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Influence of the coexisting contaminants on bisphenol A sorption and desorption in soil

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Abstract

The effects of different heavy metals (Cd, Pb), surfactants (cetyltrimethylammonium bromide (CTAB), cetylpyridine chloride (CPC)) and the ionic strength (Ca^{2+}, NH_4^+) on breakthrough curves (BTCs) for sorption and desorption of bisphenol A (BPA) were studied using soil column experiment. Results showed that the presence of heavy metals and cationic surfactants caused a significant increase on the BPA sorption. In addition, the volume required when effluent concentration reached half of the influent concentration ($V_{C_{1/2}}$) increased due to the introduction of heavy metals and surfactants. It was also found that the larger amount of BPA was absorbed with higher ionic strength. The cationic surfactants enhanced the desorption ability of BPA from the soil. The results provided a better understanding of BPA behavior in environment and facilitated more accurate assessment of its ecological risk and identification of appropriate management strategies.

Keywords: BPA; Heavy metals; Surfactants; Sorption; Desorption

1. Introduction

BPA, an alkylphenolic compound, is a principle monomer in the production of polycarbonates, epoxy resins, and other plastics [1]. The epoxies are used as food-contact surface coatings for cans, automobile parts, and adhesives and as a coating for PVC water pipe walls. BPA is suspected to enter rivers, streams and surface waters from effluents of facilities that manufacture epoxy and polycarbonate plastics and elution from the products containing BPA [2,3]. It is antioxidant, non biodegradable and highly resistant to chemical degradation. It is present in surface waters, as well as industrial wastewaters at concentrations that are of environmental concern and present a risk to humans and animals [4,5]. BPA has been reported to interact with the humans and wildlife and show adverse effect. These effects include formation of additional female organs, enlarged accessory sex glands, and a stimulation of egg and egg mass production resulting in increased female mortality [6]. One recent paper has demonstrated that laboratory mice exposure of about 20 mg/l of BPA have developed chromosomal abnormalities in eggs, raising earlier concerns about safe level of BPA exposure [7]. Therefore, BPA has been identified as the endocrine disrupting chemicals (EDCs) by the U.S Environmental Protection Agency (EPA), World Wide Fund for Nature (WWF) [8,9] and is becoming a social issue of increasing interest in the public [10–12].

Sorption and desorption are key factors in evaluating the transport, transformation, degradation and fate of BPA in environment. There have been a number of studies focused on the adsorption/partition behavior of BPA and they showed that the effects of the presence of organic pollutants on the sorption and other related fate and transport processes of BPA and other EDCs should not be ignored [10,11]. Heavy metals and surfactants are commonly coexisting with BPA in contaminated surface water and groundwater systems. Cadmium and lead as important EDCs [13] are well-detected in the natural water body, particularly in heavily contaminated wastewaters and in hazardous wastes areas [14,15]. BPA can also synergize with heavy metal cadmium and ultraviolet radiation, leading to increasing harm to the organisms [16,17]. Surfactants were also widely found in environment due to their applied strength in the fields of oil exploitation, synthetic detergents, printing and dyeing. They were found to affect

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the fate, transformation and transportation of pollutants in soils and sediments [18]. However, none of the previous studies have examined the effects of the presence of heavy metals and surfactants on the sorption and desorption of BPA in soils using soil column experiment.

Taking into account the above, the overall objective of this study was to investigate the influence of heavy metals and surfactants on the sorption and desorption of BPA. This evaluation will be carried out by studying its sorption isotherm by batch experiment. The effects of heavy metals, surfactants and ionic strength on breakthrough curves (BTCs) of BPA will be investigated using soil column experiment. The extent of surfactants desorption BPA from soil will also be measured.

2. Materials and methods

2.1. Materials

The soil sample was taken from the experimental farm, Shanghai Jiaotong University, Shanghai, China. The sample was crushed to pass through a 0.2 mm mesh sieve after air-dried. The basic characteristics of samples were analyzed using the methods described by He et al. [19] and are given in Table 1. BPA, calcium chloride, ammonium chloride, lead chloride, cadmium chloride, CTAB and CPC are all of analytical grade obtained from Shanghai Chemical Reagent Co. in China.

2.2. Sorption and desorption experiments

2.2.1. Sorption isotherm

A total of 1.5 g of soil was filled in 25 ml glass bottles with 20 ml of BPA solutions, which already contained $CaCl_2$ and NaN_3 at the concentrations of 5 mmol/l and 100 mg/l, respectively. $CaCl_2$ was used to give the appropriate ionic strength for the background groundwater and also could reduce the dispersion of particle. NaN_3 was used to inhibit the microbial activity. The glass bottles were capped with a well-fitted stopper, sealed with parafilm and then shaken in a DZK-2 thermostatted waterbath (Shanghai Jinghong Instrument Factory, China) at $25 \pm 1\,^{\circ}C$ for 24 h. Then soil suspensions were centrifuged at 10,000 rpm for 20 min using a high-speed refrigerated centrifuge (Sartorius 3–18 K, Sigma, Germany). A blank sorption experiment with no soil was performed using the same procedure to determine the loss of the BPA that might be absorbed on the glassware.

2.2.2. Sorption column experiment

The soil column experiment was carried out in a PVC column with an inside diameter of 5 cm and a length of 10 cm.One hundred grams of soil was added into the column with tapping to achieve a uniform porous medium. The upper part of the column was uniformly covered with glass beads and nylon mesh over the whole of the surface of the column to facilitate the distribution of the solution, as well as minimize surface distribution. The bottom of the column was also uniformly covered with glass beads and nylon mesh to prevent the loss of the soil. The deionized water was used to wash the soil in an upflow rate, then in a downflow rate in order to reach a constant flow rate [20]. Immediately after this, the BPA solution at the concentration of 80 mg/l containing heavy metals, surfactants and ionic strength, respectively, was continuously fed to the top of the column at a constant flow rate controlled by a BT00–300M peristaltic Pump (Baoding Longer Precision Pump Co., China) until the solute effluent concentration, C_e (mg/l), approached the influent concentration, C_0 (mg/l), i.e., $C_e/C_0 = 1$ [21]. In all column tests, the effluent samples were intermittently collected in glass tubes by a BSZ-160 automatic fraction collector (shanghai Qinpu, Co., China) and measured by the UV 2102-PC spectrophotometer (Shanghai Unico Co., China) at the wavelength of 276 nm.

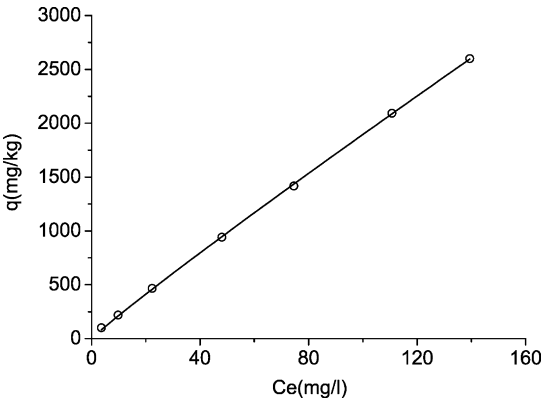

Fig. 1. The sorption isotherm of BPA in soil.

2.2.3. Desorption column experiment

For these studies, the solution containing 20 mg/l CTAB and CPC, respectively, was pumped into the top of the column, in which the initial soil was contaminated with 80 mg/l BPA solution. The solution flowed through the contaminated column until the $C_e/C_0 = 0$ was approached. All the experiments were conducted three times at 25 °C and the average values are shown in all Figs.

3. Result and discussion

3.1. Single sorption isotherm

Fig. 1 shows the sorption isotherm of BPA, which can be fitted by the Freundlich model,

$$q = K_f C_e^{N}$$

Table 1
The properties of soil

Sand (%)	Silt (%)	Clay (%)	Cation exchange capacity (c mol/kg)	Organic carbon (%)	pH (s:w = 1:2.5)
80	15	5	12.4	1.27	7.34