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Use of polysaccharide based surfactants to stabilize organically modified clay particles aqueous dispersion

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ABSTRACT

Pure as well as organically modified clay minerals are widely applied particles in different research areas. For the incorporation of hydrophobic organically modified clay particles into the hydrogel matrix, a stable aqueous dispersion must be prepared. In this article we report on the stabilization of aqueous dispersions of hydrophobic organically modified clay particles by using a non-ionic polysaccharide-based surfactant system-Inutec SP1 (based on chicory inulin). Different concentrations of surfactants were tested. Properties of the particulate surfactant-stabilized aqueous colloidal system were determined by electrophoretic mobility and dynamic light scattering measurements. Determination of contact angles gave us insight into the particles' surface interaction ability with water and also some information regarding the conformation of adsorbed surfactant molecules on the particle surface. By using Inutec SP1, the wettability of clay particles was improved, particle size was reduced and consequently, enhancement of their dispersion ability in water-based systems was observed.

1. Introduction

Various types of montmorillonite (MMT) and closely related minerals are the most important and widely used phillosilicate fillers in polymer composites (e.g. Fedulo et al., 2007; Le Baron, Wang, & Pinnavaia, 1999; Sfiligoj Smole et al., 2009). Their specific characteristics like large active surface area, ion exchange capacity and ability to swell remarkably in water improves functional properties and mechanical properties of nano-composites (Ray & Okamoto, 2003). By organic modification clay minerals obtain an organophilic character and the capacity to adsorb heavy metals (Bhattacharyya & Gupta, 2008), organic dyes (Baskaralingam, Pulikes, Elango, Ramamurthi, & Sivanesan, 2006; Koswojo et al., 2010; Kurečič & Sfiligoj, 2012; Liu & Zhang, 2007; Özcan, Ömeroğlu, Erdoğan, & Özcan, 2007; Yang, Han, Fan, & Uqbolue, 2005), pesticides (Groisman, Rav-Acha, Gerstl, & Mingelgrin, 2004) and herbicides (Hermosin, Celis, Facenda, Carrizosa, Ortega-Calvo, & Cornejo, 2006). Since organically modified clay particles are good adsorbents for pollutants, these particles can be incorporated as active fillers also in composite hydrogels through hydrogel in situ polymerization. Kurečič & Sfiligoj (2012) has reported on the synthesis of PNIPAM/O-MMT nanocomposite hydrogels for adsorption of acid dyes.

Polymer formation takes place from monomer aqueous solution containing dispersed particles. Polymerization occurs between the silicate layers after their swelling by the liquid monomer or monomer solution (Kiliaris & Papaspyrides, 2010). Therefore, the most decisive step in formation of hydrogel composites with the desired properties is the preparation of stable particle dispersions prior to polymerization (Landry, Riedl, & Blanchet, 2008).

Organically modified clay particles are hydrophobic and are therefore difficult or even impossible to disperse in aqueous solution. The most common strategy for tackling this issue is to introduce stabilizers into the system. Stabilizer quality is based on their ability to provide wetting of particles' surface and to offer a barrier to prevent particles from agglomeration. (Gabrielli, Cantale, & Guarini, 1996).

Polymeric surfactants are essential materials for preparation of many disperse systems (Tadros, 2009). As an answer to the growing demand for products made from renewable resources, there has been a considerable interest in development of polysaccharide based surfactants (Kjellin & Johansson, 2010; Tadros & Tharwat, 2005).

The present work describes the use of polysaccharide based surfactants for preparation of stable aqueous dispersions of organically modified clay particles. The polymeric surfactant, based on the polysaccharide-inulin, which is hydrophobized by grafting several alkyl groups (B) onto the linear polyfructose chain (A), is

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commercially available as Inutec SP1 from Orafti, Belgium. It is mainly used for stabilization of oil-in-water emulsions (Tadros, 2008). Due to the large carbohydrate part in the molecule, the surfactant is biodegradable and it is not toxic (Kjellin & Johansson, 2010). In our research the Inutec SP1 was used for enhancement of clay particles wettability and consequently, to improve particles dispersion ability in water-based systems. Different concentrations of surfactants were tested. Properties of stabilized aqueous colloidal systems were followed by zeta potential, dynamic light scattering measurements, contact angle determination and turbidity observation. Knowledge about electrokinetic and scattering data and established hydrophobic/hydrophilic character with analysis of particles sedimentation behavior, are important for future formation of hydrogels containing organically modified clay particles and subsequent properties and functionality of these composites.

2. Experimental

2.1. Materials

Inutec SP1 was supplied by Orafti Non-food (Tienen, Belgium). As mentioned above Inutec SP1 is a copolymer based on polyfructose backbone with grafted alkyl groups. Its average molecular mass is about 4500 g mol^{-1} (Esquena et al., 2003) and degree of polymerization for linear polyfructose backbone is above 23 monomer units (Nedyalkov, Alexandrova, Platikanov, Levecke, & Tadros, 2010).

Nanofil 8, an organically modified montmorillonite (Fig. 1), was purchased from Süd-Chemie (Germany). O-MMT particles were organically modified by distearyldimethylammonium chloride (DSDMAC).

2.2. Methods

2.2.1. Preparation of Inutec SP1 solutions

A water solution of 1 g/L Inutec SP1 surfactant in deionized water was prepared. This stock solution was used further on for preparation of diluted surfactant solutions. The Inutec SP1 surfactant concentrations used were in the range from 0.01 to 1 g/L.

2.2.2. Preparation of aqueous based O-MMT particle dispersions in surfactant solutions

O-MMT particles with the concentration 1 g/L were dispersed in Inutec SP1 solutions of different concentrations using homogenizer Ultraturax (IKA) for 10 min at 10,000/min and subsequently exposed to ultrasound for 20 min at an amplitude 50% using an ultrasound probe (Vibra-cell, Sonics). Dispersed samples were centrifuged and sedimented, in order to remove all surplus surfactant, using a Centric 322A centrifuge (Tehtnica) for 20 min (4500/min). The supernatant was removed and replaced with fresh water. The particles were redispersed in water using the ultrasound bath (Transsonic 820/H, Elma) for 30 min. This procedure was repeated three times and finally O-MMT particles modified with Inutec SP1 dispersed in water were obtained.

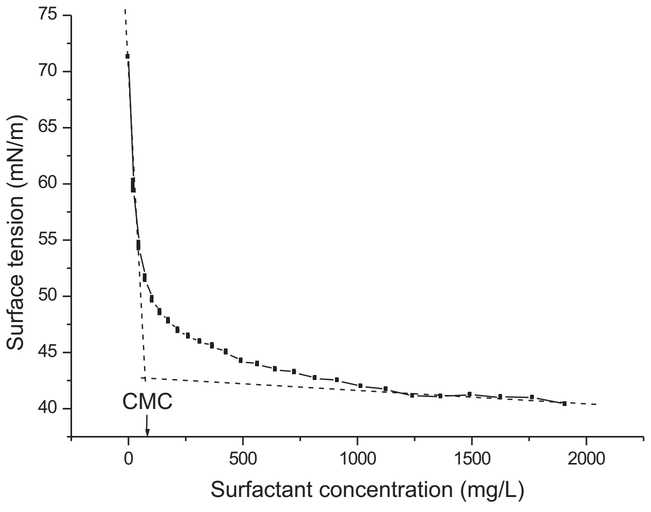


Fig. 1. Plot of water surface tension vs. Inutec SP1 concentration.

2.3. Analytical procedures

2.3.1. Determination of critical micelle concentration (CMC)

Surfactant's critical micelle concentration CMC was determined by measuring the surface tension (γ) of water upon addition of Inutec SP1. Krüss tensiometer K12 was used, employing a Wilhelmy plate method with a platinum plate which has been cleaned through heating to red hot. The method is described in detail (Peršin et al., 2011). Inutec SP1 solution with a concentration of 2 g/L was dosed into 30 ml of water. Surface tension was constantly determined over a range of addition steps 0.01 g/L of Inutec SP1 solution. Surfactant's critical micelle concentration was graphically determined from the plot of surface tension versus concentration of Inutec SP1 by modeling two straight lines of solution properties below and above the CMC which intersect each other. The intersection represents the CMC of Inutec SP1 surfactant.

2.3.2. Surface morphology observations by SEM

Surface morphology of particles prior and after adsorption of Inutec SP1 was studied by a scanning electron microscope (SEM) FE-SEM-ZEISS Gemini Supra 35 VP. Samples were prepared by deposition of a drop of O-MMT dispersion on an adhesive carbon tape, which was placed on a sample holder. Samples were dried in a vacuum oven at 40 °C.

2.3.3. Particle size determination

To determine the particle size distribution, DLS measurements were carried out. The analysis was performed using a ALV 5000 digital correlation spectrometer (Brookhaven Zeta Plus). A laser beam, with the wavelength of 532 nm and maximum output power 5 W, was used to cover the wide size range involved. Measurements were carried out at a scattering angle of 90° and at the constant temperature of 25 °C. The particle size is measured from the autocorrelation function of the intensity fluctuation of scattered lights. From this, one obtains the diffusion coefficient, D, which is used to calculate the particle hydrodynamic radius, R_H using the Stokes–Einstein equation (Brar & Verma, 2011):

$$D = \frac{kT}{6\pi\eta R_H} \tag{1}$$

where k is the Boltzmann constant, T is the absolute temperature, and η is the viscosity of the continuous phase. The value η for water at 25 °C was 8.9×10^{-4} Pa.

For the purpose of measurements samples were diluted using 0.001 M KCl.

2.3.4. Zeta potential determination

The zeta potential of the dispersed particles was determined with a Zeta meter (Brookhaven Zeta Plus), where the electrophoretic mobility of particles in dilute suspensions was measured using Zeta PALS (Phase Analysis Light Scattering) method at 25 °C and then converted to zeta potential (ζ) by utilizing the

Smoluchowski equation (Joshi, Keerthiprasad, Jayant, & Srivastava, 2010):

$$\mu = \frac{\varepsilon \varepsilon_0 \zeta}{\eta} \tag{2}$$

where ε and ε_0 are dielectric constants of dispersing medium and vacuum respectively, η is viscosity of the medium and μ is electrophoretic mobility. For the purpose of measurements samples were diluted using 0.001 M KCl.

2.3.5. Contact angle measurement

Determination of contact angle (θ) of particle layers was done using sessile drop technique, which is appropriate for solid surfaces. A 500 μL drop of the dispersion containing surfactant modified O-MMT particles was placed on a clean glass plate and dried in a vacuum oven at 40 °C. This procedure was repeated five times, resulting in a specimen with 5 layers of O-MMT particles treated with Inutec SP1 of certain concentration.

Samples were placed on a horizontal table that is attached to a mechanical device on Goniometer (DataPhysics Apparatus). Using a micro-pipette containing Milli Q water, a micro-drop with the volume 0.3 μL of water was poured on the surface of O-MMT particles. The drop on the particle' s surface was illuminated using white diffuse light and observed with a telemicroscope. A powerful objective produces a clear image of the drop which was directly transferred through a CCD-camera to show the drop profile, which was further analyzed. The contact angle was determined from the tangent to the drop at the three phase contact line.

2.3.6. Turbidity measurements

Stability of the dispersions was determined using Turbidimeter 2100P (Hach), which measures the turbidity in the range from 0.1 to 1000 NTU (Nephelometric Turbidity Unit). The turbidity (τ) is defined on the basis of the Beer-Lambert law:

$$\frac{I_t}{I_0} = e^{-\tau l} \tag{3}$$

where I_0 and I_t are the intensities of incidence and reflective beam respectively and l is the length of the light path (Maikala, 2010).

3. Results and discussion

3.1. Critical micelle concentration (CMC) of surfactant Inutec SP1

The ability of a surfactant to adsorb on a surface is related to its ability to aggregate in solution and form micelles. Therefore, determination of critical micelle concentration (CMC) of Inutec SP1 was essential to understand the subsequent action of the Inutec SP1 surfactant. Change in water surface tension was determined by gradual addition of surfactant Inutec SP1 solution (addition step: 0.01 g/L). Fig. 1 presents a plot of measured surface tension vs. Inutec SP1 concentration. It shows a reduction in surface tension with an increase in surfactant concentration, until a critical concentration above which the surface tension remains constant. CMC of Inutec SP1 surfactant was graphically defined by modeling two straight lines (dash lines in Fig. 1), where the intersection represents the CMC of surfactant. The obtained CMC value of 2.2×10^{-5} mol L^{-1} is comparable with the data from the literature (Stevens et al., 2001).

3.2. Morphology of O-MMT particles

SEM images of O-MMT particles, dispersed in water are presented in Fig. 2, where huge agglomerates, which represent randomly merged tactoids or particles with several voids, can be observed. Tactoids are formed from several associated silicate layers.

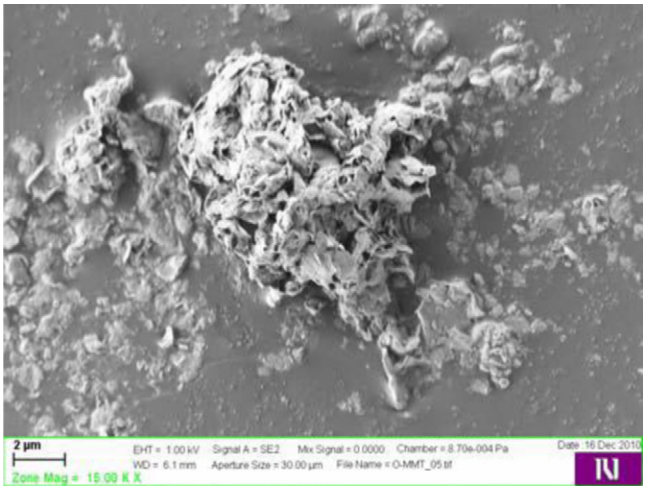


Fig. 2. SEM image of organically modified montmorillonite O-MMT particles.

SEM images of O-MMT particles modified with different concentrations of Inutec SP1 are presented in Fig 3A–E. A pronounced difference between particle samples, coated with different surfactant concentrations is noticeable. Treatment of particles in Inutec SP1 of lower concentration (0.01–0.1 g/L) (Fig. 3A–C), results in the morphology of O-MMT particles similar to that of O-MMT particles dispersed only in water. Formation of large agglomerates is characteristic for these dispersions. Concentration of Inutec SP1 above 0.1 g/L (∼CMC) considerably reduces the size of agglomerates. At an Inutec SP1 concentration of 0.5 g/L (Fig. 3D) smaller agglomerates are formed, while numerous separated particles or tactoids with only few smaller agglomerates are observed in the SEM image of O-MMT particles dispersed in surfactant solution with the concentration of Inutec SP1 1 g/L (Fig. 3E). Comparison of particles surface morphology by SEM analysis clearly demonstrates a notable impact of Inutec SP1 on the size and morphology of O-MMT particles. At this point it is necessary to emphasize, that for SEM microscopy analyses dry samples were observed, which do not represent the actual state of O-MMT particles dispersed in water, however the SEM analysis results still provide valuable preliminary information on particle size.

3.3. DLS measurements of O-MMT particles

For determination of particle size in dispersions, dynamic light scattering DLS method was involved. By DLS we have in situ determined the average particle size and particle size distribution for analyzed dispersions of O-MMT particles dispersed in water and in Inutec SP1 surfactant solutions of different concentrations. In Fig. 4 we combined results obtained from DLS measurements, the average particle size along with polydispersity. Polydispersity represents the heterogeneity of particle sizes in dispersion. O-MMT particles are, due to their very difficult to disperse in water because of their hydrophobic nature, however by employing high shear and ultrasound forces we were able to prepare unstable water dispersion of O-MMT particles without Inutec SP1 with average agglomerate size of 4812.7 nm. Particles sizes in dispersions with lower surfactant concentration of Inutec SP1 (0.01–0.1 g/L) did not change significantly; the average particle diameter is comparable with O-MMT particles in water. Significant decrease of average particle diameter was achieved with surfactant concentration of Inutec SP1 0.5 g/L (1225.6 nm), while increase in SP1 concentration (1 g/L) further decreases the size of particles 'agglomerates to a size of approximately 1092.4 nm.

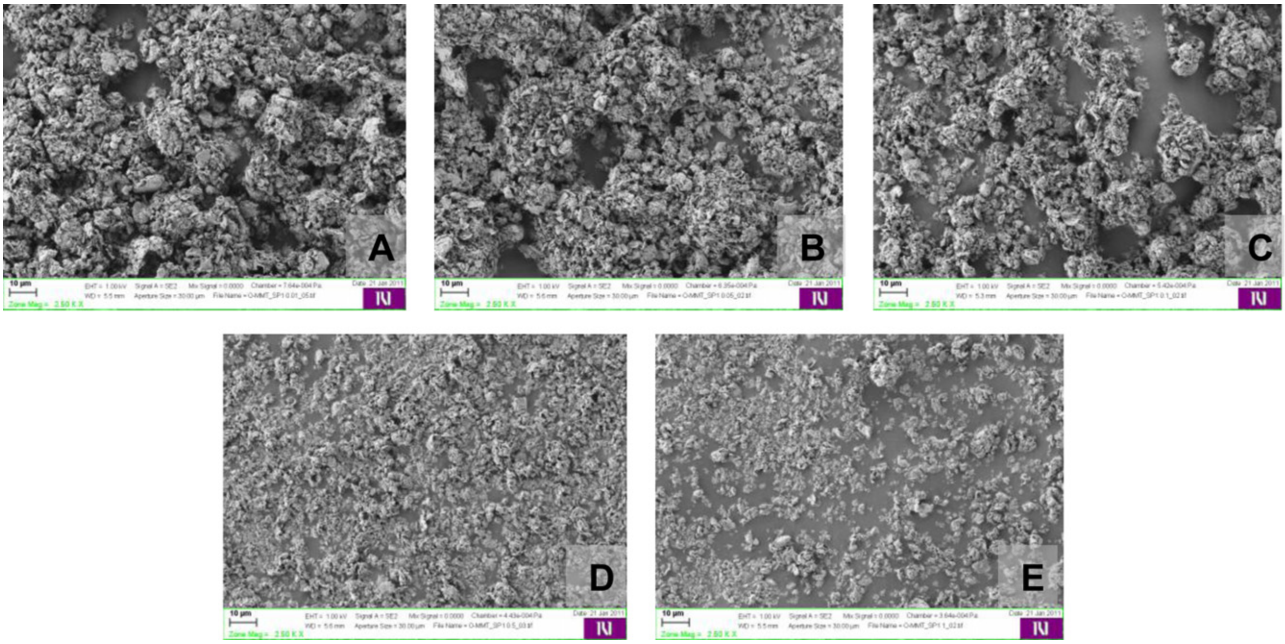


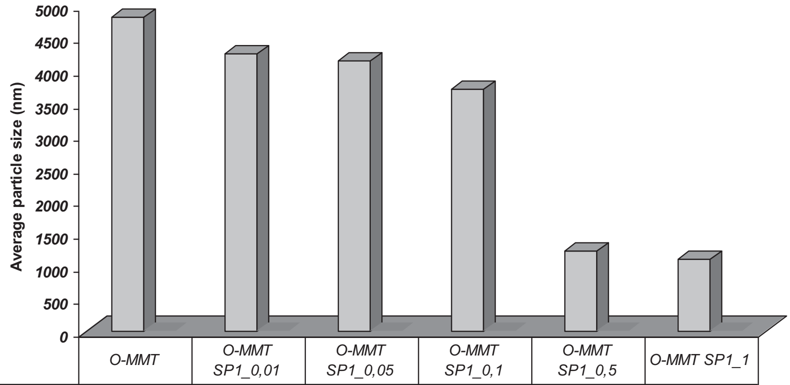
Fig. 3. SEM images of O-MMT particles dispersed in Inutec SP1 solution: (A) $c_{\text{Inutec SP1}}$ 0.01 g/L, (B) $c_{\text{Inutec SP1}}$ 0.05 g/L, (C) $c_{\text{Inutec SP1}}$ 0.1 g/L, (D) $c_{\text{Inutec SP1}}$ 0.5 g/L, (E) $c_{\text{Inutec SP1}}$ 1 g/L.

Colloid dispersions are in most cases polydisperse systems; therefore it is necessary along with particles 'diameter to consider the size distribution and polydispersity of these systems, as well.

Figs. 4 and 5 present the polydispersity and particle size distributions of prepared dispersions, respectively. The latter clearly shows that different concentrations of Inutec SP1, used for preparation of O-MMT dispersions, yield different size distributions. Water dispersion of O-MMT particles without surfactant exhibits high polydispersity value (0.476); large agglomerates are present. Similar behavior is observed with O-MMT particles, dispersed in Inutec SP1 solution with concentration 0.01–0.1 g/L. Fig. 5A–C exhibits two peaks on the size distribution plots, indicating bimodal size distribution. Increase of surfactant concentration of Inutec SP1 above 0.1 g/L again acts favorably in achieving homogenous dispersions with narrow size distribution. Fig. 5D–E shows monomodal size distribution of samples with surfactant concentration of Inutec SP1 of 0.5 and 1 g/L. Monomodal distribution is formed with average particle diameter around 1000 nm. When one compares the results of the O-MMT particle size with the CMC of added surfactant Inutec SP1, we can see that below CMC no significant changes in average particle diameter are observed, but with increasing the surfactant concentration above the CMC more uniform particle size distribution is observed with smaller average particle diameter. From these results we conclude that addition of Inutec SP1 surfactant above critical micelle concentration CMC gives rise not only to formation of smaller agglomerates, but also results in more homogeneous and uniform particles size.

3.4. Zeta potential of O-MMT particles dispersion in different Inutec SP1 solutions

Influence of different surfactant concentrations of Inutec SP1 on zeta potential of O-MMT particles was determined by using fixed concentration (1 g/L) of O-MMT particles. All measurements were performed at pH values of dispersions (pH 8). Results are given in Fig. 6A. Pronounced positive zeta potential value of 38 mV, exhibited by aqueous O-MMT particles 'dispersion, is due to the alkylammonium groups attached on the organically modified MMT particles. This highly positive zeta potential value is drastically reduced by the addition of Inutec SP1 surfactant when preparing the stabile O-MMT particles aqueous dispersion. By adding lower concentrations (below CMC) of Inutec SP1 (0.01–0.1 g/L) we observe that zeta



	O-MMT	O-MMT SP1_0,01	O-MMT SP1_0,05	O-MMT SP1_0,1	O-MMT SP1_0,5	O-MMT SP1_1
Average particle size (nm)	4812	4248	4141	3696	1225	1092
Polydispersity	0,476	0,216	0,047	0,207	0,069	0,031

Fig. 4. Average particle size and polydispersity values of O-MMT particles in water and Inutec SP1 solutions of different concentration.

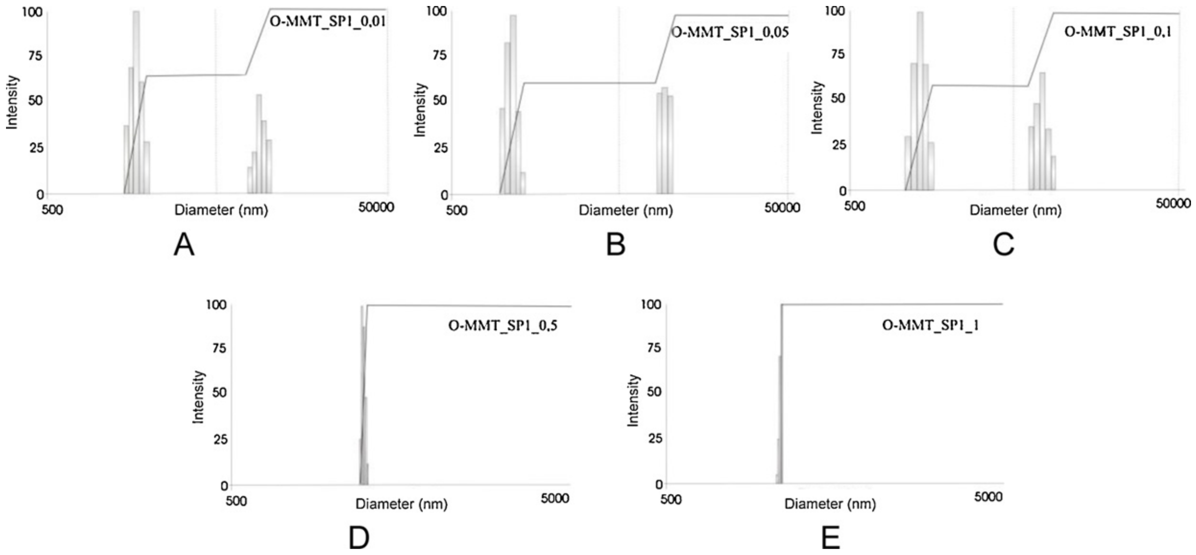


Fig. 5. Size distribution of O-MMT particles dispersed in Inutec SP1 solutions of different concentrations.

potential is lowered to about 10 mV. This decrease can be correlated to partially screening of alkylammonium groups situated on O-MMT particles surface. While treatment of O-MMT particles with surfactant solutions concentration below CMC did not considerably affect the particle size in comparison to the water-dispersed O-MMT particles, it did modify their surface properties in a pronounced manner. We presume that the reason for this phenomenon is the bridging effect, where surfactant molecule is adsorbed simultaneously on two or more particles' surface. Inutec SP1 surfactant molecule adsorbed on an O-MMT particle surface lowers zeta potential, but at the same time, the surfactant molecule is adsorbed on the second particle surface acting as a binder between them. Therefore, the particle size is not reduced as agglomerates are formed due to bridging. With increasing concentration of Inutec SP1 above the CMC (0.5 and 1 g/L), an additional decrease in zeta potential is observed. Concentration of Inutec SP1 above the CMC value results in further drop in zeta potential, bringing the final values close to 0 mV. This vigorous drop, in comparison to zeta

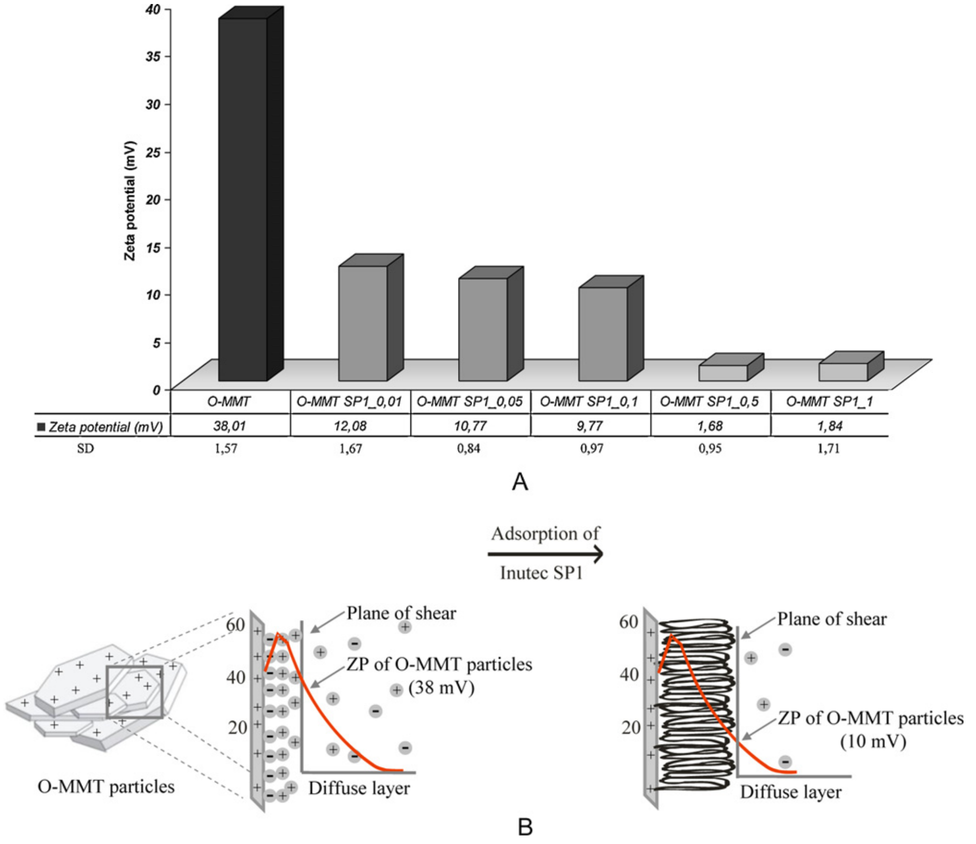


Fig. 6. (A) Zeta potential of O-MMT particles dispersed in water and in Inutec SP1 solution of different concentrations. (B) Scheme of change in electric double layer due to the adsorption of Inutec SP1 on O-MMT particles 'surface.

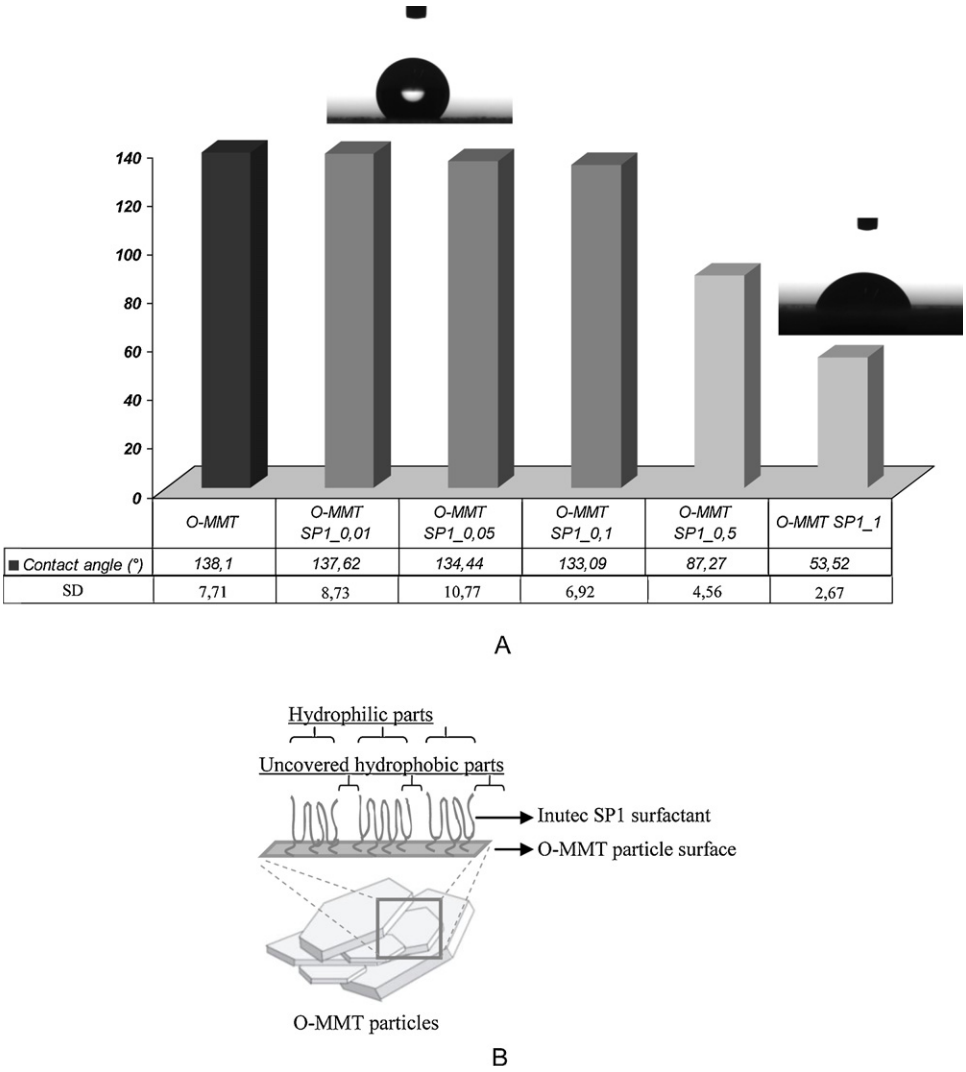


Fig. 7. (A) Contact angles of O-MMT particles modified with surfactant Inutec SP1 of different concentrations. (B) Model of an adsorption of Inutec SP1 molecules on O-MMT surface.

potential of O-MMT particles in water alone, is probably due to the nearly complete screening of the surface charge with the adsorption of nonionic surfactant molecules on to the particles 'surface.

It is known, that during the adsorption of surfactant, the modification of electric double layer takes place (Ridaoui, Jaba, Vidal, & Donnet, 2006). According to study published byTadros (Tadros, 2009) we can conclude that modification of electric double layer in our system proceeds, due to hydrophobic parts (alkyl chains) of Inutec SP1 surfactant molecules that adsorb on the O-MMT particles 'surface and change the thickness of the Stern layer. While in the second phase, loops and tails from hydrophilic part (inulin backbone) of surfactant molecules change the outer diffuse layer. Observed decrease in zeta potential is due to the shift of plane of shear away form the hydrophobic surface, which is the result of newly formed layer of adsorbed nonionic surfactant. Fig. 6B schematically presents the change in Stern and diffuse layer by the shift of plane of shear due to the adsorption of Inutec SP1 on O-MMT particles 'surface.

3.5. Contact angle measurements

Adsorption of polysaccharide surfactant on O-MMT particle surface can alter the hydrophilic/hydrophobic character of particles, which can be effectively monitored by the contact angle method, which can also give us some information regarding the conformation of adsorbed surfactant molecules on the particle surface (Nedyalkov et al., 2008).

Values of contact angles of O-MMT particles and O-MMT particles modified with Inutec SP1 are shown in Fig. 7A. Results show high contact angle value for O-MMT particles (137°), which corresponds to the strong hydrophobic character of particles due to the organic modification with alkylammonium salts and causes organophilic character. O-MMT particles, dispersed in Inutec SP1 solution of concentrations of Inutec SP1 0.01; 0.05 and 0.1 g/L, show insignificant reduction in contact angle values. The results of contact angle values confirm the assumption of the bridging effect phenomena observed at surfactant concentrations below surfactant critical micelle concentration CMC. Notable decrease in contact angle is observed at concentration of Inutec SP1 higher than 0.1 g/L. The contact angle values at concentration of Inutec SP1 0.5 and 1 g/L demonstrate a clear transition from a hydrophobic surface of O-MMT particles to a hydrophilic surface, achieved with higher Inutec SP1 concentration. It is known that contact angle values below 90° represent hydrophilic character of the surface. At concentration of Inutec SP1 0.5 g/L contact angle is only slightly lower in the hydrophilic region (87.27°) which indicates that the particle

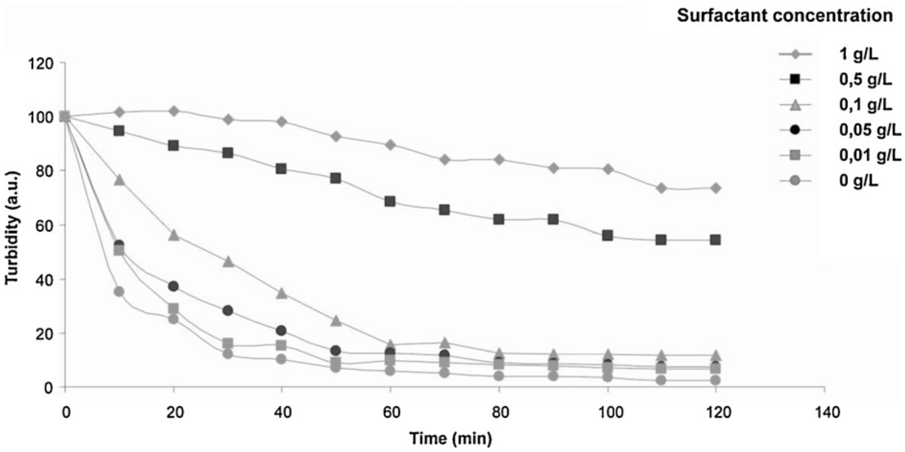


Fig. 8. Time dependence of turbidity of O-MMT particles dispersions in water and in Inutec SP1 solutions of different concentrations.

surface is probably not completely covered with adsorbed surfactant layer. But at concentration of Inutec SP1 1 g/L the contact angle is substantially reduced to the value 53.52°. This could be an indicator for more complete coverage of particles with the adsorbed surfactant layer.

Concentration of Inutec SP1 above CMC is needed to ensure effective coverage of O-MMT particles, which is reflected in obtaining a pronounced hydrophilic nature of otherwise intrinsically hydrophobic particles. This absorption could be driven from a hydrophobic part of surfactant, which has the ability to give rise to hydrophobic effect. Surfactants adsorb with their hydrophobic hydrocarbon moiety to the hydrophobic particle surface, while their hydrophilic moieties stretch into the solution (Holmberg, Jönsson, Kronberg, & Lindman), Nedyalkov, Alexandrova, Platikanov, Levecke, and Tadros (2009) have studied the conformation of adsorbed Inutec SP1 surfactant layer on hydrophilic and hydrophobised quartz glass surfaces using the sessile drop technique. According to this study we can anticipate that Inutec SP1 surfactants 'alkyl chains are adsorbed on the O-MMT hydrophobic surface while the hydrophilic polyfructose loops and tails are dangling into the solution (Fig. 7B). Observed reduction in contact angle is therefore a consequence of an adsorption of surfactant in a particular conformation on the particle surface.

3.6. *Dispersion stability of O-MMT particles in Inutec SP1 solutions*

Adsorbed layers of surfactant molecules on the particles surface influence the interactions which result from electric double layer and van der Waals forces.

Stability of a colloid dispersion represents its resistance to change over a period of time under certain conditions. The time for which the solid particles are stable i.e. the speed of forming the agglomerates, can range from a few second to few years. Adsorption can be considered stabile, when a time needed to form particles agglomerates is longer than the time in which the dispersion will be applied. In our research we studied the dispersion stability in a time frame of 120 min which corresponds to the time of UV polymerization of hydrogel. After the completion of polymerization the particles are completely fixed in hydrogel matrix. Fig. 8 presents turbidity measurements results for O-MMT particles in water and in Inutec SP1 solutions of different concentrations determined at various times. Turbidity of a dispersion of O-MMT particles in water decreases over time in a steep manner and reaches the plateau value after 30 min. The turbidity value after 120 min of sedimentation experiment is 2.34% which clearly shows that O-MMT system without an addition of surfactant is not stable. Complete sedimentation of O-MMT water dispersion is observed also with the naked eye. Sedimentation behavior and turbidity of O-MMT particles treated in solutions of Inutec SP1 lower concentrations (0.01–0.1 g/L) after 120 min is very similar to the sedimentation process of a dispersion of O-MMT particles in water. Significant changes in turbidity can be observed at a concentration of Inutec SP1 of 0.5 and 1 g/L. At concentration of Inutec SP1 0.5 g/L, where the sedimentation velocity is decreased and therefore after 120 min turbidity reaches 54.16%. Even lower sedimentation can be observed at the concentration of Inutec SP1 of 1 g/L, where the dispersion is completely stable for first 30 min and after that only a slight decrease in turbidity values is observed. After 120 min the turbidity reaches 73.36%.

4. Conclusions

In the present paper we have study the use of surfactant Inutec SP1 for stabilization of aqueous dispersions of clay minerals, which is essential for preparation of composites. Based on measurement of particle size and size distribution, zeta potential, contact angle and turbidity we can conclude that Inutec SP1, which is a class of polysaccharide graft copolymer surfactants, is useful for stabilization of O-MMT particles aqueous dispersions.

The results indicate, that at surfactant concentration below the CMC the adsorption of surfactant on O-MMT particles occurred, however DLS and turbidity measurements demonstrate that at surfactant concentration below and near CMC, bridging effects takes place. At surfactant concentrations above CMC the adsorption of surfactant appears on individual particles 'surfaces and therefore the stabilization of dispersion is improved. The DLS, zeta potential, contact angle and turbidity measurements showed that good and preferred stability of O-MMT particles can be achieved upon addition of non-ionic surfactant Inutec SP1 of concentration 1 g/L. Such stabilization effect could be explained in terms of steric repulsion due to the formation of hydrophilic polyfructose loops and tails that occurs with multi-point attachment of surfactant alkyl chains on the O-MMT particle surface. The adsorption of this surfactant, detected by reduction of zeta potential and contact angle values, rapidly influences the particle size and therefore the stabilization of the dispersion is improved.

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