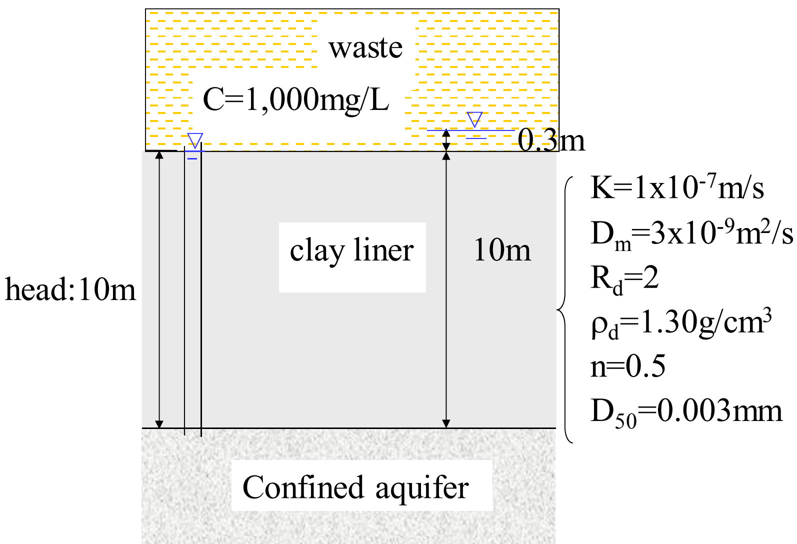
Final exam. Geoenvironmental Engineering

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 Fig.1 and Fig.2*)
   ・Leachate height over the clay liner: 0.3m,
   ・Hydraulic head of the aquifer below the liner: 10 m from the bottom of the clay layer,
   ・Concentration of a hazardous solute in the leachate: C_0=1,000mg/L,
   ・Hydraulic conductivity of clay: $K=1\text{x}10^{-7}$m/s,
   ・Free water diffusion coefficient of the solute: $D_0=1\text{x}10^{-8}\text{m}^2/\text{s}$,
   ・Effective diffusion coefficient of the solute in the clay: $D_m=2\text{x}10^{-9}\text{m}^2/\text{s}$,
   ・Porosity of clay: n=0.5; Dry density of clay: $\rho_d=1.35\text{g/cm}^3$,
   ・ Mean diameter of clay particle: $D_{50}=2.0\text{x}10^{-6}$m,
   ・Coefficient of retardation of the solute in clay: R_d=2,
   ・Allowable concentration of the solute at the bottom of liner: less than 20mg/L
   ・Allowable mass flux of the solute at the bottom of liner: less than $5\text{g/(m}^2\cdot\text{year)}$
   ・Design life time of the landfill: t_d= 50 year
   (1) How much are the density of soil grain (ρ_s), and saturated density (ρ_{sat}), the void ratio (e) and water content (w) of the clay?
   (2) How much is the apparent tortuosity factor (τ_a) of the clay?
   (3) Assuming liner equilibrium sorption, how much is the partitioning coefficient (K_d) of the solute on the clay?
   (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) Estimate the micro scale Peclet number and explain why the mechanical dispersion can be negligible in the process of contaminant transport in clay.
   (6) Draw the concentration profile of the solute with depth at time of 30 years
   (7) Obtain the time at which the concentration of the bottom of the clay liner becomes the allowable limit.
   (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.



Natural clay liner above natural soil layer

2. Choose two questions from the following four and answer them. (20)

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

1) flowing artesian aquifer, 2) transmissivity, 3) intrinsic permeability

(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. Due to a flooding , a land in a factory is susceptible of contamination and became a brown field. Propose a revitalization project with a roadmap, including preparation and several stage in the project. And also explain the possible benefit and limitation of the revitalization project.(15)

4. After Great Tohoku Earthquake, 2011.3.11, we are facing serious disaster waste problems, such as huge volume of rubble, and soils, wastes and sewage sludge contaminated with radionuclide. Select one specific problem and give your own view about how to deal with the specific problem.(15)

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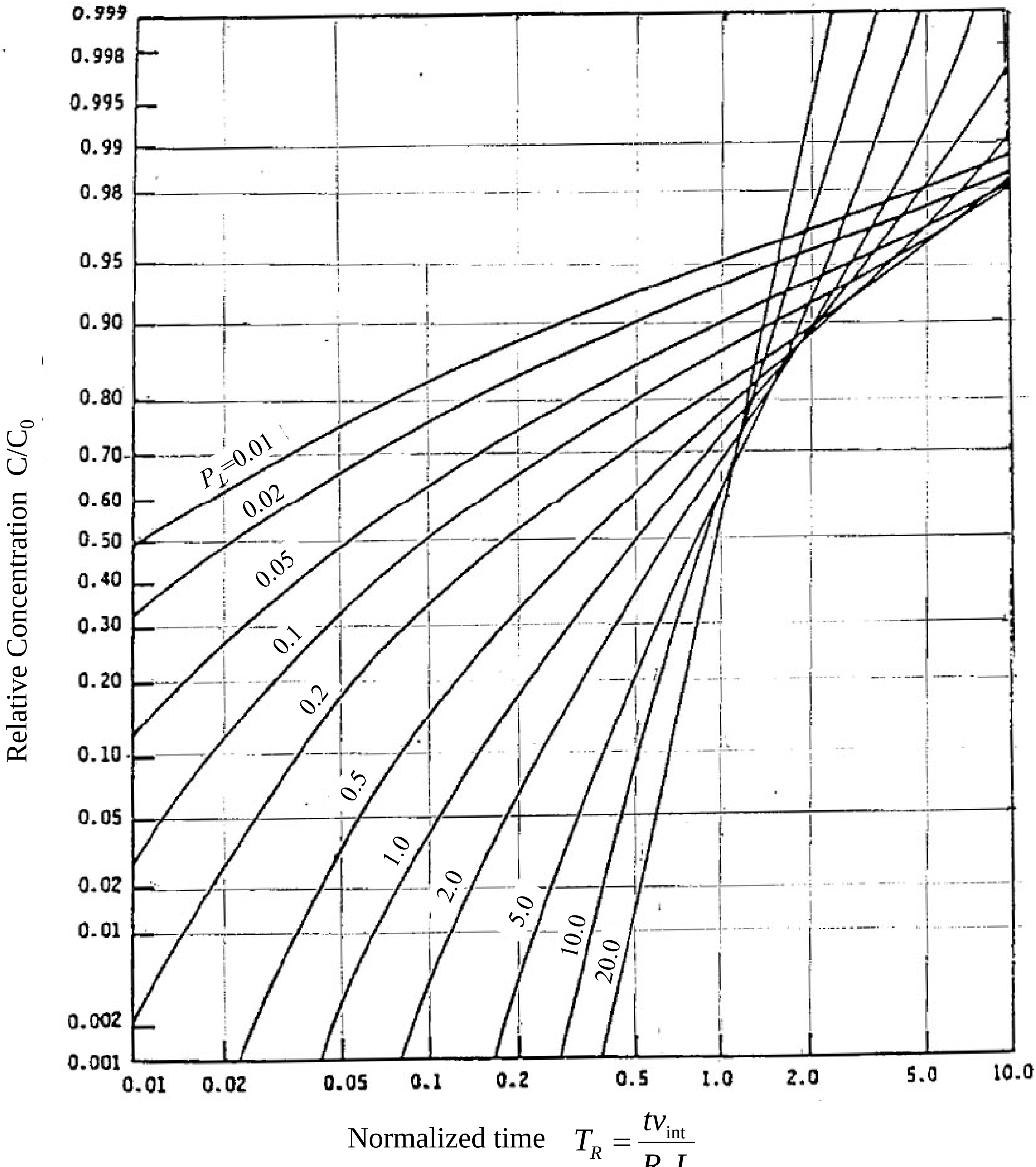

Normalized time $T_R = \frac{t v_{\text{int}}}{R_d L}$

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

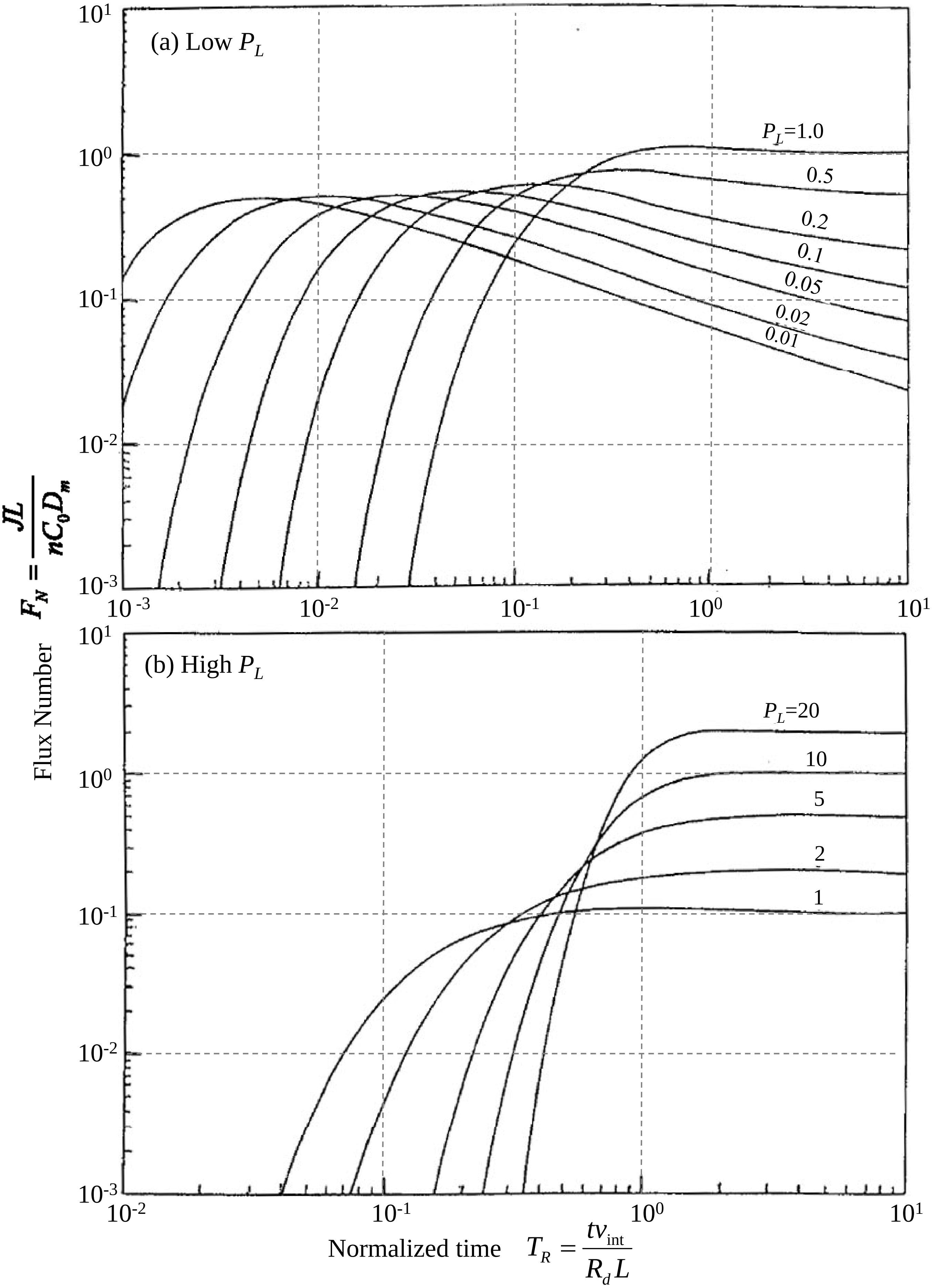

Fig.2 Dimensionless flux number (F_N) as a function of the dimensionless parameters (T_R and P_L).