# Final exam. Geoenvironmental Engineering

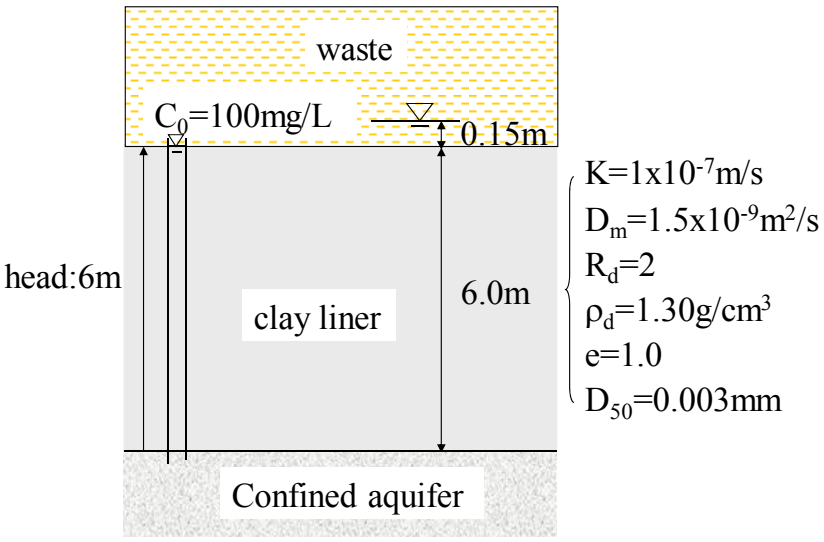
1. Consider a natural **saturated** clay barrier of waste landfill overlaying an aquifer as shown in the bottom figure.

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: 0.15m,
- Hydraulic head of the aquifer below the liner: 6 m from the bottom of the clay layer,
- Concentration of a hazardous solute in the leachate: $C_0$=100mg/L,
- Hydraulic conductivity of clay: $K$=1.0x10$^{-7}$m/s,
- Free water diffusion coefficient of the solute: $D_0$=1x10$^{-8}$m$^2$/s,
- Effective diffusion coefficient of the solute in the clay: $D_m$=1.5x10$^{-9}$m$^2$/s,
- Void ratio: $e$=1.0; Dry density of clay: $\rho_d$=1.30g/cm$^3$,
- Mean diameter of clay particle:$D_{50}$=3.0x10$^{-6}$m,
- Coefficient of retardation of the solute in the clay: $R_d$=2,
- Allowable concentration of the solute at the bottom of liner: less than 5mg/L
- Allowable mass flux of the solute at the bottom of liner: less than 0.5g/(m$^2$·year)
- Design life time of the landfill: $t_d$= 50 year

(1) How much are the density of soil grain ($\rho_s$), and saturated density ($\rho_{sat}$), porosity (n) 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 **three** questions from the following four and answer them. (25)

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

1) confined aquifer, 2) transmissivity, 3) hydrodynamic dispersion coefficient

(2) Firstly explain typical properties of VOCs. Secondly assume conditions of a contaminated site with VOCs, e.g., type of soil, depth of the contaminant, relative depth of GWT to the contaminant, and the others, and propose a remediation method to the site with the reasons why you choose the specific method for the assumed conditions.

(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 what is the advantage and disadvantage of the ex-situ methods in comparison with the in-situ methods.

3. More than one year after Tohoku Earthquake and Tsunami, 2011.3.11, we are still facing various environmental problems, such as huge volume of disaster wastes, and contamination of foods, water, soils, and wastes by radioactive materials.

Firstly select one specific problem and outline it, and then give your own view about how to solve the specific problem. You may propose the ways for a short term and a long term time spans, considering broad aspects on the problem or the effective preparedness for mitigating the disaster caused environmental problems. (25)

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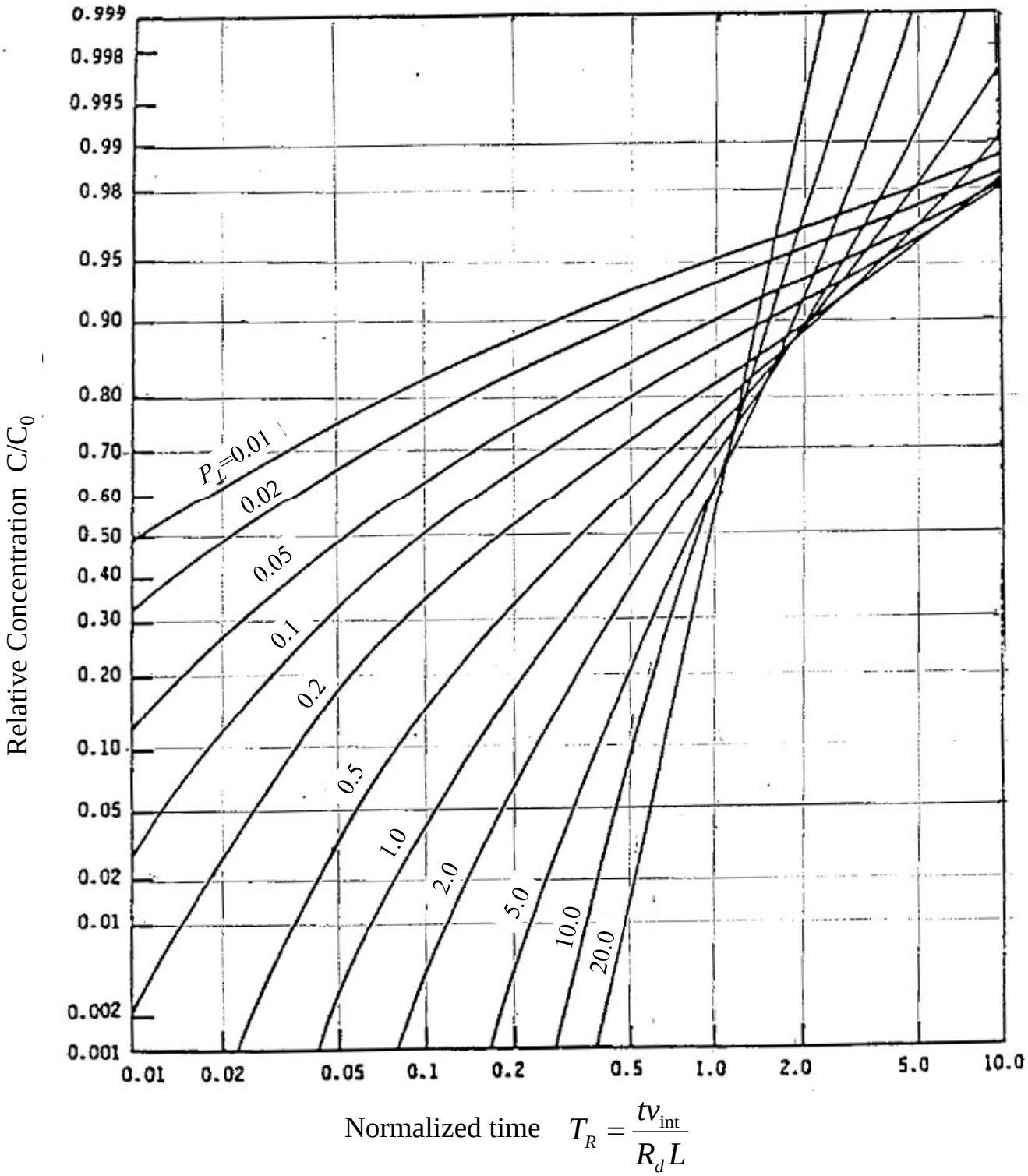


Fig.1 Relative concentration of leachate constituent ($C/C_0$) as a function of the dimensionless parameters ($T_R$ and $P_L$).

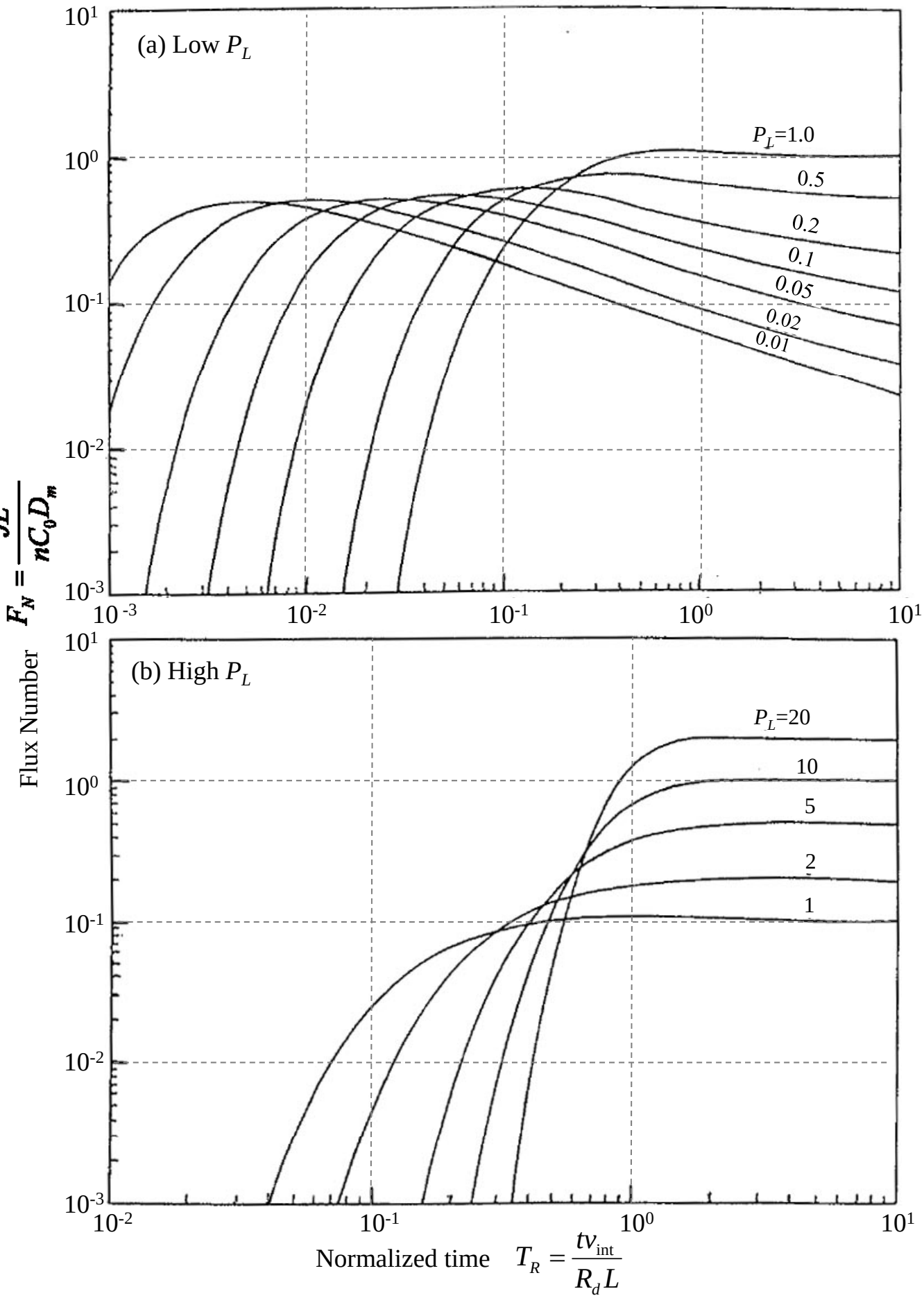


Fig.2 Dimensionless flux number ($F_N$) as a function of the dimensionless parameters ($T_R$ and $P_L$).