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Research article

Adsorptive removal of cationic surfactants from aqueous solutions onto high-area activated carbon cloth monitored by in situ UV spectroscopy

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ABSTRACT

Activated carbon cloth (ACC) was used as adsorbent for the removal of cationic surfactants such as benzyltrimethylammonium chloride (BTMACl), benzyltriethylammonium chloride (BTEACl), benzyltributylammonium chloride (BTBACl), benzyldimethyldecylammonium chloride (BDMDACl), benzyldimethyltetradecyl ammonium chloride (BDMTDACl), benzyldimethylhexadecylammonium chloride (BDMHDACl), N-dodecylpyridinium chloride (N-DPCl) and N-cetylpyridinium chloride (CPCl) from aqueous solutions. The adsorption efficiency of the ACC was evaluated for cationic surfactants. Adsorption process was followed by in situ UV spectroscopic technique. The kinetic data, so obtained, were treated according to the pseudo first-order, the pseudo second-order, the Elovich and the intraparticle diffusion models in order to understand the adsorption mechanism of cationic surfactants onto the ACC. The best fit was found with the pseudo second-order model. The experimental isotherm data were obtained at 30 °C and analyzed by the Freundlich and the Langmuir models. The parameters of isotherm equations were determined. The Freundlich model was found to represent the experimental data better than the Langmuir model. The observed adsorption behaviors are discussed in terms of the pH of the solution, the nature of cationic surfactants (e.g. functional groups, size, and hydrophobicity) and the nature of the ACC (e.g. surface charge, pore size). A fair linear correlation was found between some adsorption parameters and apparent molar volumes at infinite dilution for benzyltrialkylammonium chlorides.

1. Introduction

Surfactants constitute the most important group of detergent components and are present in all types of detergents [1]. They are of toxic nature and their presence in water creates health hazards like dermatitis, unpleasant taste and smell. They cause foams in waters. Some surfactants are biodegradable, but many of them are not [2]. For this reason the amount of surfactants in wastewaters should be reduced at least to acceptable levels.

There are four types of surfactants: anionic, cationic, zwitterionic and non-ionic. Cationic surfactants are widely used as textile softeners, dispersants, emulsifiers, dye-fixing agents, wetting agents, disinfecting agents and corrosion inhibitors in various industries [3].

One of the commonly used methods for removal of pollutants from wastewaters is adsorption and probably the most widely used adsorbent in adsorption is activated carbon [4]. There are three types of activated carbon in commercial use: powder activated carbon, granular activated carbon and activated carbon fiber or cloth. Activated carbon fiber or cloth has several unique characteristics compared with conventionally used granular or powder activated carbons. These materials are composed of thin fibers of the order of ten microns in diameters leading to greater adsorption rates, and hence contributing to the minimization of the reactor size. The cloth or fiber form of activated carbon also makes the handling of adsorbents much easier [5]. For these reasons, the activated carbon cloth (ACC) has received considerable attention, in recent years, as a potential adsorbent for water treatment applications. ACC has been used for successful adsorptive removal of some organic compounds [6–14], various inorganic anions [15] and some metal ions [16–18].

The adsorption of some cationic surfactants was studied previously using various adsorbents such as silica [19,20], quartz [21], zeolite and clinoptilolite [22], rutile [23], cellulose [24], carbon black [25], coal [26] and activated carbon [27–29]. However, we have not met any study for the adsorption of cationic surfactants using the ACC adsorbent in literature.

The aim of the present study is to investigate the adsorption behaviors of some cationic surfactants from aqueous solutions onto the ACC by in situ UV spectroscopic method. Eight cationic surfactants were selected in such a way that the structural factors affecting their adsorption behavior could be examined. The names,

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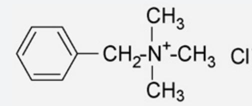
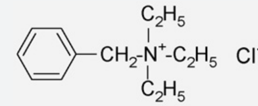
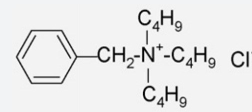
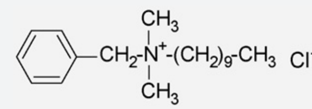
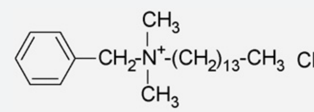
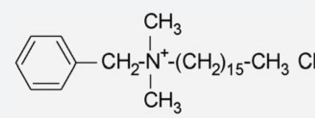
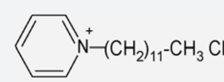
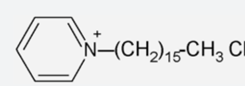
Table 1
Chemical structures of cationic surfactants.

Cationic surfactant	Abbreviation	Chemical structure
Benzyltrimethylammonium chloride	BTMACl	
Benzyltriethylammonium chloride	BTEACl	
Benzyltributylammonium chloride	BTBACl	
Benzyldimethyldecylammonium chloride	BDMDACl	
Benzyldimethyltetradecylammonium chloride	BDMTDACl	
Benzyldimethylhexadecylammonium chloride	BDMHDACl	
N-dodecylpyridinium chloride	N-DPCl	
N-cetylpyridinium chloride	CPCl	

abbreviations and structures of the selected cationic surfactants are given in Table 1.

2. Materials and methods

2.1. Materials

The ACC used in the present work was obtained from Spectra Corp. (MA, USA) coded as Spectracarb 2225. Although the full details of its mode of preparation are regarded as proprietary, it originates from pyrolysis of phenolic polymer fibers followed by heat treatment in O_2-free N_2 between 800 and 900 °C for some hours. In this respect, it differs from other fibrous carbon materials derived by pyrolysis of rayon [16].

BTMACl, BTEACl, BTBACl and CPCl were obtained from Aldrich, BDMDACl, BDMTDACl and BDMHDACl from Fluka and N-DPCl from Merck. All chemicals used in this study were reagent grade. Deionized water was used in adsorption experiments.

2.2. Treatment and properties of the ACC

A washing procedure was applied for the ACC as described previously [6,7,12]. Several properties of the ACC such as specific surface area, volumes of micropores and mesopores, elemental composition, pH_{PZC} which is the pH of solution at which net charge on the surface of the ACC is zero, and acidic and basic group contents were determined in our previous works [7,12,14]. These properties are listed in Table 2. The SEM pictures and electrochemical characterization of the ACC were also reported earlier [30].

2.3. The design of the adsorption cell and optical absorbance measurements

A specially designed cell was used to carry out the adsorption and simultaneously to perform in situ concentration measure-

Table 2
Properties of the ACC.

Specific surface area	1870 $m^2\ g^{-1}$
Total pore volume	0.827 $cm^3\ g^{-1}$
Micropore volume	0.709 $cm^3\ g^{-1}$
Mesopore volume	0.082 $cm^3\ g^{-1}$
Average fiber diameter	17 μm
Carbon content	95.14%
Hydrogen content	0.37%
Oxygen content	4.49%
Nitrogen and sulfur content	0%
pH_{PZC}	7.4
Total acidic group content	0.25 $mmol\ g^{-1}$
Carboxylic group content	0.093 $mmol\ g^{-1}$
Lactonic group content	0.020 $mmol\ g^{-1}$
Phenolic group content	0.14 $mmol\ g^{-1}$
Total basic group content	0.28 $mmol\ g^{-1}$