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Adsorption of anionic and nonionic surfactant mixtures from synthetic detergents on soils

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Abstract

Adsorption of anionic surfactant (sodium dodecylbenzenesulfonate, SDBS) and nonionic surfactant (an alcohol ethoxylates with 12 carbons and 9 oxyethyl groups, $A_{12}E_9$) mixtures, widely used as the major constituents of synthetic detergents in China and become the most common pollutants in the environment, on soils was conducted to investigate the behavior of mixed surfactants in soils. The effects of addition order and mixing ratios of two surfactants, associated with pH and ion strength in solutions, on adsorptions were considered. The results show that saturated adsorption amount of SDBS and $A_{12}E_9$ on soils decreased respectively when $A_{12}E_9$ was added into soils firstly compared with that secondly, possibly resulting from the screening of $A_{12}E_9$ to part adsorption sites on soils and the hydrocarbon chain–chain interactions between SDBS and $A_{12}E_9$. The adsorption of SDBS and $A_{12}E_9$ on soils was enhanced each other at pre-plateau region of isotherms. At plateau region of isotherms, the adsorption of SDBS on soils decreased with the increase of molar fraction of $A_{12}E_9$ in mixed surfactant solutions, while that of $A_{12}E_9$ increased except the molar ratio of SDBS to $A_{12}E_9$ 0.0:1.0. With the increase of pH in mixed surfactant solutions, adsorption amount of SDBS and $A_{12}E_9$ on soils decreased, respectively. The reduction of ion strength in soils resulted in the decrease of adsorption amount of SDBS and $A_{12}E_9$ on soils, respectively.
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Keywords: Addition order; Adsorption; Molar ratio; Soil; Surfactant mixtures

1. Introduction

Contamination of soils by organic pollutants has become an issue of increasing worldwide concern (Zhu et al., 2003; Zhang et al., 2004), and the study about the adsorption of pollutants on soils is necessary to understand their behavior in the soil environment (Monkiedje and Spiteller, 2002). Surfactants are considered as one of the most common pollutants found in soils due to extensive use in household products, industrial processes, and pesticide formulations (Karagunduz et al., 2001; Hung et al., 2004; Jia et al., 2005). After entering into soils, surfactants may adsorb on soils and subsequently affect the physico-chemical and biological properties of soils, including stability of soil aggregates (Piccolo and Mbagwu, 1989), hydraulic conductivity of soils (Allred and Brown, 1994), soil water retention (Karagunduz et al., 2001), and the metabolism of microbes in soils (Kuhnt, 1993; Wang et al., 2005),

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etc. Especially, the surfactants may affect the adsorption, mobility and degradation of other organic substances in soils (Sánchez-Camazano et al., 1995; Iglesias-Jiménez et al., 1996; Krogh et al., 2003; Zhao et al., 2005).

A few authors have reported on the researches about the adsorption of surfactants on soils. Urano et al. (1984) reported that there existed a correlation between adsorption of surfactants and organic carbon content of soils. Dai et al. (1999) described that the increase of ionic strength in solutions enhanced the adsorption of anionic surfactant on soils, while hardly affected the adsorption of nonionic surfactant. The adsorption of nonionic surfactants on soils increased with the number of oxyethylene and alkyl chain length (Kiewiet et al., 1996; Brownawell et al., 1997). Soils with larger value of Si:(Al + Fe) exhibited higher adsorption capacity to nonionic surfactant (Shen, 2000). In despite of these reports, the information about the adsorption of anionic and nonionic surfactant mixtures on soils is still scarce. The adsorption of surfactant mixtures mainly focused on pure solid (e.g., alumina, kaolinite, and silicon). For example, Huang et al. (1996) found that the adsorption of nonionic surfactant on alumina was enhanced in the presence of cationic surfactant. The mixing ratio of two surfactants significantly affected adsorption behavior of surfactants on alumina. Similar behavior was also observed in anionic/nonionic surfactant system (Wang and Kwak, 1999). Somasundaran and Huang (2000) reported that the adsorption of anionic surfactant on kaolin hardly changed with hydrocarbon chain length of nonionic surfactant when the hydrocarbon chain of nonionic surfactant was longer than that of anionic surfactant. These results indicated that adsorption behavior of surfactant mixtures could be much more complex compared with that of single surfactant. Thus it is difficult to make any general conclusion about the adsorption of surfactant mixtures on the solid before more related researches are performed.

In practice, surfactants found in soils are invariably mixtures due to the use of different surfactants in different fields (Rao and He, in press). Besides, different surfactants are often intentionally mixed together to exploit high surface activity and to improve the solubility and bioavailability of organ pollutants (Stellner and Scamehorn, 1989; Zhu and Feng, 2003; Zhao et al., 2005). Therefore, it is important to investigate the adsorption of mixed surfactants on soils for the protection of soil environment. This paper mainly aimed to study adsorption behavior of anionic and nonionic surfactant mixtures from synthetic detergents on soils. The effects of addition order and mixing ratios of two surfactants, associated with pH and ion strength in solutions, on adsorptions were considered in this study in order to understand better the characteristics of anionic and nonionic surfactant mixtures in soils.

2. Materials and methods

2.1. Materials

An anionic surfactant (sodium dodecylbenzenesulfonate, SDBS) and a nonionic surfactant (alcohol ethoxylates with 12 carbons and 9 oxyethyl groups, $A_{12}E_9$) were used in this study, since they are widely used as the major constituents of synthetic detergents in China and have become the most common pollutants found in soils (Liang, 1990; Rao and He, in press). The chemical formulas of SDBS and $A_{12}E_9$ are $CH_3(CH_2)_{11}C_6H_4SO_3Na$ and $CH_3(CH_2)_{11}(OCH_2CH_2)_9OH$, respectively. The sulfonate group of SDBS and the oxyethyl group of $A_{12}E_9$ function as hydrophilic groups, respectively, while their hydrocarbon chains as hydrophobic groups. SDBS and $A_{12}E_9$ with a degree of purity >99% were obtained from Sigma Chemical Company and Nikko Chemicals, Japan. The critical micelle concentrations (CMC) of single surfactant and their mixtures were determined by surface tension measurement using ring method (Ou et al., 1996). The results are given in Fig. 1.

The samples of the paddy soil widely distributed in Shanghai were taken from the Experimental Farm, Qibao Campus, Shanghai Jiaotong University, Shanghai, China (Hou, 1992). The soil is classified as anthrosols (AT) according to the world reference base (WRB) for soil resources classification. The samples were 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. (2003). The soil texture is silty loam according to the international soil texture classification. Organ matter,

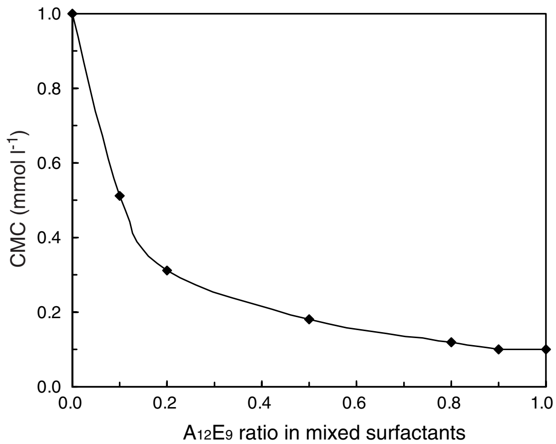

Fig. 1. The critical micelle concentrations (CMC) of mixed surfactants (SDBS and $A_{12}E_9$) in 0.01 mol l^{-1} NaCl solutions at pH 7.0. SDBS, sodium dodecylbenzenesulfonate; $A_{12}E_9$, an alcohol ethoxylates with 12 carbons and 9 oxyethyl groups.

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