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Adsorption behavior of bisphenol-A and diethyl phthalate onto bubble surface in nonfoaming adsorptive bubble separation

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Abstract

To clarify adsorption–equilibrium relationship at liquid–atmosphere interface, adsorption behavior of bisphenol-A (BPA) and diethyl phthalate (DEP) onto bubble surface was studied by using nonfoaming adsorptive bubble separation (NFBS) technique. The adsorption isotherms of BPA and DEP were obtained experimentally. The experimental results showed that adsorption equilibrium of BPA and DEP on bubble surface followed Langmuir's adsorption isotherm. Two adsorption parameters, the adsorption equilibrium constant and the saturated adsorption density on bubble surface could be determined and were 2.04×10^5 cm^3/g and 1.35×10^{-8} g/cm^2 for BPA and 9.41×10^4 cm^3/g and 1.79×10^{-8} g/cm^2 for DEP, respectively.

Keywords: Nonfoaming adsorptive bubble separation; Endocrine disruptor chemical; Bisphenol-A; Diethyl phthalate; Separation

1. Introduction

Recently influences of environmental distributed chemicals, so called as endocrine disrupting chemicals (EDCs), on human, vertebrate and so on have been reported [1–8]. Among EDCs, bisphenol-A (BPA) is well known one and its influences of hormonal signals and irreversible effects on the development of the reproductive organs. Especially, many reports of these influences on fish have appeared in literature [9–15]. Fish and shellfish are important for human as not only protein resources but also resources of physiologically active and bioactive substances. For conservation and restoration of the aquatic environments, these substances are attempted to remove from aqueous environments. To this purpose, several techniques have been attempted and developed, i.e., adsorption method using solid adsorbent [16–20], degradation using ozone and ultraviolet light irradiation [21], degradation by catalyzed or enzymatic method [22,23] and degradation by ultrasonic sound irradiation [24].

On the other hand, many EDCs have hydrophobic functional groups in their structure [25–27]. The authors focus on the hydrophobicity of EDCs and suppose that the adsorption phenomenon of EDCs at liquid–air interface will be utilized to remove EDCs from aqueous environments. Among them, nonfoaming adsorptive bubble separation (NFBS) [28,29] and ultrasonic atomization techniques [30] have been proposed to remove/enrich surface-active substances from dilute aqueous solution [28–30]. Especially, ultrasonic atomization technique can be effective and potential method to remove EDCs due to its high ability of producing the specific surface area based on volume of liquid, i.e., liquid–atmosphere interfacial area [31]. For the process design of this method, adsorption behavior of EDCs at liquid–atmosphere interface should be important to determine adsorption equilibrium relationship. The NFBS technique is also available methods for not only a tool of investigation of adsorption behavior onto bubble surface of surface-active substances diluted in aqueous media but also removal of these substances in dilute solution, and has some advantages, i.e., low energy requirements, a little mechanical parts in the apparatus, no-requirement of tedious treatments such as desorption or addition of any other chemicals and extending to a continuous operation with ease.

In this study, nonfoaming adsorptive bubble separation experiments were conducted with bisphenol-A and diethyl phthalate (DEP) as model EDCs, which have different value of partition coefficient *n*-octanol/water ($\log K_{ow}$), respectively. The aim of this study is determination of adsorption equilibrium parameters

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Nomenclature

A	a cross-sectional area of bubble column (m^2)
C_b	concentration of bulk liquid (kg/m^3)
C_i	initial concentration of bulk liquid (kg/m^3)
C_{tr}	concentration of liquid droplets (kg/m^3)
d_b	average diameter of bubble swarm dispersed within the column defined by Eq. (4) (m)
g	the gravitational acceleration (m/s^2)
H	distance between the bottom of the droplet trap and the liquid surface within the column (m)
K	adsorption equilibrium constant (m^3/kg)
L	Avogadro's number
M_w	molecular weight (kg/mol)
q	volumetric flow rate of liquid droplets (m^3/s)
q_0	intrinsic volumetric flow rate of liquid droplets (m^3/s)
S_b	production rate of bubble surface area (m^2)
U_g	superficial gas velocity (m/s)
X	adsorption density on bubble surface (kg/m^2)

Greek symbols

ε_g	gas holdup
γ	saturated surface adsorption density on bubble surface (kg/m^2)
ρ_g	gas density (kg/m^3)
ρ_l	liquid density (kg/m^3)
μ_l	liquid viscosity (kg/(m s))

of BPA and DEP. Determination of the adsorption parameters for EDCs is important to develop and design the further removal process.

2. Materials and methods

2.1. Materials

Bisphenol-A and diethyl phthalate were purchased from Kanto Chemical Co. Inc. (Tokyo, Japan) and were used without further purification. These were dissolved in distilled water containing 1.0 wt.% NaCl. The solutions were used in experiments in this study. All experiments were conducted at room temperature and under atmospheric pressure.

2.2. Experimental setup

A schematic diagram of the experimental setup for NFBS method is shown in Fig. 1. The setup is almost the same as that used in the previous study [28,29,32]. A bubble column consisting of a cylindrical acrylic resin tube of 4.4 cm I.D. and 36 cm in height was constructed. Sintered glass filter (10–15 μm mean-pore size) was installed as a gas distributor at the bottom of the column. Air was supplied to the column through the distributor. Pressure taps for measuring gas holdup in the column were installed at intervals of 25 cm along the wall.

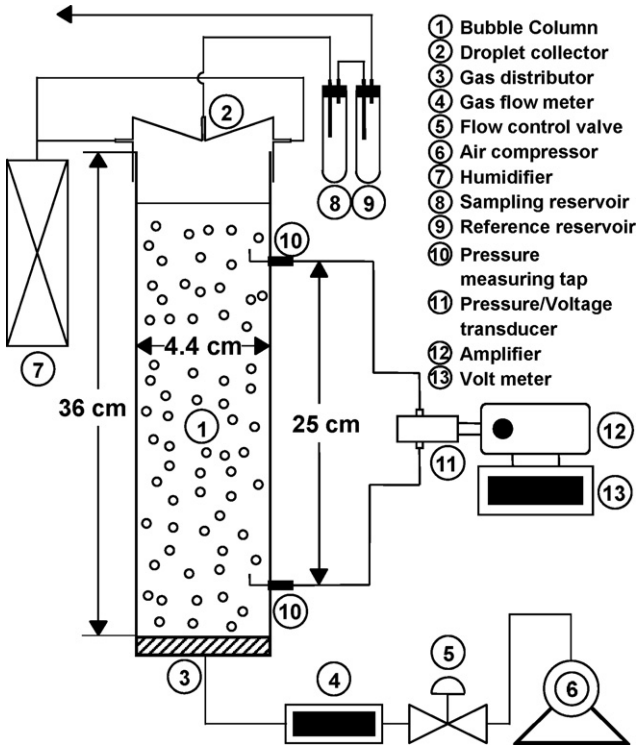

Fig. 1. Schematic diagram of experimental setup for nonfoaming adsorptive bubble separation.

The droplet trap and the droplet collector were used to measure the volumetric flow rate, q, and to determine the concentration, C_{tr}, of the droplet, respectively. They were equipped at the top of the column when they were used. The droplet trap was also made of an acrylic resin cylinder 1.8 cm in height and 5.0 cm in inside diameter (i.e., the outside diameter of the foam separation column), the bottom end of the cylinder being covered with a stainless steel net. The trap was filled with a certain amount of cotton fiber wool and fixed at the top of the foam separation column.

During the experiment, the trap was filled with a certain amount of cotton to entrap droplets generated at the liquid–atmosphere interface. The detailed drawing of the collector is shown in Fig. 2. The droplet collector was made of transparent plastic resin and was consisted of a conical upper section with a cone angle of 75° and a cylindrical lower section with a diameter of 5.0 cm and a height of 3.2 cm. A suction tap of stainless steel pipe (0.3 μm in inside diameter) was attached to the top of the cone and it was connected to a reservoir for droplet recovery. To minimize droplet drying, four glass tubes were installed at the wall of the cylindrical part to induce humidified air.

2.3. Experimental procedure

2.3.1. Measurement of droplet flow rate

An experimental setup used in this study is almost the same as that described in the previous paper [28,29] as shown in Fig. 1. 500 mL of BPA or DEP solution was prepared at a desired concentration and it was charged into the column. Nitrogen gas or