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Adsorption of CTAB onto perlite samples from aqueous solutions

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Abstract

In this study, the adsorption properties of unexpanded and expanded perlite samples in aqueous cetyltrimethylammonium bromide (CTAB) solutions were investigated as a function of ionic strength, pH, and temperature. It was found that the amount of cetyltrimethylammonium bromide adsorbed onto unexpanded perlite was greater than that onto expanded perlite. For both perlite samples, the sorption capacity increased with increasing ionic strength and pH and decreasing temperature. Experimental data were analyzed by Langmuir and Freundlich isotherms and it was found that the experimental data were correlated reasonably well by the Freundlich adsorption isotherm. Furthermore, the isotherm parameters (K_F and n) were also calculated. The adsorption enthalpy was determined from experimental data at different temperatures. Results have shown that the interaction between the perlite surface and CTAB is a physical interaction, and the adsorption process is an exothermic one.

Keywords: Perlite; Zeta potential; Surfactants; Adsorption; Adsorption heat; Adsorption isotherms

1. Introduction

Surfactants are among the most versatile of the products of the chemical industry, appearing in such diverse products as the motor oils we use in our automobiles, the pharmaceuticals we take when we are ill, the detergents we use in cleaning our laundry and our homes, the drilling muds used in prospecting for petroleum, and the flotation agents used in beneficiation of ores. The past decade has seen the extension of surfactant applications to such high-technology areas as electronic printing, magnetic recording, biotechnology, microelectronics, and viral research [1]. The application of surfactants can also produce environmental pollution and raises a series of problems for wastewater treatment plants [2]. Furthermore, surfactants adsorb readily onto crystal surfaces, owing to their surface activity, leading to crystal growth inhibition [3–5]. From this perspective, surfactants should be removed from selected stages of the industrial process or wastewater emission systems. The removal of these materials from industrial wastewaters is one of the major environmental problems because of the difficulty of treating such water by conventional treatment methods. One of the characteristic features of surfactants is their tendency to adsorb at interfaces in an oriented fashion [1]. The adsorption of surface active materials onto a solid surface from an aqueous solution is an important process both scientifically and technologically in many situations, including those in which we may want to remove unwanted materials from a system (detergency), change the wetting characteristics of a surface or stabilize a finely divided solid system in a liquid where stability may otherwise be absent [6]. The adsorption process is used especially in the water treatment field and an investigation has been made to determine inexpensive and good adsorbents. Surfactant adsorption has been studied extensively. Additionally, several materials have been investigated as surfactant adsorbents. These include layered double hydroxides [7,8], zeolites [8,9], silica [10], alumina [5,7,8,11–13], polymers [14], natural and synthetic fibers [15], and activated carbons [9].

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Perlite has recently been used as an adsorbent in the removal of wastewater. Perlite, a glassy volcanic rock, expands to about 20 times its original volume upon heating within its softening temperature range of 760 to 1090 °C. Perlite is essentially a metastable amorphous aluminum silicate. The expansion is due to the presence of combined water in the crude perlite rock. Almost all perlite is consumed in an expanded form, although a small amount of unexpanded perlite has been used in a few applications. Expanded perlite is an excellent thermal and acoustical insulator, resists fire, and is an ultralightweight material. As most perlites have a high silica content, usually greater than 70%, and are adsorptive, they are chemically inert in many environments and hence are excellent filter aids and fillers in various processes and materials [16]. A limited number of studies on the use of perlite as an adsorbent have been found in the literature. These are the removal of dyes such as methylene blue [17,18], methyl violet [19,20], and victoria blue [21,22], and metal ions such as copper (II) [23] and cadmium [24], by perlite.

The adsorption of surfactants at the solid–liquid interface is strongly influenced by a number of factors: (i) the nature of the structural groups on the solid surface, (ii) the molecular structure of the surfactant being adsorbed (the adsorbate), and (iii) the environment of the aqueous phase—its pH, its electrolyte concentration, the presence of additives, and its temperature [1]. We previously investigated some physicochemical properties of the perlite surface. Therefore, in this work, the adsorption of CTAB, a cationic surfactant, on both unexpanded and expanded perlite samples was studied as a function of pH, ionic strength, and temperature.

2. Materials and methods

2.1. Material

The unexpanded and expanded perlite samples were obtained from the Cumaovası Perlite Processing Plants of Etibank (İzmir, Turkey). The chemical composition of the perlite determined by XRF and some physical properties are given in Tables 1 and 2, respectively. The unexpanded and expanded perlite samples were treated before being used in the experiments as follows: the suspension containing 10 g L^{-1} perlite was mechanically stirred for 24 h, and after waiting for a couple of minutes the supernatant suspension was filtered. The solid sample was dried at 110 °C for 24 h, and then sieved by 100-mesh sieve [17].

The cation exchange capacity (CEC) of the samples obtained as explained above were determined by the ammonium acetate method and density by the pycnometer method. The specific surface areas of unexpanded and expanded perlite samples were measured by BET N_2 adsorption [25]. A JOE-JSM840 scanning electron microscope was used to obtain SEM pictures. The scanning electron microscopic (SEM) pictures in Fig. 1 show the shape of unexpanded and expanded perlite particles.

Table 1
Chemical composition of perlite

Constituent	Percentage present
SiO_2	72.75
Al_2O_3	13.56
Na_2O	2.92
K_2O	4.93
CaO	1.10
Fe_2O_3	0.83
MgO	0.29
LoI	3.63

Note. LoI: loss ignition of perlite.

Table 2
Some physicochemical properties of perlite samples used in the study

Sample	CEC (meg 100 g^{-1})	Density (g ml^{-1})	Specific surface area ($m^2\ g^{-1}$)
Unexpanded perlite	26	2.30	1.22
Expanded perlite	33	2.24	2.30

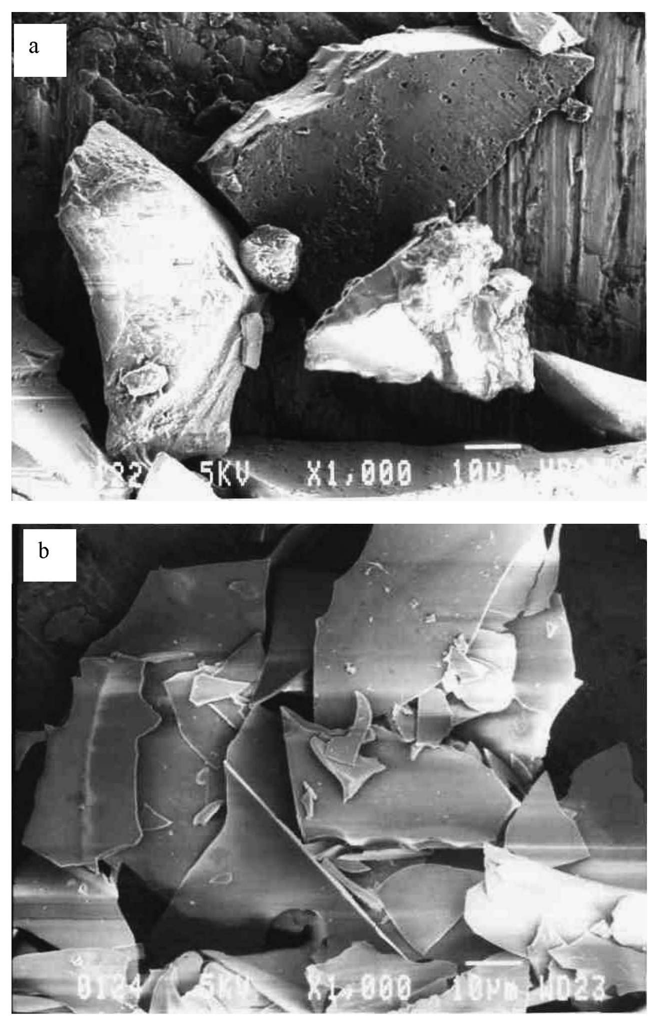

Fig. 1. SEM pictures of (a) unexpanded and (b) expanded perlite samples.