SURFACTANT COMPARISON TEST

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Washing can be defined as the act of removing impurities by an aqueous solution. In order for the washing process to be successfully employed, there must exist a mutual relationship between various chemical and physical influences. These influences include water quality, soil type, textile properties, detergent composition and washing equiptment (such as type and amount of mechanical input, time and temperature).

In the wet cleaning of historic textiles, these constituents must be altered to a degree so as not to be detrimental to the condition of the object. However, these constituents cannot be altered to a degree which would inhibit the soil removal capabilities of the washing process. For example, the soil removing action of a surfactant must be initiated by some degree of agitation, heat and temperature. However, some objects may not be able to withstand excessive movement yet some degree of agitation is needed in order to activate the cleaning power of the surfactant. Water quality is another constituent which will vary according to geographic location and affordability.

In September of 1990, the Biltmore Estate Tapestry Conservation Project decided to investigate surfactants. The purpose of this investigation was to compare the soil removal capabilities of surfactants. These surfactants include those currently being used in the wet cleaning of historic textiles and also ones chosen upon recommendation from some of the leading textile chemical companies.

Although there are many variables to be taken into consideration when wet cleaning an historic textile such as pH, degree of agitation, temperature, foamability and rinsing,

water, this means that there is less energy needed to bring the surfactant molecule to a surface than compared to a water molecule. Since the surfactant molecule concentrates at the surface, there is less work needed to break the surface tension of that surface.

When there is an absence of highly polar groups, capable of hydrogen bonding, on a surface, the surfactant will be absorbed with the hydrophobic group oriented toward the surface and the hydrophilic group oriented away from the surface, making the surface more hydrophilic.

Therefore, the amphipathic structure (hydrophobic-hydrophilic structure) causes the concentration of the surfactant at a surface and reduces the surface tension of that surface. It also orients the surfactant molecule with the hydrophobic group pointing toward the surface and the hydrophilic group in the aqueous solution.

When a surfactant penetrates a soil, the hydrophobic ends are attached to the nonpolar surface of the soil. The attraction of the water to the highly polar, hydrophilic ends of the molecule causes a swelling action which is powerful enough to dislodge or split the soil particle. Penetration of the surfactant onto the soil mass is also dependent on the temperature of the solution and agitation which activates an exchange of fresh solution for old at the soil site.

The soil particle is thus suspended from the substrate surface by the electrostatic repulsion of the hydrophilic ends to each other. Fortunately, most of the soils encountered in the conservation of textiles will probably be some sort of organic matter which oxidizes in aqueous solution to form acids. These acids will react with alkalies (surfactants) to form more water soluble substances. In addition, the fibers in an aqueous solution also acquire a negative charge which will increase with the pH. Therefore, the introduction of alkalies increases the repulsive action between the organic matter and the fiber surface.

SURFACTANT CLASSIFICATION

Surfactants are categorized into groups according to the charge of the hydrophilic portion of the molecule.

Anionic surfactants contain a negative charge in the

these were not the main focus of this investigation.

SURFACTANTS

At this point is necessary to differentiate between a detergent and a surfactant. A detergent is a formulation of different substances. These substances are catagorized into the following groups: surfactants, bleaching agents, builders and auxiliary agents. Surfactants constitute the most important group of the detergent composition.

A surfactant is a water soluble surface active agent comprised of a hydrophobic (lipophile) portion attached to a hydrophilic portion, constituting an amphipathic structure. The hydrophobic portion may be a nonpolar, long chain hydrocarbon whereas ionic or highly polar groups may act as hydrophilic groups.

Detergency of a surfactant depends on the balance of the molecular weight of the hydrophobic portion of the surfactant molecule to that of the hydrophilic portion. This balance is also known as the HLB or hydrophile-lipophile balance.

HLB values vary according to the end use of the surfactant. The following values illustrate how the HLB value determines the end use of the surfactant.

HLB Value	Application
4-6	W/O emulsifiers
7-9	Wetting agents
8-18	O/W emulsifiers
13-15	Detergents
15-18	Solubilizers

O/W=oil in water
W/O=water in oil.

A strongly hydrophobic surfactant has a low HLB, usually less than 10. A highly hydrophilic surfactant has a high HLB, greater than 10. For example, polyoxyethylene nonyl phenols have an HLB of about 13 and sodium lauryl sulfate has an HLB value of approximately 40.

When a surface active agent is dissolved in a solvent, the hydrophobic group causes a distortion of the solvent liquid structure. In a highly polar aqueous solution, like

hydrophilic portion of the molecule. Anionic surfactants constitute the largest group of surfactants. Most of them are sulphonates or sulphates of one kind or another.

Cationic surfactants contain a positive charge in the hydrophilic portion of the molecule. They are of relatively little use in cleaning because their cleaning abilities are relatively poor. Cationic surfactants are used mainly as fabric softeners (anti-static agents), germicides and specialized emulsifiers.

Nonionic surfactants contain no charge in the hydrophilic portion of the molecule. The majority of nonionic surfactants are condensation products of ethylene oxide with a hydrophobe. The hydrophobe is of a high molecular weight with an active hydrogen atom.

Amphoteric and zwitterionic surfactants contain both anionic and cationic groups in the same molecule. The amphoteric and zwitterionics' manufacturing process is considered a trade secret but they are usually made with the anionic group neutralized by sodium and the cationic associated with a hydroxyl or chloride anion. Zwitterionics contain the same groups but the positive, electrical charge is neutralized by the negative charge on the same or adjacent molecule. These surfactants have excellent foaming abilities at a neutral pH and are usually used as foam cleaners such as rug cleaners or shampoos.

Providing that the surface is negatively charged, cationic surfactants are used to make the surface water repellant and anionic surfactants are used to make the surface water "wettable". Nonionic surfactants do not change the charge of the surface. They are used more so to increase the solubility of the surfactant molecules to a surface.

The nature of the hydrophobic group of a surfactant molecule is influenced by the following properties: the length of the hydrophobic group, the amount of branching, the presence of an aromatic nucleus (such as benzene), the presence of polyoxypropylene chains, and the presence of perfluoralkyl or polysiloxane groups.

An increase in the length of the hydrophobic group decreases the solubility of the surfactant in water but increases the solubility in organic solvents. It increases

the tendency of the molecule to absorb at an interface and causes closer packing of the molecules at an interface. It also increases the melting point of the surfactant.

The amount of branching in the hydrophobic group also increases the solubility of the surfactant in water or an organic solvent. However, it decreases the melting point of the surfactant and causes looser packing of the molecule at the interface. Unfortunately, an increase in branching in the surfactant molecule decreases the biodegradability of the surfactant.

The presence of an aromatic group in a surfactant molecule increases the absorption onto polar surfaces but decreases the biodegradability. It also causes looser packing of the surfactant molecules at an interface.

The presence of polyoxypropylene chains in the hydrophobic group increases the absorption of the surfactant onto polar surfaces. It also increases the solubility of surfactant in organic solvents.

The presence of perfluoroalkyl or polysiloxane groups in the surfactant molecule decreases the surface tension of the water. Perfluoroalkyl surfaces are water repellant

CHOOSING THE SURFACTANTS

As can be seen from the previous explanation of surfactant characteristics, choosing a surfactant requires a knowledge of features such as physical and chemical properties, interfacial phenomena, surface chemical properties, and the relation of the surfactant structure to these surface properties.

It was realized that the chemical knowledge involved in choosing a surfactant was beyond the scope of my education and training. Therefore, to ensure applicability of the surfactant to conservation methods, leading textile chemical companies were contacted and asked to recommend one of their surfactants based on our needs. The needed criteria was: the surfactant would need to have a relatively neutral pH, good foamability with minimal agitation, solubility at low temperatures and had to be compatible for use on protein and vegetable fibers.

The following are the surfactants chosen for this test:

Orvus WA Paste-Proctor & Gamble
Tensopol A795-ICI Americas Inc.
Synperonic NP9-ICI Americas Inc.
Synperonic OP10-ICI Americas Inc.
Triton X-100-Rohm and Haas Co.
Igepol CO 630-Rohne Poulenc
Emulphogene L684-Rohne Poulenc
Pluronic L684-BASF
Plurafac B 25 5-BASF
Silvatol SO-Ciba Geigy

Orvus WA Paste and Tensopol A795

Orvus WA Paste and Tensopol A795 belong to a group of anionic surfactants known as sulfated linear primary alcohols (AS). They are produced from sulfated coconut oil or sulfated tallow alcohols. They are very light colored and contain excellent foaming abilities. Sodium salts are the most common type of sulfated linear primary alcohols. Sodium lauryl sulfate is used in low temperatures for delicate fabrics.

Silvatol SO

Silvatol SO is an alkyl aryl sulphonate. This is one of the largest groups of anionic surfactants and is based upon the condensation product of an aromatic nucleus, in this case benzene, with a long chain alkyl group. The surfactant in this case is a dodecyl benzene sulphonate.

Synperonic NP9, Synperonic OP10 and Plurafac B 25 5

These surfactants fall under the category of nonionic surfactants known as polyoxyethylenated alkylphenols or aklylphenol condensates (APE).

Synperonic NP9 contains 9 moles of ethoxylation and is a nonylphenol. Synperonic OP10 contains 10 moles of ethoxylation and is an octylphenol. Plurafac B 25 5 is an aloxylated fatty alcohol.

These surfactants are very mild products which do not have a tendency to distort the fibers. The only disadvantage is that the increased branching in the surfactant molecule decreases the biodegradability of the product.

Triton X-100, Igepol CO 630 and Emulphogene L684

These three surfactants fall under the category of polyoxyethylenated straight-chain alcohols or alcohol ethoxylates (AE).

Triton X-100 is an octyl phenoxy polyethoxy ethanol with 10 moles of ethylene oxide. Igepol is a nonyl phenoxy polyethoxy ethanol with 9 moles of ethylene oxide. Emulphogene L684 is a polyoxyethylated decyl alcohol with 6 moles of ethylene oxide.

These surfactants are more water soluble and obtain better wetting powers than the APE group. They are also effective for use in low temperature conditions. Most importantly, the AE category is more biodegradable than the APE category.

Pluronic L684

Pluronic L684 belongs to a group of surfactants known as block copolymers. It is a polyoxypropylene-polyoxyethylene block copolymer. The interesting property of block copolymers is that characteristics such as solubility and foaming power can be controlled and reproduced. They could be termed "taylor made" surfactants.

They polyoxypropylene-polyoxyethylene block copolymer is the most common type of this surfactant. They exhibit low foamability and are basically used as foam controlling agents.

TEST METHOD

The next step is our investigation was to construct a test which would simulate known methods of wet cleaning used in textile conservation. Although detergent industry standardized tests exist to determine the soil removal capabilities of surfactants, some variables in these tests were found to be too impractical to follow for our purposes. We devised our own test method based on the practices of the industry that we felt were applicable to the wet cleaning of historic textiles in addition to the practices of our and other textile conservation laboratories.

The variables taken into consideration included the

percent concentration, temperature, actual washing time and the degree and amount of agitation.

The percent concentration varied in research between 0.1% and 0.2%. It is our understanding that some laboratories use a higher/lower percent concentration due to geographical influences and soil identification abilities.

Temperature ranged between 32.2 c and 40.0 c.

For simplicities sake, we decided on an average of the range since temperature and percent concentration were not the main focus of this test. Precise determination of these variables can be an investigation in itself.

The degree and amount of agitation were kept to a minimum.

PRE-SOILED TEST SAMPLES

The pre-soiled test samples were obtained from Testfabrics Inc.. These samples were first developed for the Navy during World War II. They were developed to test detergents which would be used on white cotton and denim where the solvent would be salt water. The main soil concerns were grease, oil and soot from furnaces.

The soil media on the samples consists of the following components:

1.3% Keltex (thickener)	1.7% Vegetable Fat (spry)
2.2% Cornstarch	0.3% Butanol
72.4% Water	4.4% Solvesso 150
14.0% Oil (mineral)	0.7% Ethyl Cellulose
0.42% Oleic Acid	0.7% Carbon Black
0.36% Morpholine	
	Total 98.48%

The media paste is deposited evenly onto the substrate by using an engraved print roller. The printed substrate is then dried and dry heat cured using an electrically heated oven.

The samples used in our investigation were 100% wool and 100% cotton. The substrates were cut into samples measuring 8 inches by 4 inches for spectrophotometer readings.

SOIL REMOVAL EVALUATION PROCESS

To determine the results of our surfactant comparison tests a spectrocolorimeter (or more simply a spectrophotometer that is employed as a tristimulus colorimeter) was used. This type of machine has the capacity of giving tristimulus reflection and transmission values, XYZ and LAB, and supplies a computer readout with these values and their interpretation. The spectrophotometer used was a computer operated, high speed, high resolution scanning single beam ACS Spectro-Sensor II. It is housed and operated by BASF Corporation in Enka, North Carolina.

This type of color measuring device was much more sophisticated than what was needed for our experiment. The actual readings supplied us with massive quantities of color differentiation data.

The color data variables we focused on for the interpretation of our data was the percent reflection for wavelengths of 400nm to 700nm, measured on a scale from 0 to 100. The illuminant used was the "D" or daylight light source.

Our main concerns were with the Delta L (i.e., lightness and darkness) of the soiled and unsoiled portions of the Testfabrics soiled substrates. DL values of the soiled area provide a measurement of the soil removal ability of the surfactant. DL values of the unsoiled area provide a measurement of the redeposition of the soil.

The soil cloth samples were read by the spectrophotometer before and after wet cleaning. The samples were compared to themselves before and after rather than being compared to a color standard. (The test results are based on the color difference between themselves. Each sample was its own standard.)

TEST PROCEDURE

The following is a description of the actual test procedure.

A. Spectrophotometer readings of the samples were performed before and after washing.

B. An 8 gallon pot of deionized water was set to simmer to be used in subsequent steps. The pH of the deionized water was tested and recorded.

C. Tubs, similar to ones used in photographic processing, were used in order to totally immerse the samples and allow enough room for agitation. This allowed the sample to be immersed in about 1 inch of water (2 liters).

D. For each washing, the samples were presoaked in a bath of deionized water at an average temperature of 35 c for 10 minutes.

E. The pH of the presoak bath with the sample was tested and recorded.

F. The surfactant solution was mixed at a concentration of 0.15% for 2 liters of deionized water. The temperature was maintained at an average of 35 c. The pH of the surfactant solution was tested and recorded. In some cases the solution was headet on the stove in order to maintain an adequate temperature.

G. The samples was removed from the presoak bath and the used water was removed from the tub.

H. The surfactant solution was poured into the wash tub and the presoaked sample was immersed into the solution. The sample was agitated continuously for five minutes by gently pressing the solution into the sample with sponges. For the remaining 12 minutes, the sample was agitated periodically. The samples remained in the surfactant solution for a total of 17 minutes.
The pH of the sample and surfactant solution was tested and recorded.

I. The sample was removed and the surfactant solution was poured out.

J. The sample was immersed into 2 liters of fresh, deionized rinse water which maintained an average temperature of 35 c. The sample was then slowly "swirled" in the rinse water for 3 to 5 minutes.

K. Repeat rinsing were performed, removing the sample between

each step, until the surfactant foaming commenced.

L. After the final rinse bath, the sample was removed and placed on a terry cloth towel and allowed to air dry.

pH TEST RESULTS

The following illustrates the pH measurements of the test procedure. Some of the tests were repeated because "blotching" appeared on the soiled portion of the substrate. The retests are indicated by the letter "a".

The first Orvus WA Paste test did not appear "blotchy". It was retested because of its wide usage. However, the second test did experience blotching.

The pH of the consecutive steps was tested with a pH meter. However, in some cases the meter malfunctioned and the pH was recorded using Colorphast Test Strips.

pH of the deionized water at 33.5 c is 7.06

W=wool substrate
C=cotton substrate

SURFACTANT	pH OF WATER AND SAMPLE	pH OF SURFACTANT SOLUTION	pH OF SURFACTANT & SAMPLE
Orvus WA W-1	6.42	7.58	6.93
Orvus WA W-1a	6.5	6.5	6.5
Orvus WA C-1	6.5	7.58	7.22
Orvus WA C-1a	6.5	6.5	6.5
Tensopol W-2	6.4	9.07	8.35
Tensopol C-2	6.5	9.16	9.35

Synperonic NP-9 W-3	5.0	5.0	5.0
Synperonic NP-9 C-3	5.0	5.0	5.0
Synperonic OP-10 W-4	5.0	5.0	5.6
Synperonic OP-10 C-4	5.0	5.0	5.0
Synperonic OP-10 C-4a	6.27	6.43	6.5
Triton X-100 W-5	5.5-6.0	5.0	5.0
Triton X-100 C-5	5.5-6.0	5.0	5.0
Triton X-100 C-5a	6.04	5.95	6.5
Igepol CO-630 W-6	5.5-6.0	5.5-6.0	5.0
Igepol CO-630 C-6	5.5-6.0	5.5-6.0	5.5
Igepol CO-630 C-6a	6.27	6.67	6.5
Emulphogene W-7	5.3	5.5-6.0	5.5

Emulphogene C-7	5.3	5.5-6.0	5.5
Pluronic L62 W-8	5.3	5.0-5.5	5.5
Pluronic L62 C-8	5.3	5.0-5.5	5.5
Plurafac B 25 5 W-9	5.0	5.0	5.0
Plurafac B 25 5 C-9	5.0	5.0	5.0
Silvatol SO W-10	5.0	6.0	6.0
Silvatol SO C-10	5.0	6.0	6.0
Orvus/Triton W-11	5.0	6.0	6.0
Orvus/Triton W-11a	6.0	6.0	5.7-6.0
Orvus/Triton C-11	5.0	6.0	6.0
Orvus/Triton C-11a	6.0	6.0	5.7-6.0
Orvus/Igepol W-12	5.0	6.0	6.0
Orvus/Igepol W-12a	5.7-6.0	5.8-6.0	5.7-6.0

Orvus/Igepol C-12	5.0	6.0	6.0
Orvus/Igepol C-12a	5.7-6.0	5.8-6.0	5.7-6.0

DISCUSSION OF RESULTS

The results of the DL (lightness/darkness) readings are illustrated on the enclosed table.

WOOL SUBSTRATES

For the wool substrates, the surfactant with the highest soil removal reflectance value was Orvus WA Paste. The surfactant with the lowest soil removal measurement was Pluronic L684.

Of the anionic surfactants, Orvus WA Paste maintained the highest soil removal value but Tensopol A795 was comparable with the soil removal differing by less than 2%. Silvatol SO had the lowest soil removal value of the three anionic surfactants.

Orvus WA Paste exhibited the lowest amount of soil redeposition with Tensopol A795 next and Silvatol SO last.

For the nonionic surfactants, Emulphogene DA 630 had the highest amount of soil removal and Pluronic L684 the lowest. Both of these surfactants exhibited the least amount of redeposition.

Igepol CO 630 had the second best soil removal but a greater redeposition factor when compared to Emulphogene DA 630. Triton X-100 was third in soil removal with a greater redeposition problem than Igepol CO 630.

For the combination surfactants, the Orvus WA Paste/Igepol CO 630 had greater soil removal but also greater redeposition problem when compared to the Orvus WA Paste/Triton X-100 mixture.

COTTON SUBSTRATES

The surfactant with the highest amount of soil removal

value was Emulphogene DA 630 and the surfactant with the lowest amount of soil removal was Igepol CO630.

The anionic surfactants followed the same pattern for the cotton substrates as for the wool substrates in amount of soil removal and redeposition properties.

The nonionic surfactants differed somewhat with Plurafac B 25 5 obtaining the second highest amount of soil removal but also a greater amount of redeposition was noted when compared to Emulphogene DA 630. Pluronic L684 had lower soil removal but greater redeposition factor comparable to that of Plurafac B 25 5. Synperonic OP10 and Triton X-100 had low soil removal but the redeposition readings take on a negative value indicating that these surfactants made the unsoiled portion of the substrate lighter. Igepol CO 630 had the lowest soil removal value but a relatively low level redeposition property.

The combination surfactants followed the same pattern for the cotton substrates as for the wool substrates in terms of the amount of soil removal and redeposition properties.

SURFACTANT CLASSIFICATIONS

The anionic surfactants maintained better soil removal abilities on the wool substrates than on the cotton substrates. However, the redeposition properties of the anionic surfactants were greater than that of the nonionic surfactants and the combination surfactants.

The combination surfactants produced no greater amount of soil removal on the wool substrates. On the contrary, the reflectance values of the individual anionic and nonionic surfactants decreased. The addition of the likewise surfactant seemed to decrease the soil removal ability of the individual surfactant.

On the cotton substrate, each surfactant classification had comparable soil removal reflectance values. The best soil removal belonged to a nonionic surfactant with good anti-redeposition abilities.

The addition of the anionic surfactant seemed to increase the soil removal ability of the nonionic surfactants. However, the degree of redeposition decreases slightly. The

combination surfactants and the nonionic surfactants seemed to work best on the cotton substrates.

SUMMATION

The results of this investigation are successful in illustrating the soil removal capabilities of the chosen surfactants.

However, through research, it was realized that there are many variables of wet cleaning which still need to be researched and tested. One of these would be to test each of the different sub groups of surfactant classifications. This test touched on just a few of the hundreds of surfactants available from the textile chemical industry.

Other variables include: the percentage of concentration which would maintain washing ability yet not be harmful to the structure of the fiber (Critical Micelle Concentration is also involved here); surface properties of fibers and how much influence these properties have on the electrostatic repulsion of the surfactant molecule; how the physical structure (weave structure) influences the soil removal ability of a surfactant; the limits of pH and temperature also what is the least amount of agitation which will activate the soil removing ability of a surfactant; what is the most effective type of rinsing and what is the most effective type of water (deionized, distilled or tap?).

It is realized that most of these variables will depend on the condition of the piece being cleaned. However, with standardized testing of the variables involved in wet cleaning, a basis for comparison can be achieved that will make these decisions easier.

EFFECT OF SURFACTANTS ON THE APPEARANCE OF WOOL

SURFACTANT	SAMPLE	DL*
1. Orvus WA	soiled	25.84
	unsoiled	0.95
1a. Orvus WA	soiled	21.79
	unsoiled	0.86
2. Tensopol A-795	soiled	24.39
	unsoiled	1.03
3. Superonic NP-9	soiled	17.57
	unsoiled	0.53
4. Superonic OP-10	soiled	18.04
	unsoiled	0.56
5. Triton X-100	soiled	18.65
	unsoiled	0.81
6. Igepal CO-630	soiled	21.23
	unsoiled	0.74
7. Emulphogene DA-630	soiled	23.55
	unsoiled	0.63
8. Pluronic L64	soiled	11.25
	unsoiled	0.55
9. Plurafac B-25-5	soiled	17.02
	unsoiled	0.82
10. Silvatol SO	soiled	18.26
	unsoiled	0.34

* Delta values are for "D" daylight light source.

EFFECT OF SURFACTANTS ON THE APPEARANCE OF WOOL

SURFACTANT	SAMPLE	DL*
11. Orvus WA & Triton X-100	soiled	20.79
	unsoiled	0.51
11a. Orvus WA & Triton X-100	soiled	15.83
	unsoiled	0.17
12. Orvus WA & Igepol	soiled	19.26
	unsoiled	0.74
12a. Orvus WA & Igepol	soiled	19.78
	unsoiled	0.03

* Delta values are for "D" daylight light source.

THE EFFECT OF SURFACTANTS OF THE APPEARANCE OF COTTON

SURFACTANT	SAMPLE	DL*
1. Orvus WA	soiled	12.74
	unsoiled	0.16
1a. Orvus WA	soiled	19.64
	unsoiled	0.02
2. Tensopol A-795	soiled	11.00
	unsoiled	0.16
3. Superonic NP-9	soiled	10.42
	unsoiled	0.07
4a. Superonic OP-10	soiled	10.83
	unsoiled	0.02
5a. Triton X-100	soiled	9.98
	unsoiled	0.06
6a. Igepal CO-630	soiled	9.64
	unsoiled	0.06
7. Emulphogene DA-630	soiled	15.70
	unsoiled	0.16
8. Pluronic L64	soiled	10.54
	unsoiled	0.48
9. Plurafac B-25-5	soiled	14.30
	unsoiled	0.46
10. Silvatol SO	soiled	10.55
	unsoiled	0.14

* Delta values are for "D" daylight light source

THE EFFECT OF SURFACTANTS ON THE APPEARANCE OF COTTON

SURFACTANT	SAMPLE	DL*
11. Orvus WA & Triton X-100	soiled	17.61
	unsoiled	0.11
11a. Orvus WA & Triton X-100	soiled	10.97
	unsoiled	0.08
12. Orvus WA & Igepol	soiled	12.74
	unsoiled	0.29
12a. Orvus WA & Igepol	soiled	15.91
	unsoiled	0.11

* Delta values are for "D" daylight light source.

SURFACTANT	SAMPLE	DL*
16. Deionized water	soiled	1.44
	unsoiled	0.04

* Delta values are for "D" daylight light source.

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