CHAPTER VI
MECHANISTIC STUDIES OF PARTICULATE SOIL DETERGENCY: III: PERFORMANCE OF METHYL ESTER SULFONATE (MES)

6.1 Abstract

Previous works, the removal of hydrophobic soil (carbon black) as well as hydrophilic soils (kaolinite and ferric oxide) from hydrophilic substrate (cotton) and hydrophobic substrate (polyester) by using three surfactant types (sodium dodecyl sulfate, SDS, anionic; octyl phenol ethoxylate, OP(EO)10; nonionic; and cetyl trimethyl ammonium bromide, CTAB, cationic surfactants) was investigated. SDS showed the best detergency performance for all studied systems and the electrostatic repulsion between fabric and soil was found to be the most important mechanism, governing particulate soil removal. In this work, an alternative surfactant from renewable natural resources; methyl ester sulfonate (α-MES) as well as linear alkyl benzene sulfonate (LAS) were used as studied surfactants with three studied particulate soils – carbon black, ferric oxide and kaolinite. The basic properties of MES relevant to the detergency performance such as critical micelle concentration (CMC) were measured. The correlations between zeta potential, surfactant adsorption, contact angle, and solid/liquid spreading pressure to detergency performance and antiredeposition over the ranges of surfactant concentrations and pH levels were determined. The results showed that MES exhibited the best detergency performance compared to SDS (isomerically pure surfactant) and LAS (the most widely used commercial surfactant) because MES provides the highest electrostatic repulsion.

Keywords: Detergency, Particulate soil, Carbon black, Ferric oxide, Kaolinite, Methyl ester sulfonate (MES)

6.2 Introduction

Laundry detergency is a cleaning process to remove soils from fabrics. An anionic surfactant was generally used as a key ingredient in particulate soil detergency [1-4]. Nowadays, linear alkyl benzene sulfonate (LAS) is one of the workhorse surfactants used mostly in commercial detergent products. It is derived from petrochemical feedstocks, which are considered as non-renewable resources. Due to the consumption rate of petroleum used keeps steadily going up, many researchers try to develop new surfactants, derived from natural or renewable resources.

Recently, methyl ester sulfonate (MES), an anionic surfactant, has gained more attention especially in detergency field [5-6]. It is derived from palm kernel oil, palm oil or coconut oil and so it is considered as an environmentally friendly surfactant. Hence, the use of MES to replace petroleum-based surfactants can basically reduce CO_2 emission. Moreover, the production cost of MES is probably cheaper than the LAS [7]. It was reported in 2006 that the total cost for MES was 688.53 USD/MT compared to 1096.64 USD/MT for LAS [8]. MES has a variety of the combination of hydrophobic tail length depends on raw material sources. The different chain lengths of MES cause differences in physical properties [9]. Stein and Baumann [10] reported that the combination of hydrophobic chain lengths between C16 to C18 provided the optimum washing properties. Cohen and Trujillo [11] indicated that the hydrophobic chain length in the range of C16 to C18 was applicable for low to medium water hardness while the pure C16 MES was suitable for higher water hardness. They also claimed that the sulfoxylated methyl ester (MES) with randomly positioned of sulfo-groups had a significantly higher efficiency and a lower CMC than the linear alkyl benzene sulfonate (LAS). MES has many interesting properties such as an excellent biodegradability [12,13], good detergent power, good water solubility so it is easily to formulate liquid products [14], very good wetting and foaming power, low viscosity, excellent water hardness tolerance [10,11,15-17] and skin compatibility [14,18,19].

In order to improve the efficiency of MES in detergent formulation, all basic properties especially relating to particulate soil detergency are needed to be studied.

In our previous papers [20, 21], an anionic surfactant (sodium dodecyl sulfate, SDS) showed the best detergency performance on all types of studied particulate soils (both hydrophobic and hydrophilic particulate soil) from both hydrophilic and hydrophobic fabrics (cotton and polyester), in which the electrostatic repulsion forces between the same sign on fabrics and soils was found to be the major mechanism for particulate soil detergency.

In this work, the mechanism of particulate soil removal of three types of soils (carbon black, ferric oxide and kaolinite) by using MES was studied. Moreover, the MES detergency performance was also compared with SDS and LAS, which are pure and commercial surfactants, respectively.

6.3 Experimental Procedures

6.3.1 Materials

Commercial grade methyl ester sulfonate (MES) was obtained from Ballestra SpA, Italy with a total active matter more than 89.4%. The MES contained a narrow distribution of hydrophobic chain lengths between C16 to C18 (approximately 45% C16 and 55% C18). It was reported to have an average molecular weight of 382 and the pH at 5%w/v of 6.5. Commercial grade linear alkyl benzene sulfonate (LAS) was purchased from The East Asiatic (Thailand) Public Co., Ltd., with purity more than 80%. The LAS used was a mixture of C10 to C13 homologues where each homologue was a mixture of different isomers with a phenyl ring attached to the alkyl chain at different positions. Analytical grade sodium dodecyl sulfate (SDS) was purchased from Sigma-Aldrich with purity more than 99%. All studied particulate soils and fabrics were describing in Chapters IV and V. All chemicals used in this study were used without any further purification.

6.3.2 Experimental

All experiments were performed with similar procedures to those described in Chapters IV and V except that in the measurement of surface tension. Surface tension measurements were carried out with the Wilhelmy Plate method using a tensiometer, (Kruss GmbH, Germany, EasyDyne) at 30 °C with an accuracy of ± 0.1 mN/m.

6.4 Results and Discussion

6.4.1 Basic Properties of Studied Surfactants (MES, LAS and SDS)

The basic properties of all studied surfactants were used to correlate to particulate soil detergency performance in order to obtain a better understand about the mechanisms of solid particle detachment from fabric surfaces.

6.4.1.1 Critical Micelle Concentration (CMC)

Critical micelle concentration (CMC) is defined as the concentration of surfactant at which micelles start forming. Generally, it is deduced from the plot of surface tension versus surfactant concentration and the breaking point indicates the CMC value of a studied surfactant. Figure 6.1 shows the plots of surface tension versus surfactant concentration for all three studied surfactants (MES, LAS and SDS) at 30°C. Interestingly, the CMC value of MES was significantly much lower than those of LAS and SDS [10]. The approximately values for CMC of MES, LAS and SDS were 350 µM, 2500 µM and 9,000 µM, respectively. From the fundamental point of view, the lowest CMC of MES gives the easiest micelle formation at the lowest surfactant concentration, suggesting that the lowest quantity of MES is used for detergency application. Surfactant structure also plays an important role in affecting its CMC value. MES has the lowest CMC value compared to the other two studied surfactants since the hydrophobic part of MES consists of the longest linear hydrocarbon chain and the smallest head group.

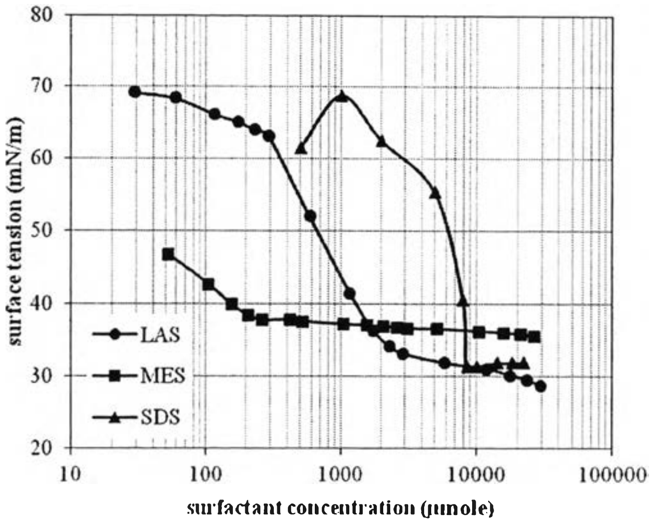

Figure 6.1 Plot of surface tension versus surfactant concentration of all studied surfactants (LAS, MES and SDS) at 30°C.

6.4.2 Surfactant Adsorption on Fabrics and Soils

Surfactant adsorption at solid/liquid interface is considered as the first important step in the detergency processes, since it can induce changes in the interfacial tension as well as eletrokinetics properties of soil and substrate [3] in which can reduce the attraction force between soil and substrate. Moreover, it helps deflocculating the detached soil particles into the colloidal size, which can form a stable dispersion in a washing solution [22]. The surfactant adsorption isotherms based on the surface areas of the dry substrate. In wet form, the cotton surface area might be altered due to swelling [23]. Table 6.1 shows the specific surface areas of the three solid particles and the two fabrics. Figure 6.2 shows the adsorption isotherms of MES onto the studied soils (carbon black, kaolinite and ferric oxide) and the studied fabrics (cotton and polyester) as a function of equilibrium surfactant concentrations at 30 °C over the studied pH range of 5-11. The adsorption isotherms of MES onto all studied surfaces showed the similar trend, which could be divided into 3 regions when plotted on a log-log scale and reached a plateau at a concentration above the CMC, as generally cases.

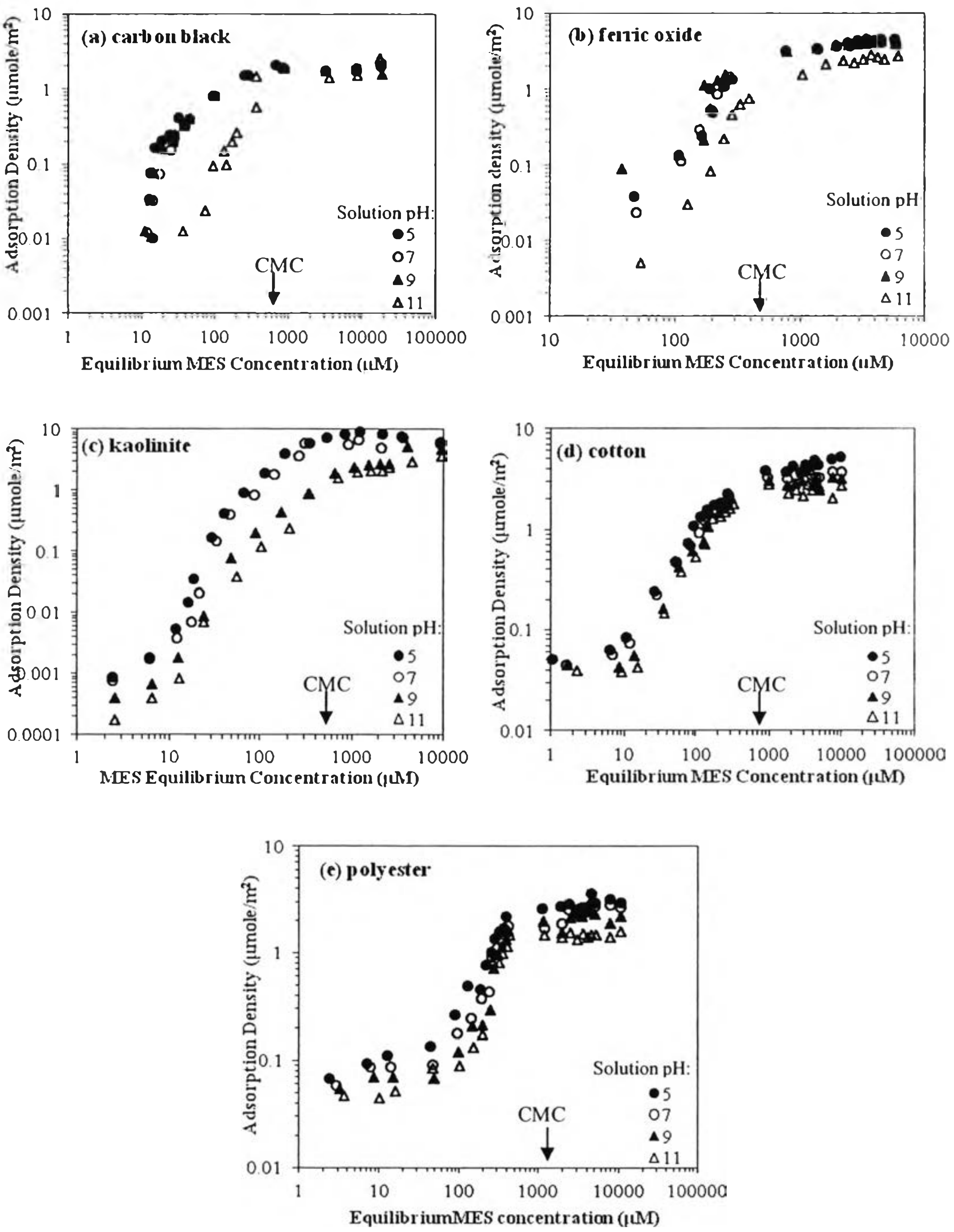

Figure 6.2 Adsorption isotherms of MES on (a) carbon black, (b) ferric oxide, (c) kaolinite, (d) cotton, and (e) polyester at different solution pHs and a constant temperature of 30 °C.

Table 6.1 Properties of studied particulate soils and substrates

Particulates/Substrates	Point of zero charge (PZC)	Dry BET surface area (m^2/g)
Cotton	2.9	4.33
Polyester	2.4	2.50
Carbon black	2.3	96.0
Ferric oxide	6.4	14.0
Kaolinite	2.5	10.6

The maximum adsorption (Γ_{max}) at different solution pHs and the fractional monolayer coverage of MES onto all studied surfaces are summarized in Table 6.2. The fractional monolayer coverage of MES onto all studied fabrics and soils were calculated from the area per molecule of MES from the air/water Gibbs close-packed monolayer [MES: 4.63 nm^2/ molecule]. This value was estimated from our experiments. From Tables 6.2, the maximum amount of MES adsorbed (Γ) decreases as solution pH increases for all cases. From the point of zero charge (PZC) values of all of the studied surfaces (Table 6.1) were between 2 and 3, which were lower than the studied pH range (5 to 11) (except ferric oxide is 6.4). Thus, the studied surfaces were negatively charged over the studied pH range (except ferric oxide at pH 5). The surface charge of any studied soils and fabrics became more negative with increasing solution pH (see Tables 6.3 and 6.4 for surfactant-free system) due to the increasing adsorption of hydroxide ions from the solution to the surfaces with increasing solution pH. Moreover, MES itself can be hydrolyzed and formed the disodium salt of sulfonated fatty acid ($RCH(SO_3Na)COONa$) at a pH higher than 9 [24]. When the disodium salt of MES is formed, the hydrophilic groups become more negative, resulting in increasing repulsion between the negatively charged surfaces and the hydrophilic group of MES. The MES adsorption onto all studied surfaces decreased as solution pH increased and the lowest adsorption density was found at pH 11. The results can be explained by the fact that an increase in solution pH simply makes the charge of solid surface become more negatively, leading to lowering MES anionic surfactant adsorption.

Table 6.2 Maximum adsorption (Γ_{max}) and fraction of monolayer adsorption of MES onto all studied surfaces at different solution pHs

Studied surfaces	Maximum adsorption or Γ_{max} (μmol/m²)				Fraction of monolayer adsorption			
	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11
Carbon black	1.73	1.70	1.63	1.38	0.48	0.47	0.45	0.38
Ferric oxide	4.56	4.22	4.04	2.67	1.27	1.17	1.12	0.74
Kaolinite	6.12	5.72	4.67	3.58	1.71	1.60	1.30	1.00
Polyester	3.00	2.67	2.20	1.31	0.84	0.74	0.61	0.36
Cotton	3.97	3.58	2.67	1.91	1.11	1.00	0.74	0.53

From our previous study [21], three pieces of evidence can be used to conclude that tail-down monolayer adsorption or bilayer adsorption of a given surfactant is occurring: fractional monolayer coverage, effect of pH on the plateau adsorption (for ionic surfactants), and whether the adsorption isotherm shapes indicate cooperativity or not in aggregate formation. For bilayer, the adsorption shows a substantial pH effect and the isotherm shapes exhibit cooperative behavior (slope of log (adsorption) versus log (equilibrium concentration) is higher than unity) while the tail-down or monolayer adsorption shows a modest pH effect and the isotherm shapes indicate neutral or anti-cooperative behavior. The detailed of adsorption isotherm slopes of MES onto ferric oxide, kaolinite and cotton [25] were greater than unity and the critical admicelle concentration or CAC was clearly observed. Moreover, the adsorptions exhibit a substantial pH effect on plateau adsorption for all surfaces except that of carbon black as seen in Figure 6.2 and Table 6.2. The sudden increase in the adsorption isotherm slope in region II indicates the formation of surface aggregates of the MES molecules onto the studied surfaces. As a result of the highly negative charges of all studied hydrophilic surfaces, the MES molecules oriented their head groups toward the surfaces and their tail group striking out into the liquid phase, generally called as head-down adsorption. The adsorption of MES onto kaolinite at pH 5 is almost reach the bilayer (fraction of monolayer = 1.71) and higher than monolayer for ferric oxide and cotton (fraction of monolayer = 1.27 for ferric oxide and 1.11 for cotton), indicating the hydrophobic interaction between surfactant and the heterogeneity of the surface. Even though the studied soils and fabrics have a net negatively charge (see Tables 6.3 and 6.4) but there still have some positive charge sites. Thus, the MES could adsorb head–down onto all hydrophilic surfaces (ferric oxide, kaolinite and cotton). On the other hand, the adsorption of MES onto carbon black or polyester surface was less than the monolayer (fraction of monolayer adsorption less than unity) with relatively small pH effect on the plateau adsorption, suggesting tail–down adsorption onto the two studied hydrophobic substrates.

6.4.3 Zeta Potential of Studied Fabrics and Particulate Soils in Surfactant Solution

Generally, increasing solution pH will increase hydroxyl anions as a usually potential determining ion adsorbing onto solid surfaces, which are responsible for increasing in negative charge of both fabric and particulate soil surfaces, as seen in Tables 6.3 and 6.4 for surfactant free system. The adsorption of MES onto all studied surfaces caused their zeta potentials to become even more negative as compared to those of surfactant−free systems for all pHs levels at plateau concentrations (see Tables 6.3, 6.4, 6.5 and 6.6). In comparisons among the three studied particulate soils in the presence of MES, kaolinite had the highest negative zeta potential value, which corresponded to the highest electrostatic repulsion force followed by ferric oxide and carbon black, respectively.

“Summation of ζ” in Tables 6.3-6.7 is the sum of ζ for any studied particulate soil (carbon black, ferric oxide or kaolinite) and any studied fabric (polyester or cotton) in order to quantify the electrostatic repulsion force between any studied particulate soil and fabric in a single parameter. The higher the summation of ζ, the higher the dispersion stability or the lower the soil redeposition which will further discussed in the next section.

Table 6.3 Detergency, redeposition, zeta potential and contact angle of surfactant-free solutions with polyester fabric and three different particulate soils at different solution pHs

Polyester	Carbon black				Ferric oxide				Kaolinite			
	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11
Detergency (%)	5.42±1.3	9.84±2.2	13.2±0.8	16.1±1.7	10.3±1.2	11.4±1.3	11.5±2.3	14.8±1.6	13.7±0.8	18.4±1.3	24.8±1.6	31.1±1.3
Redeposition (%)	5.12	4.12	3.75	2.75	4.36	3.94	3.47	3.34	1.29	1.22	1.20	1.21
Zeta potential or ζ of polyester (mV)	-50.0±0.8	-64.3±0.5	-68.1±1.1	-70.0±0.6	-50.0±1.3	-64.3±0.8	-68.1±1.6	-70.0±1.1	-50.0±0.4	-64.3±0.8	-68.1±1.2	-70.0±0.6
Zeta potential or ζ of studied soils (mV)	-20.0±0.4	-36.4±0.6	-41.7±0.9	-44.6±0.8	-33.6±1.1	-30.3±0.9	-55.4±1.4	-69.5±1.4	-42.9±1.2	-44.3±1.7	-50.1±0.9	-54.1±1.4
Summation of ζ (mV)	-70.0	-101	-110	-115	-83.6	-94.6	-123	-140	-92.9	-109	-118	-124
Contact angle or θ of polyester (deg)	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
Contact angle or θ on carbon black (deg)	68.0	68.1	68.2	68.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 6.4 Detergency, redeposition and zeta potential of surfactant-free solutions with cotton fabric and three different particulate soils at different solution pHs

Cotton	Carbon black				Ferric oxide				Kaolinite			
	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11
Detergency (%)	5.43±1.4	7.82±1.9	11.4±0.8	14.2±1.2	12.6±1.6	12.9±1.3	13.7±1.1	15.5±1.2	14.7±1.3	19.3±0.9	26.3±0.8	32.9±1.2
Redeposition (%)	4.09	3.76	2.91	2.45	4.89	4.80	4.76	3.54	1.30	1.45	1.12	1.02
Zeta potential or ζ of cotton (mV)	-13.7±0.9	-20.3±0.8	-23.3±1.2	-24.6±0.7	-13.7±1.2	-20.3±1.1	-23.3±0.5	-24.6±0.8	-13.7±0.8	-20.3±0.6	-23.3±0.4	-24.6±1.2
Zeta potential or ζ of studied soils (mV)	-20.0±0.4	-36.4±0.6	-41.7±0.9	-44.6±0.8	-33.6±1.1	-30.3±0.9	-55.4±1.4	-69.5±1.4	-42.9±1.2	-44.3±1.7	-50.1±0.9	-54.1±1.4
Summation of ζ (mV)	-33.7	-56.7	-65.0	-69.2	-47.3	-50.6	-78.7	-94.1	-56.6	-64.6	-73.4	-78.7

Table 6.5 Detergency, redeposition, maximum adsorption, fraction of monolayer adsorption, zeta potential, contact angle and surface pressure at solid/liquid interface for MES system with polyester at plateau concentrations of different particulate soils and at different solution pHs

Polyester	Carbon black				Ferric oxide				Kaolinite			
	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11
Detergency (%)	45.5±1.3	57.5±1.1	60.8±1.5	77.4±0.9	39.7±1.4	51.5±2.0	61.2±1.5	74.1±1.7	58.6±1.3	63.3±0.8	68.5±0.9	78.9±1.4
Redeposition (%)	1.99	1.85	1.30	1.15	1.27	1.12	1.03	0.77	0.90	0.74	0.62	0.45
Zeta potential or ζ of polyester (mV)	-88.7±0.4	-92.6±0.6	-109±0.3	-116±0.7	-88.7±0.4	-92.6±0.6	-109±0.3	-116±0.7	-88.7±0.4	-92.6±0.6	-109±0.3	-116±0.7
Zeta potential or ζ of studied soils (mV)	-69.0±1.3	-80.1±0.5	-88.7±0.4	-95.5±0.6	-76.5±0.8	-92.7±1.3	-106±0.4	-110±0.7	-99.4±0.3	-106±0.9	-119±1.2	-126±1.4
Summation of ζ (mV)	-158	-173	-198	-212	-165	-185	-215	-226	-188	-199	-228	-242
Contact angle or θ on polyester (deg)	19.5	19.6	20.6	21.1	19.5	19.6	20.6	21.1	19.5	19.6	20.6	21.1
Contact angle or θ on studied soil (deg)	23.8	24.1	24.8	26.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Surface tension (mN/m)	36.7	36.4	36.6	36.8	36.7	36.4	36.6	36.8	36.7	36.4	36.6	36.8
Surface pressure or π_{SL} on polyester (mN/m)	14.4	14.1	14.1	14.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Surface pressure or π_{SL} on studied soil (mN/m)	6.95	6.60	6.59	6.33	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 6.6 Detergency, redeposition, maximum adsorption, fraction of monolayer adsorption and zeta potential for MES system with cotton at plateau concentrations of different particulate soils at different solution pHs

Cotton	Carbon black				Ferric oxide				Kaolinite			
	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11	pH 5	pH 7	pH 9	pH 11
Detergency (%)	46.4±1.3	58.8±1.6	60.2±0.9	73.3±1.4	40.2±1.4	46.0±1.3	61.1±1.7	78.8±0.8	62.2±1.3	72.5±1.3	80.6±1.6	87.4±1.1
Redeposition (%)	1.64	1.21	0.88	0.86	1.13	0.94	0.83	0.71	0.77	0.65	0.54	0.54
Zeta potential or ζ of cotton (mV)	-71.0±0.7	-77.9±0.9	-98.5±0.5	-112±1.2	-71.0±0.3	-77.9±0.4	-98.5±0.9	-112±1.1	-71.0±0.9	-77.9±0.7	-98.5±1.2	-112±0.4
Zeta potential or ζ of studied soils (mV)	-69.0±1.3	-80.1±0.5	-88.7±0.4	-95.5±0.6	-76.5±0.8	-92.7±1.3	-106±0.4	-110±0.7	-99.4±0.3	-106±0.9	-119±1.2	-126±1.4
Summation of ζ (mV)	-140	-158	-187	-207	-147	-171	-205	-222	-170	-184	-207	-228

Table 6.7 Detergency, redeposition and sum of zeta potentials of carbon black, ferric oxide and kaolinite at plateau concentrations of different surfactants (MES, LAS and SDS) at pH 11 for both fabrics of polyester and cotton

Polyester	**Carbon black**			**Ferric oxide**			**Kaolinite**		
	MES	**LAS**	**SDS**	**MES**	**LAS**	**SDS**	**MES**	**LAS**	**SDS**
Detergency	77.4±0.9	68.4±1.2	67.4±0.3	74.1±1.7	65.3±1.1	56.7±2.6	78.9±1.4	65.3±0.8	69.1±0.9
Redeposition	1.15	1.25	1.45	0.77	0.87	0.99	0.45	0.56	0.61
Summation of ζ (mV)	-212	-201	-156	-226	-205	-197	-242	-205	-214
Cotton	**Carbon black**			**Ferric oxide**			**Kaolinite**		
	MES	**LAS**	**SDS**	**MES**	**LAS**	**SDS**	**MES**	**LAS**	**SDS**
Detergency (%)	73.3±1.4	70.6±1.4	63.3±0.7	78.8±0.8	69.8±1.2	61.1±1.6	87.4±1.1	82.2±1.2	74.4±1.7
Redeposition (%)	0.86	0.97	1.73	0.71	0.98	1.54	0.54	0.61	0.77
Summation of ζ (mV)	-207	-192	-120	-222	-195	-161	-228	-195	-178

6.4.4 Dispersion Stability

The zeta potential can be used to directly relate to the colloid stability in electrostatically stabilized systems [26, 27]. Zeta potentials above an absolute value of 40 mV indicate a high charge density at the surface, leading to high dispersion stability due to high repulsion between particles in suspension [22, 28]. From Tables 6.3-6.6 for all studied systems, an increase in solution pH increases the negative zeta potential value, leading to an increase in dispersion stability of all studied particulate soils with both fabrics, as confirmed by the dispersion stability results, as shown in Figure 6.3. Figure 6.3 shows the dispersion stability of studied particulate soils (carbon black, ferric oxide and kaolinite) in the presence of any studied surfactants (MES, LAS and SDS) at plateau surfactant adsorptions as a function of solution pH at settling time of 1 h for carbon black and ferric oxide and 10 h for kaolinite. High absorbance means high particle density and higher dispersion stability. From previous work, the dispersion stability of detached soil particles in washing solutions is related to redeposition of particulate soil [21]. The better the dispersion stability, the lower the soil redeposition. In comparisons among the three studied surfactants (MES, LAS and SDS), MES provides the highest dispersion stability followed by LAS and SDS, in which the highest dispersion stability can be well correlated to the lowest soil redeposition with the highest detergency, as shown in Table 6.7.

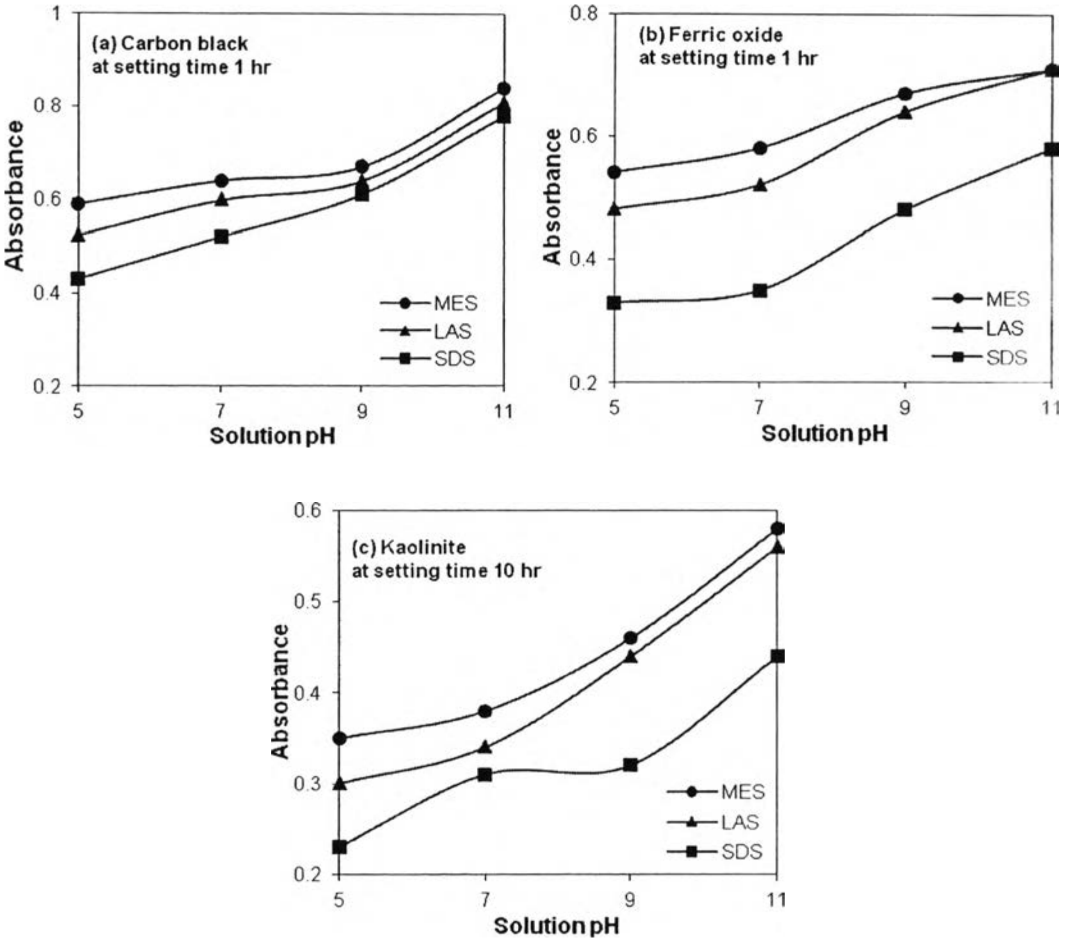

Figure 6.3 Dispersion stability of three studied soils (a) carbon black, (b) ferric oxide and (c) kaolinite in the presence of three studied surfactants (MES, LAS and SDS).

6.4.5 Contact Angles of Surfactant Solutions

Measurement of the contact angle of aqueous solutions onto solid surfaces has two basic purposes. First, the wash solution needs to contact the soil and fabric to permit detachment and the contact angle indicates how well the solution wets the surface – a lower value of contact angle (θ) indicates better wetting [3, 29, 30]. Second, contact angle is necessary to calculate solid/solution surface pressures. The MES solution/substrate contact angle values for carbon black and polyester at different solution pHs are shown in Tables 6.5. Spontaneous wetting/soaking up of solution with or without MES occurred on cotton, kaolinite, and ferric oxide (contact angle ≤ 0), so θ was not measureable. From Table 6.5, the presence of MES causes a great reduction in the contact angle compared to the surfactant-free solution (see Table 6.3). Additionally, MES caused the contact angle on carbon black and polyester lower than those of SDS and LAS at plateau surfactant adsorption for all pHs studied (5 to 11), inducing the best improvement of the wettability as shown in Figure 6.4, and subsequentially leading to the detergency enhancement.

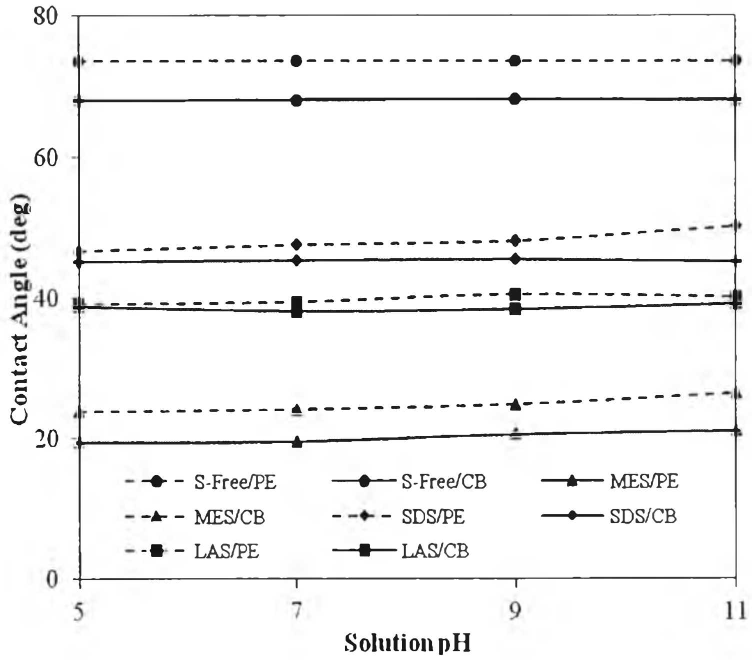

Figure 6.4 Contact angle values of surfactant-free (S-Free), MES, LAS and SDS solutions on carbon black (CB) or polyester (PE) surface as a function of solution pH.

6.4.6 Correlation between Zeta Potential to Detergency Performance and Redeposition at Plateau Concentration

The detergency performance of MES at the plateau concentration increases markedly with increasing solution pH for all studied particulate soils with either cotton or polyester fabric, which is coincident with the zeta potential results, as shown in Table 6.5 for the polyester and Table 6.6 for the cotton. Previous studies concluded that the most important force aids particulate soil detergency in the presence of anionic surfactant is the electrostatic repulsion between soil and fabric. The correlations among detergency, redeposition and summation of zeta potential for the three studied particulate soil (carbon black, ferric oxide and kaolinite) and the studied fabrics (polyester and cotton) in the presence of three studied surfactants (MES, LAS and SDS) are shown in Table 6.7. The MES showed the best detergency performance with the lowest soil redeposition for all types of studied particulate soils with either cotton or polyester fabric, in which the MES provides the highest summation of zeta potential.

6.5 Summary of Detergency Mechanisms

Electrostatic repulsion between fabric and soil particles was proved to be the main mechanism responsible for the detergency for an anionic surfactant [20-21]. As described before, MES provided the highest detergency performance with the lowest soil redeposition compared to LAS and SDS. This is because the adsorption of MES onto the negatively charged fabrics and soils yielded the highest negative electrical potentials and the highest wettability performance. Moreover, the presence of MES surfactants was found to provide the best stability of suspensions as compared to LAS and SDS, which correlated to the lowest soil redeposition.

6.6 Acknowledgements

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