

CONCENTRATION CHANGE IN A BATCH ADSORPTION TANK

回分吸着における濃度変化

—Freundlich Isotherm with Particle-to-fluid Mass Transfer Controlling—

フロインドリッヒ平衡における液境吸物質移動律速の場合

Motoyuki SUZUKI* and Kunitaro KAWAZOE*

鈴木基之・河添邦太朗

Freundlich isotherm, $q/q_0=(C/C_0)^{1/n}$ is frequently met in adsorption in liquid systems. In the case of batch adsorption in this type of isotherm system, prediction of concentration change in liquid must be made numerically since analytical solution is not possible for arbitrary Freundlich constant, n .

For the cases where only intraparticle diffusion is a rate-limiting factor, this was done by the authors for two types of intraparticle diffusion kinetics.^{1, 2)} When particle size is very small or rapid intraparticle diffusion is expected, adsorption rate is possibly determined solely by film mass transfer rate between particle surface and bulk liquid.

The similar diagrams to those reported earlier^{1, 2)} are obtained here for the case where particle-fluid mass transfer is a rate controlling factor.

Basic Equations

For a batch adsorption, material balance equations are given as

$$-V_L \frac{\partial C}{\partial t} = k_f \left(\frac{3W_s}{R\rho_p} \right) (C - C^*) \quad (1)$$

$$(C_0 - C) V_L = W_s \cdot q \quad (2)$$

$$q/q_0 = (C^*/C_0)^{1/n} \quad (3)$$

with the initial conditions

$$C = C_0, \quad q = C^* = 0 \quad \text{at } t = 0$$

Dimensionless form of Eqs. (1-4) becomes

$$-\frac{\partial Y}{\partial \tau_F} = 3 \cdot \alpha (Y - Y^*) \quad (5)$$

$$1 - Y = \alpha \cdot X \quad (6)$$

$$X = (Y^*)^{1/n} \quad (7)$$

$$Y = 1, \quad X = Y^* = 0 \quad \text{at } \tau_F = 0 \quad (8)$$

where $Y = C/C_0$, $Y^* = C^*/C_0$, $X = q/q_0$,

$$\alpha = W_s q_0 / V_L C_0, \quad \tau_F = (k_f t / R) (C_0 / \rho_p q_0)$$

C^* denotes the concentration in equilibrium with

q and k_f is the mass transfer coefficient between particle surface and bulk fluid (cm/sec). It should be noted that the parameter α which corresponds to carbon load and determines the slope of operating line, defines final equilibrium concentration C_∞ by the following equation

$$\alpha = \{1 - (C_\infty / C_0)\} / (C_\infty / C_0)^{1/n} \quad (9)$$

Eqs. (5-7) are modified to give the relation between $X(\tau_F + \Delta\tau)$ and $X(\tau_F)$.

$$\frac{X(\tau_F + \Delta\tau)^n + X(\tau_F)^n}{2} - \left\{ 1 - \alpha \frac{X(\tau_F + \Delta\tau) + X(\tau_F)}{2} \right\} \\ = - \frac{X(\tau_F + \Delta\tau) - X(\tau_F)}{3} \quad (10)$$

Eq. (10) can be solved by Regula-Falsi technique. The computation was started from $\tau_F = 10^{-5}$ until $\tau_F = 10$ was reached. The time increment, $\Delta\tau$, was first chosen to be 10^{-7} , which was then changed to 10^{-6} , 10^{-5} , 10^{-4} , 10^{-3} and 10^{-2} when τ_F arrived at 10^{-4} , 10^{-3} , 10^{-2} , 10^{-1} and 1 respectively. The computer results are given in Figs. 1-6 for $n=1.25$, 1.5, 2.0, 3.0, 5.0, and 10.0, in the form of C/C_0 ($=Y$) versus τ_F where C_∞/C_0 is chosen as a parameter.

In the case of a linear isotherm ($n=1$) the analytical solution is possible.

$$Y = \frac{1 + \alpha \exp\{-3(1 + \alpha)\tau_F\}}{1 + \alpha} \quad (11)$$

Also for a rectangular isotherm ($n=\infty$) the following solution is obtained

$$Y = \exp(-3\alpha\tau_F) \quad \text{for } Y \geq Y_\infty = 1 - \alpha \quad (12)$$

Eqs. (11) and (12) are also illustrated in Figs. 7 and 8 respectively.

The accumulation of errors in the computation can be checked by comparing the numerical result obtained for $n=1$ with Eq. (11). Coincidence of Y up to more than three decimal places suggests the validity of the technique applied here, at least for

* Dept. of Industrial Chemistry and Metallurgy,
Inst. of Industrial Science, Univ. of Tokyo.

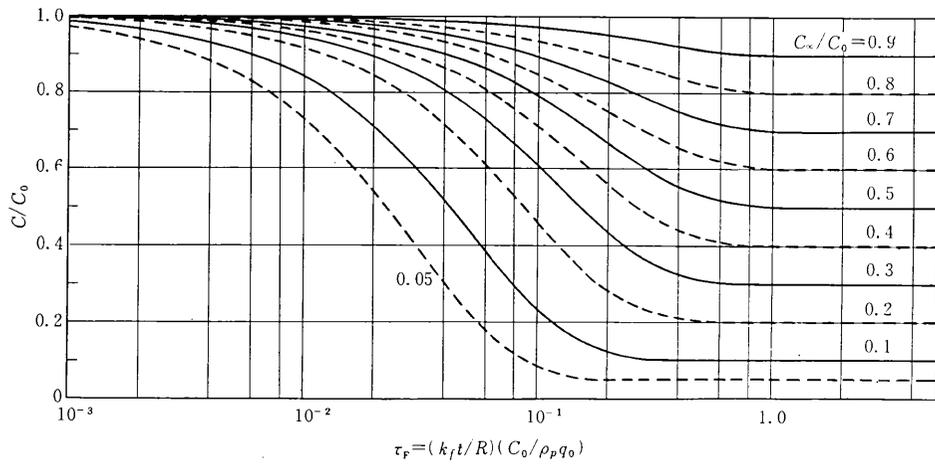


Fig. 1 C/C_0 versus $\tau_f = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=1.25$

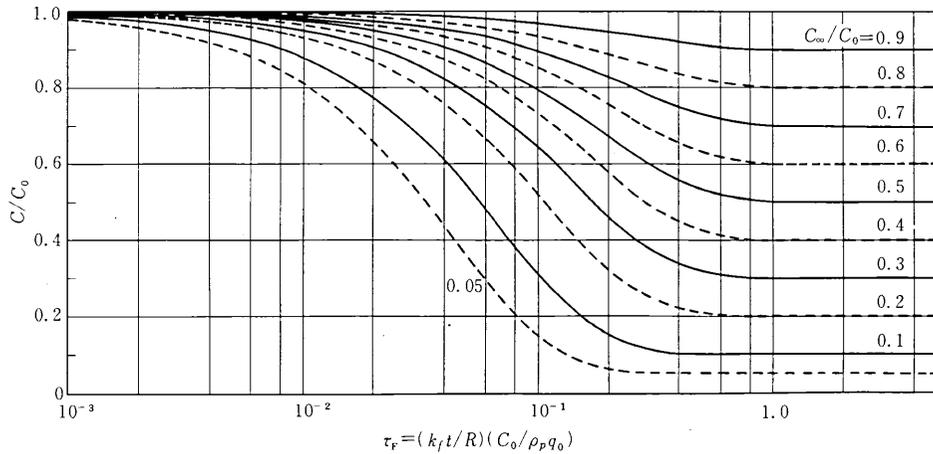


Fig. 2 C/C_0 versus $\tau_f = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=1.5$

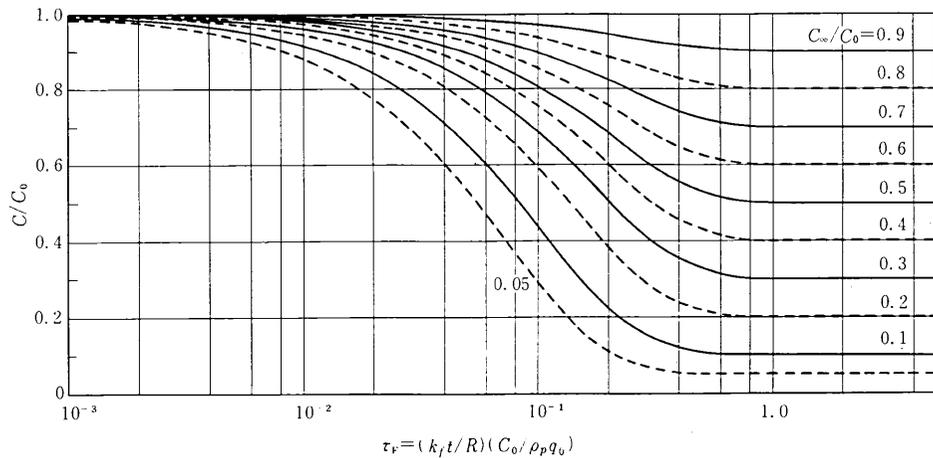


Fig. 3 C/C_0 versus $\tau_f = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=2$

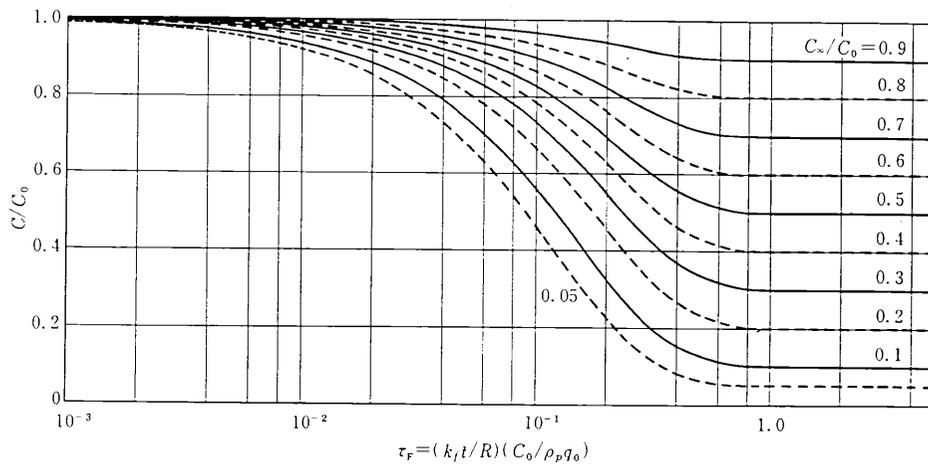


Fig. 4 C/C_0 versus $\tau_f = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=3$

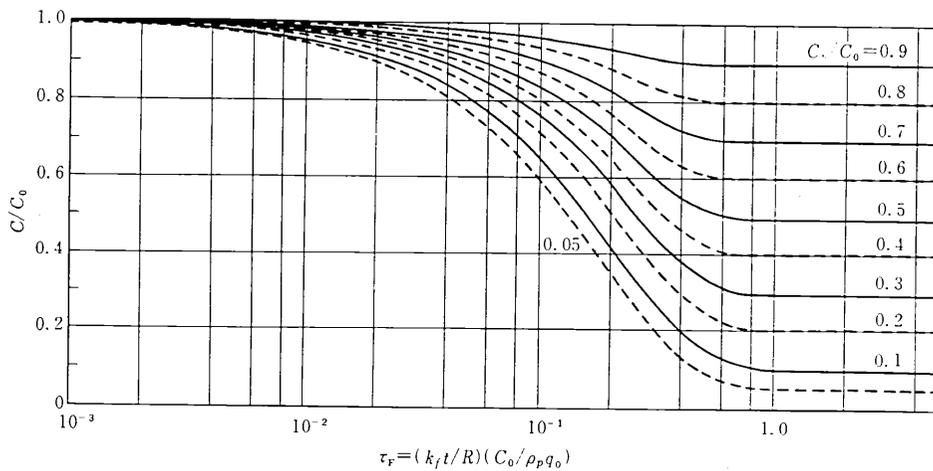


Fig. 5 C/C_0 versus $\tau_f = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=5$

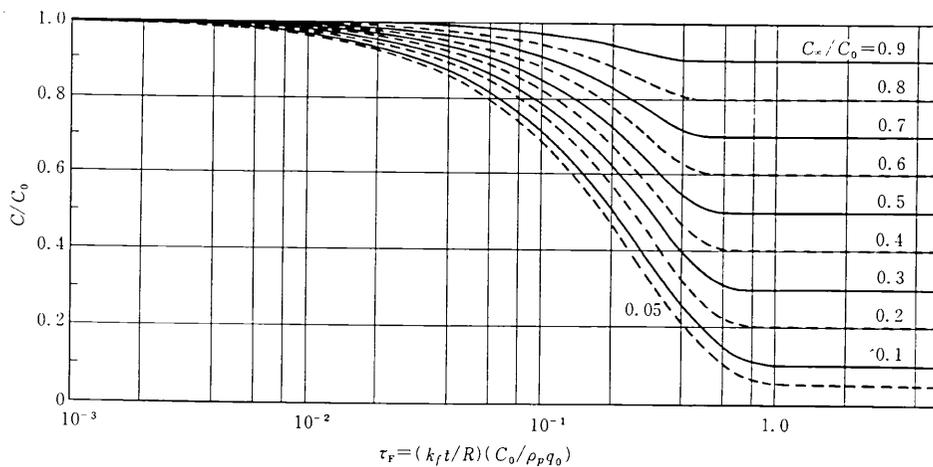


Fig. 6 C/C_0 versus $\tau_f = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=10$

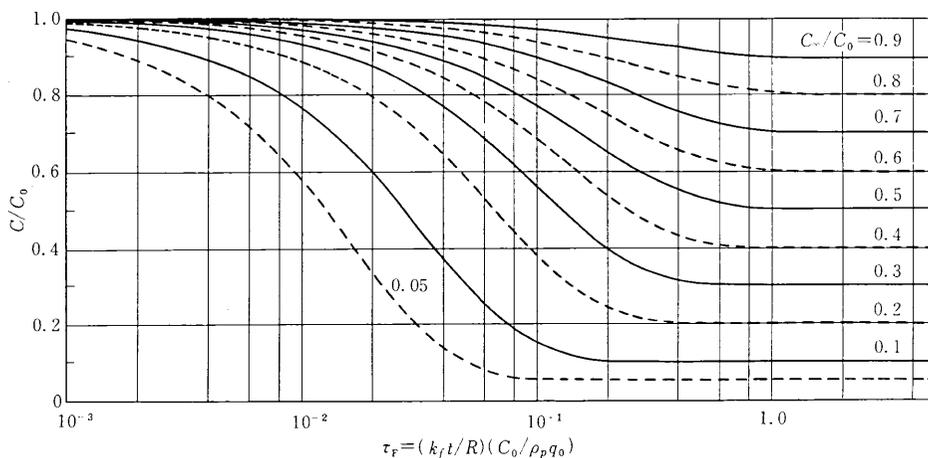


Fig. 7 C/C_0 versus $\tau_F = (k_f t / R)(C_0 / \rho_p q_0)$ for $n=1$ obtained from Equation (11)

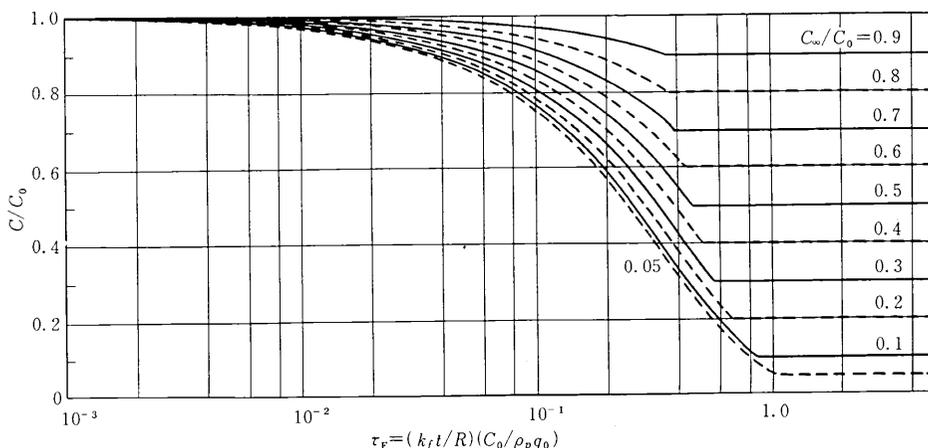


Fig. 8 C/C_0 versus $\tau_F = (k_f t / R)(C_0 / \rho_p q_0)$ for irreversible isotherm systems (Eq. (12)).

the value of n around unity.

The use of these diagrams for determining k_f can be made in a similar manner as shown in the earlier report¹⁾

(Manuscript received, June 10, 1975)

Nomenclature

- C : concentration in bulk fluid (g/cc)
- C_0 : initial concentration (g/cc)
- C_∞ : final concentration (g/cc)
- C^* : concentration in equilibrium with q (g/cc)
- k_f : mass transfer coefficient between particle surface and bulk fluid (cm/cc)
- n : Freundlich constant (-)
- q : amount absorbed (g/g)
- q_0 : amount absorbed in equilibrium with C_0 (g/g)

- R : particle radius (cm)
- t : time (sec)
- X : q/q_0 (-)
- Y, Y^* : $C/C_0, C^*/C_0$ (-)
- V_L : volume of fluid (cm³)
- W_s : amount of adsorbent (g)
- α : $W_s q_0 / V_L C_0$ (-)
- ρ_p : particle density (g/cm³)
- τ_F : $(k_f t / R)(C_0 / \rho_p q_0)$

Literature

- 1) Suzuki, M. and K. Kawazoe : Seisankenkyu, 26, No. 7, 275 (1974)
- 2) Suzuki, M. and K. Kawazoe : Seisankenkyu, 26, No. 8, 296 (1974)
- 3) Suzuki, M. and K. Kawazoe : J. Chem. Eng. Japan, 7, 346 (1974)