

UPDATE: DETERGENCY & THE AQUEOUS CLEANING OF ANTIQUE TEXTILES

MARY W. BALLARD

ABSTRACT—The European Union has curtailed the use of nonylphenol ethoxylates. In the United States, octylphenol ethoxylates have also been questioned for their safety to humans and for their waste products. Yet the search for substitutions has led to cleaning agents designed for metal, glass, and nonabsorbent plastics in specialized industrial settings: dairies and breweries. How did we get so far afield? How effective are these products? The current study will review the current legislation and examine the efficacy of potential choices, nonionic and anionic within the context of museum textile and clothing collections.

ACTUALIZACIÓN: DETERGENCIA Y EL LAVADO ACUOSO DE ARTÍCULOS TEXTILES ANTIGUOS POR MARY W. BALLARD, RESUMEN—La Unión Europea ha restringido el uso de etoxilatos de nonilfenol. En los Estados Unidos, los etoxilatos de octilfenol también han sido cuestionados por su seguridad para los seres humanos y por sus productos de desperdicio. Aún así la búsqueda de substituciones ha conducido a agentes de limpieza designados para metal, vidrio y plásticos no absorbentes en entornos industriales especializados: centrales lecheras y fábricas de cerveza. ¿Cómo llegamos a lugares tan distantes? ¿Cuál es la efectividad de estos productos? El estudio actual revisará la legislación actual y examinará la eficacia de las elecciones potenciales, no iónicas y aniónicas dentro del con contexto de textiles de museo y colecciones de ropas.

1. INTRODUCTION

In earlier times, centuries passed without substantial changes to the type of fibers available, the type of finish available, or the type of surfactant available for textiles and costumes within a culture. Today, the post-1950 additions to the fiber and fabric content are now arriving in textile collections; they incorporate substantially new synthetic fibers and new finishes. Textile conservation generally works 50 to 100 years behind the American apparel and furnishings market, as clothing and fabric gradually become treated as heirlooms and accessioned into museum collections. With these new synthetic fabrics and finishes, it is especially useful to revisit surfactant selection. This paper will address the soil removal mechanism, fiber type, and fiber finishes as well as a discussion of detergency and surfactants, with particular attention to nonionic alkyl phenol ethoxylates. It was given as an oral presentation to the Textile Specialty Group, at the 37th Annual AIC Meeting.

2. SOILS & SOIL REMOVAL METHODS

Detergent manufacturers divide soil into six major groups: particulate soil, water soluble soil, oily or greasy soil, liquid food stains, protein or starch based stains, and odors (table 1) (Broze, 1994).

Soil Group		Examples
Particulate soil		Dirt, Dust
Water Soluble soil		Table salt, table sugar
Oily (liquid) soil	Oily Soil	Non-polar hydrocarbons—motor oil
	Greasy Soil	Fatty foods with polar components-vegetable or animal greases
Fruit, beverage stains		Coffee, tea, cola
Protein or starch		“macaroni & cheese”
Odors		Esters, diamines, body oils (squalene, sebum)

Table 1. Soil groups and examples (after Broze, 1994).

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Oily soils and particulates have been thoroughly characterized in order to evaluate home laundry detergents and commercial soil release agents (Kissa, 1987a, Kissa 1987b). Yet such oily soiling common to home laundry is uncommon in museums. Antique textiles--tapestries, carpets, flags, or costumes--are more likely to be acquired by a museum in a "clean" state although prior soap residues in the form of salt or fatty acids may be mistaken for mold when they tend to outgas from silk or wool, suggesting a preferential deposition or adsorption on these substrates (Heald et al., 1994). Sometimes museum records and circumstantial evidence can help to determine past wet cleaning treatments (Kajitani, 1987).

Heirloom textiles and antique textiles are more likely to have soils associated with their location in an exhibition hall or due to their fundamental nature. Water soluble soils and oily or greasy soils—kitchen or garage soils—are much less common. Costumes might have old stains or odors, archaeological textiles might have stains as well as particulates. Museums with antique textile collections are most often located in urban settings. Soils deposited on antique textiles after acquisition (and while on exhibition) are associated with street dust (Francis, 2002). In the United States, an early major study of street soil showed a variation on the quantity and quality of soils in different cities (table 2). The soils have fairly uniform inorganic components, perhaps due to a similarity of city building materials and street pavements; the non-combustible ash content is over half the material. The most variable part of urban soil is the solvent soluble component--the oiliness of the soil which was as low as 4.9% in Detroit and as high as 12.8% in St. Louis.

The majority of city soil particles are surprisingly small; this is particularly important for museums since the smaller particles can travel farther with lighter breezes. A series of studies of soil deposited in museums have focused on modeling the velocity and deposition rate of airborne particles (Nazaroff et al., 1990a). Here the soil inside museums is divided into elemental carbon (soot) and soil dust into grades with a 2.0 micron diameter cut-off point. New ventilation and filter systems can reduce the level of indoor soils to 15-20% (fine) or even less than 5% (coarse), although one museum has more measured elemental carbon inside than out (Nazaroff et al., 1990a:71). In a related article, the authors correlate the velocity and turbulence of mechanical ventilation

Component	Pittsburgh	Detroit	Cleveland	Buffalo	St. Louis	Boston
Water-soluble	15.4	13.5	15.9	11.4	14.9	15.4
Ether-soluble	10.8	4.9	7.1	6.5	12.8	7.7
Moisture	--	1.7	3.0	-	-	2.1
Total Carbon	26.4	24.7	24.0	26.9	25.6	28.9
Ash	53.8	57.8	56.3	52.0	51.2	50.5
SiO ₂ (total)	25.6	25.5	26.4	24.0	21.4	21.4
R ₂ O ₃ (total)	11.6	9.9	11.1	9.5	9.4	11.1
CaO (total)	6.2	8.4	7.7	6.9	7.4	6.4
MgO (total)	1.7	2.0	1.7	2.0	1.6	1.7
CaO (water-soluble)	0.3	0.4	0.7	0.3	0.4	0.7
MgO (water-soluble)	0.1	0.2	0.2	0.2	0.2	0.2
N	-	1.6	-	-	-	2.1
pH (10% slurry)	7.0	7.3	6.7	7.2	7.0	7.3
Carbon black ("")	0.8	0.6	0.55	0.5	0.5	0.6

Table 2. Analyses of natural dirt from various U.S. cities (after Sanders & Lambert, 1950).

registers, temperature and circulation currents near windows or doors to the level of soil disposition (Nazaroff et al., 1991). An early analysis by the Hoover Company found that 45% of “natural soils” picked up by vacuum cleaners were sand and clay. Vacuum cleaners picked up the particles in the size range of 0.3 to 35 microns, but the soil left on the fibers of carpets is smaller: 0.2 to 4 microns (Martin and Fulton, 1958).

3. DETERGENCY

If the commercial categories of soil are grouped by their typical removal method, there are three major options: mechanical removal, specialty reagent removal, and detergency (table 3). Technically, detergency is defined as “the removal of unwanted substances from a solid surface brought into contact with a liquid” (Kissa, 1987a: 2). There is agitation or mechanical action during detergency cleaning, of course, and detergency can be aided by specialty chemicals. Certainly, commercial detergents accommodate water conditions and climatic variation by adding various auxiliaries. However, detergency as an aqueous soil removal method mainly involves removing a solid substance either by a reduction in soil adhesion or by liquefaction and solubilization. Liquid soils are ‘rolled up’ by detergency (table 3) (Cox, 1994).

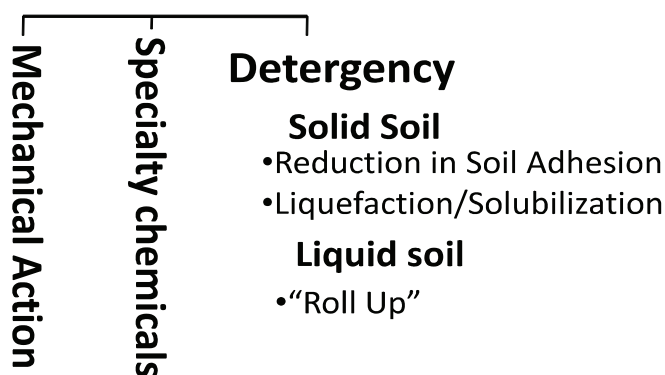


Table 3. Soil removal mechanisms (after Cox, 1994).

Surface active agents, a term condensed to *surfactants*, are used to remove soils. They are the diplomats of the chemical community, getting disparate factions working together—getting oil and water to mix. These surfactants wet surfaces, suspend soils in water, and absorb onto surfaces. They function as biocides, they enable soil removal. Surfactants are identified by their two part composition: one part of their chemical structure is hydrophilic, one part of their structure is hydrophobic; they are chemically bilingual. Other chemical structures also affect surface tension. The surface tension rises with the concentration of electrolytes. Solvents, like ethanol, can help to wet out a surface when they are mixed with water. However, surfactants will lower the surface tension at an extraordinarily low concentration, and at the same time suspend soils, again because of their chemical bilingualism.

The surface active agent has a “head” that is the water-soluble component-- a carboxylate, sulfate, sulfonate, quaternary ammonium, ethylene oxide chain (EO), etc.—and a non-aqueous “tail” that is a straight or branched

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hydrocarbon. For Synperonic N, the hydrocarbon is a 9-carbon chain attached to a phenol ring; for Triton X-100, an octyl (8-carbon) group is attached to the phenol. For Orvus WA Paste, the lauryl (12-carbon chain) is hydrophobic. Here, lauryl suggests a vegetable origin for the carbon chain; its synonym, dodecyl, indicates a petroleum origin, so the surfactant can be abbreviated SLS or SDS.

Another term for the hydrophobic tail is ‘lipophilic,’ having an affinity for oils. The relative strength of head versus the tail is characterized as the hydrophilic lipophilic balance or HLB number. For the last half century the HLB values have been provided by surfactant manufacturers for nonionic surfactants: the HLB value is the percentage weight of the hydrophilic group, divided by 5. A large water soluble component will increase the number; a large hydrophobic or lipophilic group will reduce it. Wetting agents have an HLB of 6-9; oil in water emulsifying agents 8-18, solubilizing agents, 10-18. Triton X-100 has a HLB of 13.5, and Synperonic N, a HLB of about 13.4. As measured by the HLB values of its two halves, Orvus WA Paste would have an equivalent HLB value of 40 (Merianos, 2001; Jönsson, et al., 1998).

Ionic surfactants have a charge—anionic or cationic depending on the type of “head.” Orvus WA Paste, a SDS, is one of the most researched anionic surfactants (Preston, 1948). As with all surfactants, a very small quantity has a pronounced effect on water and on a fabric/solid surface. At the critical micelle concentration (CMC) it begins to function as a detergent. Values of CMC are specific for specific surfactants and the values are widely reported (Mukerjee and Mysels, 1971; Jakobi and Löhr, 1987; Kaler, 1994; Merianos, 2001). The CMC for ionics is generally two orders of magnitude greater than for nonionics (Jönsson, et al., 1998). Ionics work best in a range at or slight above the CMC (Boring and Ewer, 1991 & 1993). Both ionics and nonionics have temperature parameters: ionics have a Krafft point temperature and concentration below and beyond where they change phase structure; nonionics have a phase change above a certain temperature where they cease to act as surfactants. Blends of surfactants can affect the cloud point and additives like electrolytes will alter the Krafft point (Kaler, 1994; Patterson and Grindstaff, 1977). Greatly increased concentrations, though, do not increase efficacy, and can gum up the solution, taking it out of phase (Jönsson, et al., 1998).

With different types of soils, the functioning mechanism of soil removal by surfactants changes, regardless of the type of surfactant. For solid soil particles, surfactants remove particles by reducing the adhesion between the fiber surface and the soil and by reducing the size of the contact between the fiber surface and the soil (Kissa, 1981). Anionic surfactants remove and suspend solid, particulate soil very well (Cox, 1994). Another kind of solid soil is the organic solid—solid at room temperature but semi-solid or liquid in lukewarm water. Surfactants can slice off layers of this type of soil, peeling layers off. Nonionic ethoxylates are very useful for dishwashing and cleaning glassware for this reason (Cox, 1994). Once peeled off, surfactants can form stable “micro-emulsions” that keep the oil solubilized in water. Again, this works most successfully with a little surfactant, a lot of water, and a little oil (Kaler, 1994).

In addition to solid soils, there are entirely liquid soils which surfactants can remove by changing the interfacial tensions—increasing the tension between the oil and the fabric while reducing the tension between the water and the fabric. Surfactants can make the fiber much more hydrophilic, but even as adept chemical ambassadors, surfactants have their limits.

4. FIBERS

Fibers vary in several fundamental ways (table 4). Hydrophobic, synthetic fibers do not become hydrophilic in

water with the addition of anionic surfactants and liquid oily soil does not “roll up” from a hydrophobic fiber in the presence of anionics. In table 5, the results of an experiment to remove a fatty soil, a triglyceride, are compared. Cellulosics are well cleaned by ionics or nonionics; on Teflon, this soil is only removed by a nonionic surfactant. Oily soil on nylon is poorly removed by ionics; and oily soil on polyester is virtually unaffected by anionic surface active agents.

Classification System	Example
Chemical Formation	Natural, Regenerated, or Synthetic
Polar or non-polar	Attract head or tail of surfactant
Porous or non-porous	Staple fiber or spun fiber
Critical surface tension	Affect of water droplet on fiber surface
Electrical charge in water	Natural fibers have a negative charge

Table 4. Fiber classifications.

Fiber (without finish)	Soap	Anionic	Nonionic	Cationic
	Sodium palmitate	Sodium lauryl sulfate	Nonylphenyl- ethoxylate	Cetyltrimethyl- ammonium bromide
Cellulose	--	92%	94%	93%
Polyester	78%	3%	99%	7%
Nylon	--	28%	99%	82%
Teflon	--	22%	96%	22%

Table 5. Percentage of oily soil removal* from various surfaces by different surfactants (after Patterson and Grindstaff, 1977).

*glyceryl tristearate tagged ester removed from 0.01M surfactants in 15 minutes at 60°C.

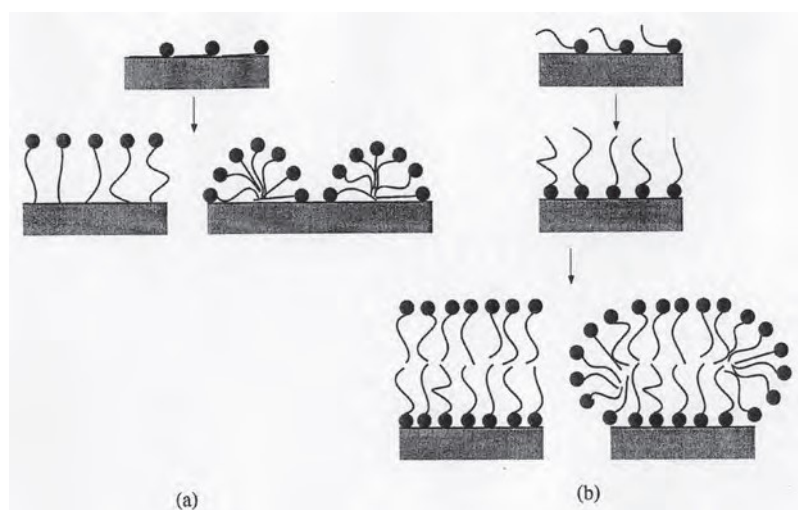


Figure 1. On a non-polar fiber surface (a) the hydrophobic hydrocarbon will align in contact while on a polar fiber surface (b), the hydrophilic head of the surfactant will be the point of contact (Jönsson et al., 1998).

A fiber and its properties will profoundly affect the efficacy of a surfactant. Nonionics are absorbed on cotton, but only slightly on wool. SLS absorbs onto wool and silk significantly, but not on cotton (Weatherburn and

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Bayley, 1952; Rhee and Ballard, 1994). The polarity of the fiber is also important: on non-polar surfaces the hydrocarbon tails of the surfactants will sit on the fiber surface; on polar surfaces, the hydrophilic heads will be attracted (fig. 1a). Natural fibers carry a negative charge in water, and the positive ‘head’ of cationic surfactants will attach to cotton at a magnitude greater than that of anionic surfactants (Weatherburn and Bayley, 1952). For non-polar fibers, the interaction with the hydrocarbon portion of the surface active agent may be independent of the character of the hydrophilic head (fig. 1b). Surfactants can wet out polymeric surfaces with very different critical surface tensions. Yet, blends of anionic and nonionic surfactants can be preferentially absorbed. Thus a blend of 70:30 anionic to nonionic surfactant solution can be absorbed inversely by a non-polar hydrophobic surface (Jönsson, et al., 1998).

5. FINISH

Though the type of fiber and type of soil will influence the selection of surfactant, the fiber itself can be engineered and modified by its finish. Durable press, permanent press resins, or ‘easy care’ finishes are applied after weaving and dyeing to modify the performance of a garment or furnishing textile. A cross-linked cotton is less hydrophilic, less polar than its untreated relative. Cross-linked cottons will swell less in water and function more like a polyester fabric: liquid oily soil will not ‘roll up’ with anionic surfactant; a nonionic surface active agent is required (Kissa, 1981). On the other hand, alkali-treated polyester is rendered much easier to clean than the untreated but infamous ‘easy care’ polyester tablecloths that tenaciously held oily stains. What was once a specialty soil and a tedious stain removal problem on a natural fiber may become a straightforward water-soluble one on a synthetic fiber like nylon or acrylic. Similarly, the natural fiber can be modified with (synthetic) polymers to resist staining. Fluorinated polymer finishes—Teflon coated—on natural fibers will enable them to repel the absorption of polar liquid stains (Regulatory Technical Information Center, 1985).

6. SAFETY ISSUES

Initially, safety issues were perceived to pertain to safety for the object or for the environment. The high pH of laundry surfactants rendered them too caustic for museum textile cleaning (Rice, 1966 and 1970). In consultation with the manufacturer, Procter and Gamble, Kathryn Scott found SDS a suitable surfactant for archaeological textiles (Scott, 1972). Ecologically, anionic surfactants with branched hydrocarbon hydrophobic tails - branched alkyl benzene sulfonates - were banned from commercial anionic surfactants in 1965 because they did not biodegrade. At that time, industrial studies were undertaken to determine the fate of a widely used nonionic surfactant, octylphenol ethoxylate with 9-10 ethylene oxide units, along with other representative nonionic surface active agents. The scope of the term “environmentally acceptable biodegradation” was interpreted to mean a set of nontoxic products acceptable to the receiving environment (air, soil, or water), but principally as treatable by sewage treatment plants. The aesthetics of the downstream environment were also recognized (Mauser et al., 1969).

Back then, the difficulty lay in formulating consistent, accurate test methods to monitor the rate of degradation of organic compounds and, most especially, analytical measurements that would provide the precision and repeatability required. Field tests with oxygen consuming microorganisms were undertaken but actual quantitative analysis of the ethoxylated chains had limited sensitivity (Burttschell, 1966). Throughout the 1970’s, the limits of effective biodegradation were noted. Nonylphenol, a “moderately toxic” compound, was found to accumulate in a holding pond downstream from a carpet mill at eighty times the level of concentration in the plant effluent itself, which is 0.05mg/l versus 4.0 mg/l (Garrison and Hill, 1972). It was then postulated that the high level of

nonylphenol was a result of anaerobic conditions, a theory refined by a more extensive 1984 European study on nonylphenols in sewage sludge. The latter study suggested it was possible that the aerobic microbial elimination of the hydrophilic EO groups and the sorption of the hydrophobe by the sludge led to the measureable, persistent residues (Giger, Brunner, and Schnaffner, 1984). In the studies, the causal agent was identified as nonionic alkylphenol ethoxylated surfactants. Broader ecological questions about the aquatic toxicity of these surfactants were also investigated, as part of the general policy of protecting waterways and water sources in the United States and Europe (Malle, 1984).

A second type of toxicological concern with alkylphenol ethoxylates emerged in the 1990's: one based on the potential hazard for biological effects, specifically to act like an estrogen. Hormonal effects from octylphenols and nonylphenols and their ethoxylated adducts were cited in studies publicized by the Environmental Protection Agency (EPA) (Federal Register, 1996). It should be noted that both nonylphenol ethoxylate and octylphenol ethoxylate have been categorized and sold as spermacides for some time (Merck Index, 1983). Several aquatic toxicity studies and small mammalian studies have focused on the hormonal effects of nonylphenol and octylphenol as alkylphenol ethoxylate degradations. The European community has acted to suspend the use of nonylphenol ethoxylates on this basis (Fields, 2000).

When the American EPA sought to include a priority testing list of alkylphenol ethoxylates, the Toxic Substances Control Act Interagency Testing Committee (ITC) had a problem trying to establish the Chemical Abstract Service (CAS) Numbers and chemical names associated with specific alkylphenol ethoxylates for 28 alkyl phenols and alkylphenol ethoxylates that were initially listed. Variations because of EO ratios (hence differences in physical properties), proprietary information, and idiosyncratic nomenclature have made it difficult to correlate CAS numbers with competing non ionic surfactants for the EPA and for the end-user. Nonylphenol ethoxylate is called "Nonylphenol polyethylene glycol ether" in the *Federal Register* and has 7 CAS numbers: #9016-45-9, #20636-48-0, #26027-38-3, #2606402-8, #27177-01-1, #37205-87-1, and #127087-87-0 (*Federal Register*, 2000). Analogs of Synperonic N (Alkasurf 630) with the CAS #68412-54-4 include a range of 9 to 30 moles of EO and HLB values from 4.6 to 17.1 (McCutcheon's, 1998).

Conversely, a single product may have more than one CAS number: Triton X-100, for example, has two CAS numbers, #9036-19-5 and #9002-93-1 for the same octylphenol ethoxylate, which older literature described as para-tertiaryoctylphenoxypolyethoxyethanol (Lashen et al., 1966). It should be noted that, as late as 1985, *McCutcheon's Volume 1: Emulsifiers and Detergents, North American Edition* did not list CAS numbers for products. The products were simply described by a general chemical classification or by the manufacturer's designated chemical formula. The emphasis was not on the precision of the formula but on the efficacy of the surfactant for certain processing operations, as described in brief "remarks."

7. DISCUSSION

Ironically, the current ecological concerns have propelled the museum world to reexamine its dependence on two nonionic surfactants: an octylphenol ethoxylate (Triton X-100, Dow Chemical, in the United States) and a nonylphenol ethoxylate (Synperonic N and ND, formerly ICI, in Great Britain). Some time ago European conservation literature sought to match the type of soiling with the surfactant and water quality: for mixed [substrate] collections in non-deionized water, an alpha-olefin sulfonate, and a fatty acid methyl ester alpha-sulphonate for very acidic soiling, and a nonylphenol ethoxylates for oily soiling (Hofenk de Graaff, 1982). Some literature had emphasized the use of builders, chelating agents, and anti-redeposition agents to overcome

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the short-comings of alkylphenol ethoxylates (Tímár-Balázsy and Eastop, 1998). Recent literature has focused on the necessity of matching the fiber properties with the surfactant, soiling type, and the role of the critical micelle concentration (Tinkham and Kerr, 2001, Francis, 2002). For the most part, the efficacy of a surfactant or surfactant mixture for cleaning antique fabrics has been determined experimentally using the standard industrial soil cloths created to simulate home laundry soils (Fields et al., 2004; Tinkham and Kerr, 2001; Lewis and Eastop, 2001).

Another response has been to seek a near substitute, like an alkyl ethoxylate with a primary alcohol, such as Triton XL-80N, but this method accentuates the short-comings of the replacement: it is propyloxylated, non-gelling, with differences in CMC, and a greater tendency for eye and skin irritation; Dehypon LS 45 also suffers in a comparison to Triton X-100 (Stravroudis, 1995a; Fields et al., 2004). Even closely related analogs can produce very different working properties: The Igepal CO nonylphenol-ethoxylates - again CAS # 68412-54-4 - include Igepal CO 530 “a deicing fluid for jet aircraft,” with an EO of 6 to Igepal CO-730 used as a “metal cleaner [and in] bottle washing formulations” while the HLB values range from 4.6 to 15.0 (McCutcheon’s, 1998). Information on the working properties of surfactants is not always easy to obtain because of the sales and acquisitions of surfactant units among chemical manufacturing firms. Triton X-100 was once a Rohm and Haas product; it was purchased by Union Carbide, and it is currently produced by Dow Chemical. Product literature has been produced by all three firms.

Tergitol	HLB	Moles EO	CMC ppm at 25° C	Cloud Point in °C at 1% wt conc	Dynes/cm at 0.1% conc at 25° C
#1: 15-S-5	10.6	5	--	insoluble	-24
#2: 15-S-9	13.3	8.9	56	60	9
#3: 15-S-12	14.7	12.3	110	89	20

Table 6. Secondary alcohol ethoxylate surfactant mixture proposed by Delcroix and Bureau, using tergitols (Dow Chemical).

Combining a series of nonionic surfactants or a mixture of anionic and nonionic surfactants to address the issues of residual fatty acids, salt residues, and particulates is a third attractive answer for surfactant selection (Delcroix and Bureau, 1990-1; Lewis and Eastop, 2001). For cleaning the protein fibers of antique carpets and tapestries, one European recipe combines a series of three secondary alcohol ethoxylates to achieve good fiber wetting with one, good oil in water micro-emulsification with a second, and good detergency with a third in a ratio 75% CMC, 45% CMC, and 30% CMC (table 6) (Delcroix and Bureau, 1990-1). However, their effective temperature range would ostensibly fall outside the 20°-30°C range in which antique textiles are wet cleaned. Combining selected surfactants also changes the functional temperature range; studies have indicated a mixture of ethoxylated chain lengths has a positive effect on the stability of oil in water and nonionic micro-emulsifications (Saito et al., 1990). Cloud point and temperature are also important for anionic-nonionic mixtures as are factors like the nature of the oil, any electrolyte concentration, any co-surfactant, and the type of salt. More polar soils may be removed most effectively just below the cloud points of nonionic surfactants. In fact, the ratio of the surfactants will change continuously because the surfactant with the higher ethylene oxide chains (6-9) will pull off the more polar oily soil components (Raney and Benson, 1990). The temperature best suited for a particular oily soil is known as its phase inversion temperature (PIT). The oily soil is most effectively removed slightly above its PIT and below the cloud point of the nonionic surfactant. While this is pertinent for nonionics with ethoxylated chains and for cotton/polyester fabrics, it also begins to clarify the optimum temperature and ratio for

anionic-nonionic mixtures (Raney and Benson, 1990; Raney, 1991; Jönsson, et al., 1998). In fact, for anionic-nonionic mixtures, the short-comings of the nonionic surfactant are more than mitigated by the addition of anionic surfactants. Such synergy is typically used for commercial formulations (Jönsson, et al., 1998).

Certainly, it is simpler to continue to use two of the most widely used (and cheapest) surfactants available, octylphenol ethoxylate and sodium lauryl sulfate. Multiple levels of understanding are needed to select suitable replacements for the particular octylphenol ethoxylate and nonylphenol ethoxylate surfactants previously used in museums. There is some merit with nonionic ethoxylated alcohols and with methylester ethoxylates as alternative surfactants (Cox and Weerasooriya, 1997). Yet, simple substitution may be more complex than anticipated because the nature of the soil, the fabric fibers, and the fabric finish may be different now than it was half a century ago. This complexity is compounded by obfuscating terminology as well as a lack of understanding of the features, physical chemistry, and working properties associated with modern surfactants and classic soaps. Our limited characterization of the soils on antique fabrics also conspires against our understanding.

ACKNOWLEDGEMENTS

Portions of this paper were developed in conjunction with course requirements for TC530, The Chemistry of Textile Auxiliaries, given by Prof. Peter J. Hauser at North Carolina State, Raleigh through the long-distance TOP program. I am grateful to the thoughtfulness of Tom Klaas of Testfabrics, Inc. As a fabricator of standard industrial soil cloths, he helped me consider more closely the efficacy of their use for museum studies.

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MARY W. BALLARD is the Senior Textiles Conservator at the Museum Conservation Institute, Smithsonian Institution. She received a BA from Wellesley College and an MA from the Institute of Fine Arts, New York University with a Diploma in Conservation in addition to apprenticeship training and course work here and abroad. She is a Fellow of the American Institute for Conservation and of the International Institute for Conservation as well as being a senior member of the American Association of Textile Chemists and Colorists. Address: Museum Conservation Institute, Smithsonian Institution, Museum Support Center, 4210 Silver Hill Road, Suitland, MD 20746. Telephone: 301-238-1210. Fax: 301-238-3709. Email: ballardm@si.edu.