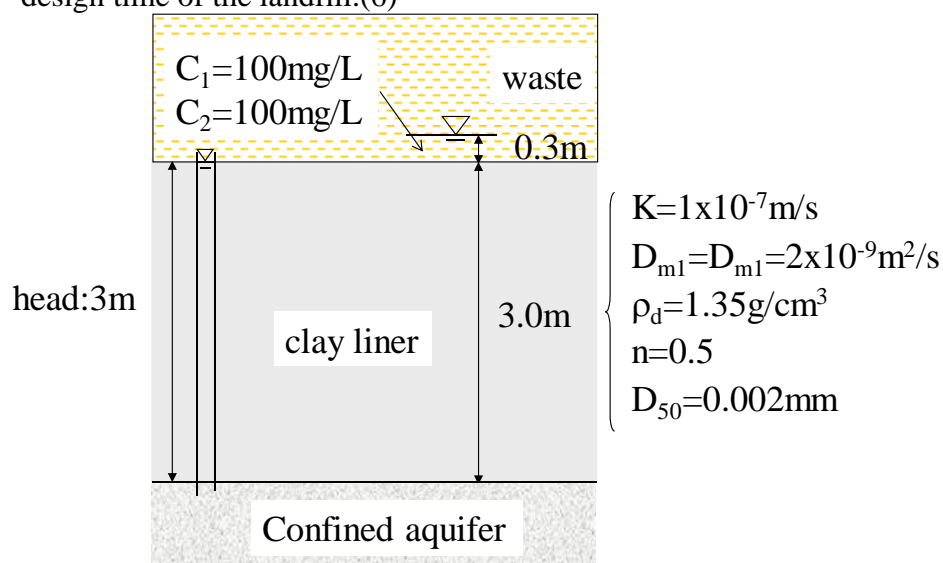
1. Consider a natural saturated clay barrier of waste landfill overlaying an aquifer as shown in the bottom figure.

Using the following conditions and assuming that the step function type boundary conditions (Concentration of solute,  $C = 0$  at  $t=0$ ,  $C$  at the top of clay layer is fixed  $C_0$ ) can be reasonably applied in this situation, answer the following questions. (50)

(To answer the questions (6) to (9), use the attached charts of Fig.1 and Fig.2. Submit the sheet of the charts showing the processes of determination of necessary values.)

- Leachate height over the clay liner: 0.2m,
- Hydraulic head of the aquifer below the liner: 5 m from the bottom of the clay layer,
- Concentration of a hazardous solute in the leachate:  $C_0=1,000\text{mg/L}$ ,
- Hydraulic conductivity of clay:  $K=1 \times 10^{-7}\text{m/s}$ ,
- Free water diffusion coefficient of the solute:  $D_0=1 \times 10^{-8}\text{m}^2/\text{s}$ ,
- Effective diffusion coefficient of the solute in the clay:  $D_m=2 \times 10^{-9}\text{m}^2/\text{s}$ ,
- Porosity of clay:  $n=0.5$ ; Dry density of clay:  $\rho_d=1.35\text{g/cm}^3$ ,
- Mean diameter of clay particle:  $D_{50}=2.0 \times 10^{-6}\text{m}$ ,
- Coefficient of retardation of the solute in the clay:  $R_d=3$ ,
- Allowable concentration of the solute at the bottom of liner: less than  $20\text{mg/L}$
- Allowable mass flux of the solute at the bottom of liner: less than  $5\text{g}/(\text{m}^2 \cdot \text{year})$
- Design life time of the landfill:  $t_d=30$  year

- (1) How much are the density of soil grain ( $\rho_s$ ), and saturated density ( $\rho_{\text{sat}}$ ), the void ratio ( $e$ ) and water content ( $w$ ) of the clay? (8)
- (2) How much is the apparent tortuosity factor ( $\tau_a$ ) of the clay? (5)
- (3) How much is the partitioning coefficient ( $K_d$ ) of the solute on the clay? (5)
- (4) Calculate the time for the solute to reach the bottom of liner for the condition of zero dispersion, i.e.,  $D_m=0$ . (5)
- (5) Estimate the micro scale Peclet number and explain why the mechanical dispersion can be negligible in the process of contaminant transport in clay. (8)
- (6) Draw the concentration profile of the solute with depth at time of 30 years.(7)
- (7) Obtain the time at which the concentration of the bottom of the clay liner becomes the allowable limit. (6)
- (8) Confirm if the mass flux is below the allowable value at the bottom of the clay liner at the design time of the landfill.(6)



**Natural clay liner above natural soil layer**

2. Choose two questions from the following four and answer them. (25)

(1) Briefly explain the following terms about hydrogeology and geo-environment

1) flowing artesian aquifer, 2) transmissivity, 3) intrinsic permeability, 4) brown field

(2) Firstly explain typical properties of VOCs. Secondly assume a contaminated site with VOCs and propose a remediation method to the site.

(3) Explain the performance of composite clay liner (CCL) in comparison with those of geo-membrane liner and clay liner. What are the critical conditions in the performance of CCL? For answering the question, draw the structure of landfill liner with basic components.

(4) Ex-situ remediation, i.e., excavating and treating contaminated soils, is the most commonly used remediation method for soil contamination. Explain the reasons why the ex-situ methods are more common than the in-situ methods.

3. After Tohoku Earthquake and Tsunami, 2011.3.11, we are facing various disaster caused waste problems, such as huge volume of rubble, and contaminated soils, wastes and sewage sludge by radionuclide. Select and outline one specific problem, and give your own view about how to deal with the specific problem. You may propose the ways for a short term and a long term, considering broad aspects on the problem. (25)