

CORRELATION OF ADSORPTION EQUILIBRIUM DATA OF VOLATILE CHLORINATED HYDROCARBONS FROM AQUEOUS SOLUTIONS TO ACTIVATED CARBON FIBERS BY THE DUBININ-ASTAKHOV EQUATION

AKIYOSHI SAKODA AND KUNITARO KAWAZOE

Department of Industrial Administration, Science University of Tokyo, Noda 278

MOTOYUKI SUZUKI

Institute of Industrial Science, University of Tokyo, Tokyo 106

Key Words: Adsorption, Adsorption Equilibrium, Dubinin Equation, Volatile Chlorinated Hydrocarbon, Activated Carbon Fiber

Introduction

Recently the contamination of groundwater by organic solvents has become a new environmental problem. The contaminants are volatile chlorinated hydrocarbons such as trichloroethylene, tetrachloroethylene and related compounds, and the concentration of these compounds in contaminated groundwater is usually in the order of magnitude of microgram per liter. Since these compounds are believed to be carcinogenic when they are accumulated in a specific organ of the human body, treatment is needed when we use the water taken from contaminated groundwater sources, particularly as drinking water. The adsorption treatment using granular activated carbons is one of the effective treatments at present.^{2,3)} Recently developed adsorbents, activated carbon fibers, are considered promising for use for this purpose since they have large adsorption capacity and very rapid adsorption rate in comparison with granular activated carbons.⁴⁾

In this work, adsorption equilibrium relations of trichloroethylene, tetrachloroethylene and chloroform from aqueous solutions to activated carbon fibers were obtained and correlation by the Dubinin-Astakhov equation was tried.

1. Experimental

1) Material Activated carbon fibers (ACFs) FT15, FT20 and FT25 manufactured by Kuraray Chem. Co. from phenol resin were used. The pore size distribution of the sample ACFs was obtained by the Dollimore method and are shown in Fig. 1. As seen in Fig. 1, ACFs used here are activated to a higher degree according to their grade number expressed as

15, 20 and 25 and their pore size is relatively uniform and small in comparison with that of granular activated carbons commonly used for water treatment.

Adsorbates chosen as typical contaminants of groundwater are trichloroethylene, tetrachloroethylene and chloroform. Aqueous solutions of these compounds were prepared by using distilled, ion-exchanged water.

2) Procedures Measurements of adsorption equilibrium were conducted by the batch adsorption method when the equilibrium concentration was lower than 1×10^{-3} kg/m³ and by the column adsorption method in the higher concentration range. The concentrations of aqueous solutions were determined by the head space method in the former case and by the hexane-extraction method in the latter case, using gas chromatography with an electron capture detector. Adsorption temperature was controlled at 293 ± 0.1 K. Details of experimental procedures were presented in another paper.⁴⁾

2. Results and Discussion

The Dubinin-Astakhov equation (the D-A equation) given by Eqs. (1) and (2) is often used for describing adsorption equilibrium relations of gases and vapors on microporous adsorbents.^{1,5)}

$$W = W_0 \exp(-(A/E)^n) \quad (1)$$

$$\ln \ln(W_0/W) = n(\ln A - \ln E) \quad (1)$$

$$A = RT \ln(P_s/P) \quad (2)$$

where W_0 is the adsorption space of micropores, W is the volume of micropores filled with adsorbates, E is the characteristic energy of adsorption, A is the adsorption potential at the relative pressure P/P_s , and n is a non-integer constant between 1 and 3.

When the adsorbate is volatile, the concentration of

Received May 22, 1986. Correspondence concerning this article should be addressed to A. Sakoda.

Table 1. Values of n and E determined from equilibrium data

ACF	Adsorbate					
	Trichloroethylene		Tetrachloroethylene		Chloroform	
	n [—]	E [kJ/mol]	n [—]	E [kJ/mol]	n [—]	E [kJ/mol]
FT15	1.65	10.8	1.5	8.1	1.65	9.5
FT20	1.55	8.8	—	—	—	—
FT25	1.45	7.6	1.2	5.9	1.3	5.8

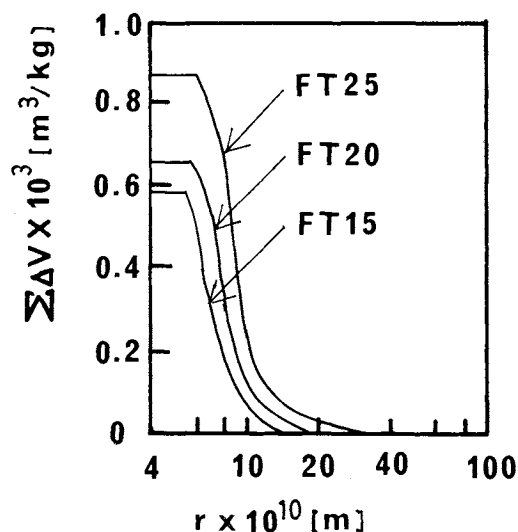


Fig. 1. Pore size distribution of sample ACFs.

the aqueous solution, C , is equilibrated with the partial pressure in gas phase, P , under the control of Henry's law. Then the adsorption potential, A , is written as

$$A = RT \ln(C_s/C) \quad (3)$$

where C_s is the concentration equilibrated with the saturation vapor pressure, P_s , and represents the solubility at the temperature T .

Figure 2 shows the adsorption equilibrium of trichloroethylene from aqueous solution to ACFs. To determine the parameters n and E , adsorption equilibrium data were plotted on $\ln \ln(W_0/W)$ versus $\ln A$ plots according to Eq. (1)', which is the linear expression of Eq. (1). Correlation was successful and parameters n and E were respectively determined from the slope and the intercept of the abscissa axis in Fig. 2. The same procedures were taken with the adsorption equilibrium data of the other adsorbates. The parameters thus determined are listed in Table 1. In the calculation for correlating equilibrium data mentioned above, the adsorption space of micropores, W_0 , was regarded as the same as the total volume of micropores given by Fig. 1. Also, the volume of micropores filled with adsorbates, W , was evaluated by using the density of the adsorbate in the liquid phase.

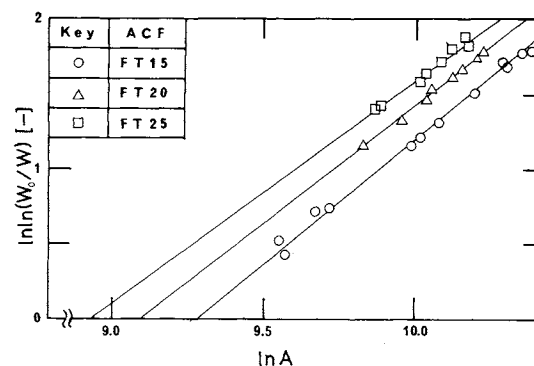


Fig. 2. $\ln \ln(W_0/W)$ vs. $\ln A$ plots of adsorption equilibrium data of trichloroethylene from aqueous solution to ACFs.

We previously derived an empirical equation, which describes the dependency of the parameter n on the ratio of mean pore-size of the adsorbent to the molecular size of adsorbate, from adsorption equilibrium of three kinds of gases to molecular sieving carbons.⁵⁾ The resultant values of n listed in Table 1 are close to the estimation by using that empirical equation. Also, another empirical equation describing the relation between E and n was derived in the same work. The resultant values of E are smaller than the values estimated by using the relation.

Nomenclature

A	= adsorption potential	[J/mol]
C	= concentration	[kg/m³]
C_s	= solubility	[kg/m³]
E	= characteristic energy of adsorption	[J/mol]
n	= exponent in Eq. (1)	[—]
P	= pressure	[Pa]
P_s	= saturation vapor pressure	[Pa]
R	= gas constant	[J/(mol · K)]
T	= temperature	[K]
$\Sigma \Delta V$	= cumulative pore volume	[m³/kg]
W	= adsorption space of micropores filled with adsorbate	[m³/kg]
W_0	= adsorption space of micropores	[m³/kg]

Literature Cited

- 1) Kawazoe, K., T. Kawai, Y. Eguchi and K. Itoga: *J. Chem. Eng. Japan*, **7**, 158 (1974).
- 2) Love, O. T. Jr. and R. G. Eiler: *J. AWWA*, **74**, 413 (1982).
- 3) Petura, J. C.: *J. AWWA*, **73**, 200 (1981).
- 4) Sakoda, A., K. Kawazoe and M. Suzuki: *Wat. Res.*, in press.
- 5) Suzuki, M. and A. Sakoda: *J. Chem. Eng. Japan*, **15**, 279 (1982).