

## Final Exam Geo-environmental Engineering

### Answer the following questions

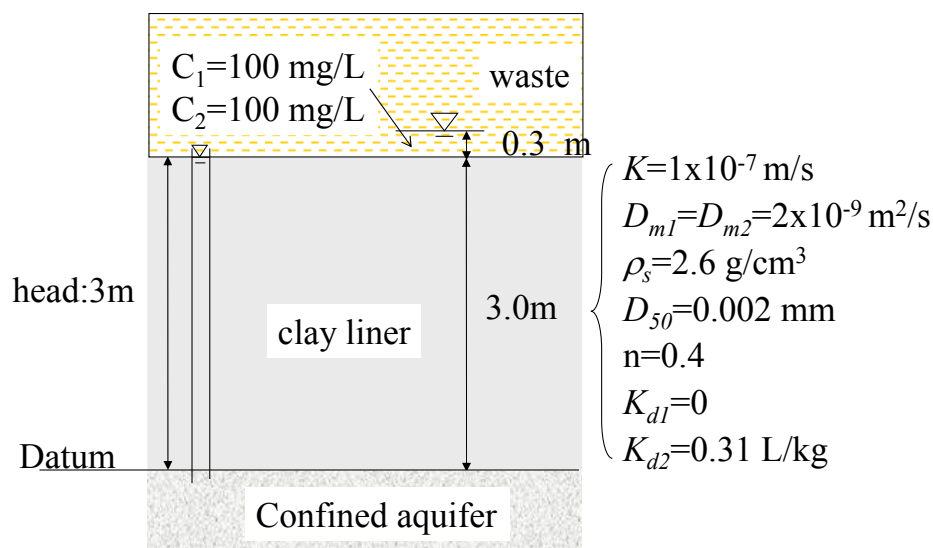
1. Briefly explain the following terms about hydrogeology and geo-environment. For the explanation you may draw a key sketch about the terms. (30)

- 1) Artesian confined aquifer, 2) Darcy's law, 3) Hydrodynamic dispersion coefficient, 4) Composite clay liner

2. Consider a natural saturated ( $S_r=100\%$ ) clay barrier (liner) of waste landfill overlaying an aquifer as shown in the bottom figure. Using the following conditions and assuming that the concentration of two pollutant chemicals  $C_1$ ,  $C_2$  in the leachate will be kept constant (10 mg/L) at the top surface of the clay, and the concentrations of these chemical is zero in the clay at time  $t=0$ , answer the following questions. (40)

- Thickness of clay liner:  $L=3\text{m}$ ,
- Leachate height over the clay liner: 0.3m,
- Hydraulic head of the bottom aquifer below the liner: 0m from the surface of the clay liner,
- Hydraulic conductivity of clay:  $K=10^{-7}\text{ m/s}$ ,
- Effective diffusion coefficients of two pollutants in the clay:  $D_m=2\times 10^{-9}\text{ m}^2/\text{s}$ ,
- Porosity of the clay:  $n=0.4$ ; density of soil grain:  $\rho_s=2.6\text{ g/cm}^3$ ,
- Liner equilibrium sorption with partitioning coefficient  $K_{d2}=0.31\text{ L/Kg}$  for the pollutant  $C_2$
- No sorption takes place for the pollutant  $C_1$ , namely  $K_{d1}=0$

- (1) How much are the void ratio ( $e$ ) and moisture content ( $w$ ) of the clay?
- (2) How much is the hydraulic gradient of downward seepage flow in the clay?
- (3) How much is the interstitial velocity of the downward flow in the clay?
- (4) Calculate the time (years) for the pollutant  $C_1$  to reach the bottom of liner in the case with no dispersion condition, i.e.,  $D_m=0$ .
- (5) How much is the retardation factor ( $R_d$ ) of the pollutant  $C_2$
- (6) Draw the approximate concentration profile of the two pollutants,  $C_1$  and  $C_2$  with depth at  $t=4$  years. (*hint*: boundary condition, shape and relative position of  $C_1$  and  $C_2$ )
- (7) Draw the approximate breakthrough curves at the depth of 1.5m.
- (8) Explain why the mechanical dispersion can be negligible in the process of contaminant transport in the clay.



3. There is a former site of chemical factory with waste piles on the ground surface. As this waste contains hazardous chemicals, such as benzene, arsenic, this land is designated as a contaminated site for which the land owner or the polluter should take necessary action to prevent the harmful effects to human health. The figure below shows the ground conditions of the site,

e.g.

- 15 meters from the ground surface is relatively permeable sandy soil layer,
- The ground water level of the top permeable layer is about 5 meters below the ground surface,
- Below the sandy layer a very low permeable thick clay layer exists.

With these conditions above, make plans of the necessary actions for the two objectives below respectively. (30)

- (1) to prevent the harmful effects in economical manner,
- (2) to revitalize this brown field for the positive use of this land, such as selling the land, or constructing residential or shopping complex.

In the plan making, you can presume any additional conditions, which could be reasons of the actions in your proposal. But the assumptions should be described accordingly.

**Key words for the plans:** *risk evaluation, risk communication, prevention, cleaning, monitoring, economical feasibility,*

