Surface Chemical Processes for Removal of Solid Sebum Soil[1]

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Optimizing the removal of solid sebum soil appears to depend on both the surfactant and the soil substrate. Like other solid, organic soils, sebum's removal from hard surfaces involves penetration of the surfactant (and associated solvent molecules) into the soil. This soil-softening (liquefaction) process prepares the soil for secondary processes (roll-up, abrasion, emulsification, etc.) which accomplish soil removal. A smaller hydrophobe and lower HLB both appear to aid soil removal by increasing surfactant penetration into the soil. However, when solid sebum is present on cloth, the ability to wet the cloth matrix becomes important. Surfactants better able to promote cloth wetting appear to be better at penetrating the soil, because wetting increases the amount of surfactant in contact with the soil.

Sebum refers to the fat and cellular debris continuously released by thousands of sebaceous glands contained in the human skin (1). Considerable work has been done in an attempt to characterize this material, because it represents one of the most common laundry soils encountered by the consumer. Consequently, most facilities using detergency evaluation tests use a sebum soil, usually one based upon the synthetic sebum recipe offered by Spangler (2,3).

At wash temperatures greater than about 30 C (86 F), sebum is a liquid. Its removal is accomplished through a simple "roll-up" mechanism where the soil is more or less pinched off the substrate by surface chemical forces which preferentially wet the cloth surface (4).

At wash temperatures below 30 C, however, sebum exists as a solid. Although little information is available in the literature, characterization of sebum removal at temperatures below 30 C is important because the current trend is toward cooler wash temperatures (5).

This study examines the effect of surfactant molecular structure on removal of solid sebum soil from both hard and soft surfaces. A surface chemical model is proposed which relates surfactant performance to its ability to penetrate the soil and to its ability to concentrate at the soil/water interface.

EXPERIMENTAL

Soil-submersion tests. Soil-submersion tests were performed to measure the ability of surfactant solutions to penetrate and/or remove solid sebum soil. Each test consisted of suspending preweighed soiled-substrate coupons in a series of identical 200-ml solutions of 1.00% (wt/wt) surfactant. Each coupon was submersed at a specific time relative to the total length of time desired for submersion. At the appropriate time, all coupons were removed from their solutions simultaneously, allowed to air-dry for 2 hr (to remove surface moisture), and then reweighed to determine the change in soil-substrate weight as a function of submersion time. Data were plotted as a function of time submersed in surfactant solution.

Thin aluminum coupons (3.8 cm in diameter, ~275 mg in weight) were used as the soil substrate. Coupons were soiled by brief submersion in melted soil. Approximately 300 mg of soil was applied to each coupon.

Tests were performed under static conditions (no mixing). Submersion times of up to 30 min were necessary to observe significant differences in the soil penetration and soil removal properties of various surfactants. Surfactant concentrations below 1% could not readily be used because substantially longer submersion times would be required.

A more detailed description of the equipment, materials and procedures used in the submersion tests, as well as a discussion of test reproducibility, is given elsewhere (6).

Detergency testing. Detergency tests were performed using materials and procedures outlined in Table 1. Performance was determined by monitoring soil-substrate weight and calculating percent soil removal.

$$\%\ \text{Soil removal} = \frac{\text{Wt (washed)} - \text{Wt (soiled)}}{\text{Wt (unsoiled)} - \text{Wt (soiled)}} \times 100$$

Sebum-soiled cotton and permanent press cloths were prepared by applying melted sebum directly to the cloth using an automated soiling system (E. Benz AG, Zurich, Switzerland).

Microscopy/photography. Microscopic examinations were performed using an Olympus BH-2 microscope

TABLE 1

Detergency Test Materials and Procedures

Testing apparatus	Terg-O-Tometer
Wash cycle	10 min
Rinse cycle	5 min
Wash temperature	68 F (20 C)
Water hardness	none
Number of soiled cloths (3 by 2 1/4 inch)	6 (3 cotton and 3 perma press)
Number of unsoiled cloths (as ballast)	3 (cotton)
Soil	Sebum
Cloth	Cotton[a] and permanent press[b]
Test procedure	Vista Lab Method 303-84[c]
Weight measuring device	Mettler AE 163 0.1 mg balance

[a]Test fabrics S/419.
[b]65% dacron/35% cotton with a permanent press finish (Test fabrics S/7406).
[c]Similar to ASTM Standards, Part 30, 465-466 (1977).

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equipped with an Olympus C-35AD camera. Photographs were taken at 40x.

Surfactants/sebum soil. Descriptions of the surfactants and soil used in these experiments are given in Tables 2 and 3.

RESULTS AND DISCUSSION

Removal of solid sebum from hard surfaces. The ability of various surfactants to penetrate and remove solid sebum soil from hard surfaces was examined using soil-submersion tests. These tests monitored soil weight as a function of time submersed in various surfactant solutions. Soil weight was observed to increase due to penetration of surfactant and solvent molecules into the soil. Previous studies suggest that it is this liquefaction or soil-softening step which prepares the soil for other processes (emulsification, agitation, etc.) which actually accomplish soil removal (6). Surfactant penetration should therefore be maximized for optimum soil removal.

The effect of surfactant hydrophobe size was examined by comparing an 8-60 ethoxylate and a 12-60 ethoxylate (Fig. 1A). Both surfactants show an increase in soil weight resulting from penetration of surfactant and solvent into the soil. The rate observed with the 8-60 ethoxylate is significantly greater than that observed with the 12-60 ethoxylate. As observed with other solid soils (6), a smaller hydrophobe appears to result in a faster rate of penetration. A smaller hydrophobe also has been shown to improve hard-surface cleaning performance on greasy soils (7,8).

The effect of surfactant HLB (hydrophile-lipophile balance) was examined by comparing a series of C-12 ethoxylates containing varying degrees of ethoxylation (Fig. 1B). Although differences are small, a lower HLB (lower EO content) appears to improve the rate of penetration. (Note: Although not shown, the curves for

TABLE 2

Surfactants Used in Soil-Submersion and Detergency Testing

Nonionic surfactants (alcohol ethoxylates)

Surfactant	Alcohol base	% EO	Moles EO
8-60	C_8, linear, primary	60	4.5
12-55[a]	C_{12}, linear, primary	55	4.7
12-60	C_{12}, linear, primary	60	6.3
12-70	C_{12}, linear, primary	70	9.8
12-80	C_{12}, linear, primary	80	17

Anionic surfactants (linear alkylbenzene sulfonate)

Surfactant	Avg. carbon chain length	Avg. Mol. Wt.	Typical 2-phenyl isomer content
C_{12} LAS	12	343	14.5

[a]1:1 blend of C_{12}-50% EO/C_{12}-60% EO surfactants.

TABLE 3

Synthetic Sebum Formula

Component	Source	Wt. percent
Palmitic acid	Kodak	10.0
Stearic acid	Kodak	5.0
Coconut oil	Sargent-Welch	15.0
Paraffin wax	Paraseal	10.0
Spermaceti wax	Sargent-Welch	15.0
Olive oil	Pompeian	20.0
Squalene	Kodak	5.0
Cholesterol	Kodak	5.0
Oleic acid	Kodak	10.0
Linoleic acid	Kodak	5.0

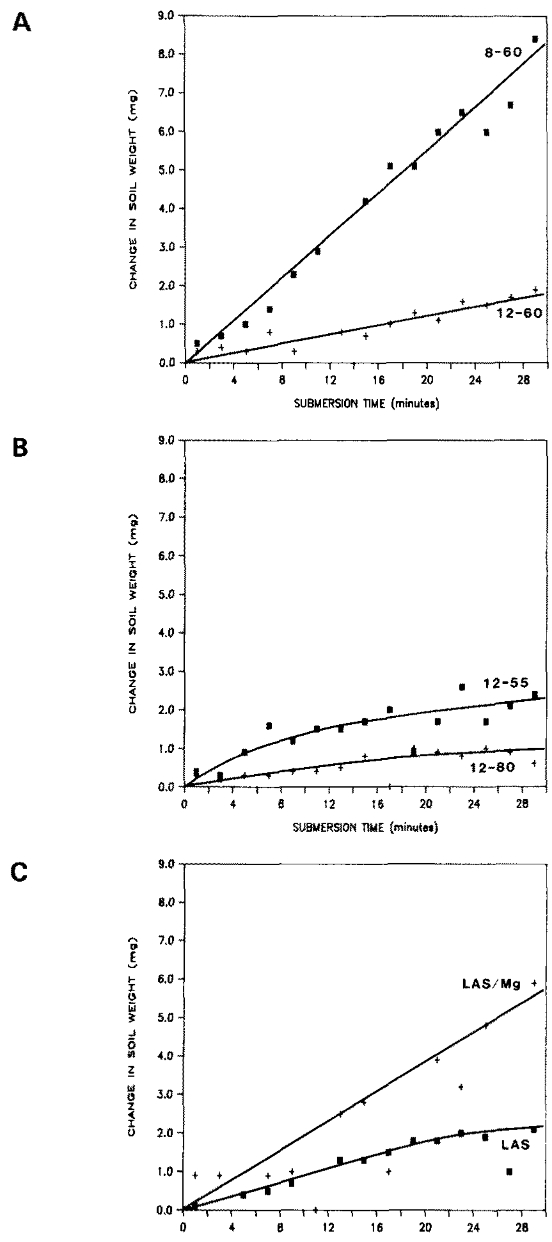

FIG. 1. Effect of (A) ethoxylate carbon chain length, (B) ethoxylate EO content, and (C) LAS HLB on the change in soil-substrate weight observed as a function of submersion time (sebum soil, 68 F, 1% surfactant).

the 12-60 and 12-70 ethoxylates fall between those of the 12-55 and 12-80 ethoxylates).

The effect of HLB was also examined by comparing dodecyl LAS vs a 2:1 molar blend of LAS and $MgCl_2$. The purpose of the magnesium chloride was to lower HLB by forming $Mg(LAS)_2$. Results (Fig. 1C) again show that a lower HLB (lower water solubility) yields an increase in the ability of the surfactant to penetrate the soil.

The dependence of soil penetration on soil temperature was examined by testing surfactant performance at 40 F, 55 F and 68 F (Fig. 2). As expected, penetration rate increases as temperature is increased.

The interaction of solid sebum soil with various surfactant solutions was also monitored microscopically. During these examinations, it became apparent that "roll-up" was an important soil removal mechanism (Fig. 3). Although roll-up likely removes liquid soil components, it may also account for removal of "liquefied" solid soil components as well. Because soil weight consistently increased as a function of submersion time, surfactant penetration apparently is more effective in increasing soil weight than roll-up is in reducing it. It is also likely that surfactant penetration aids roll-up by preferentially wetting the matrix formed by the more solid soil components.

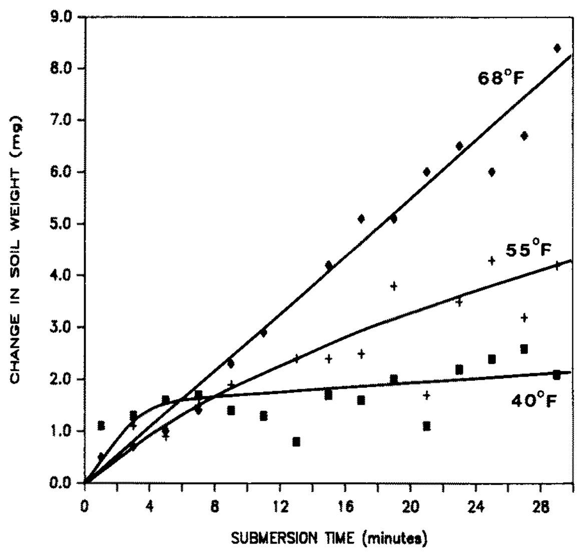

FIG. 2. Effect of temperature on the change in soil-substrate weight observed as a function of submersion time in 1% 8-60 ethoxylate.

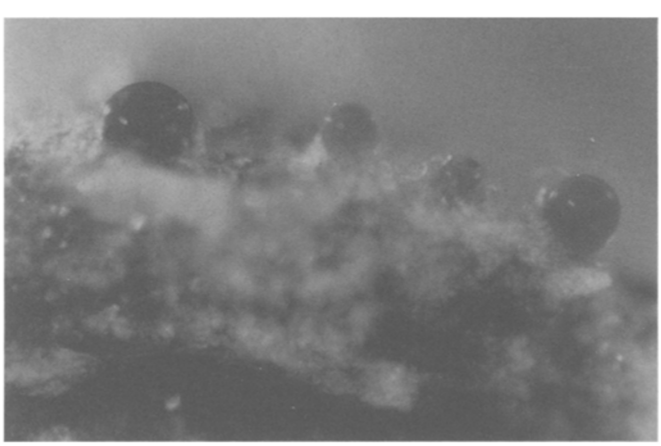

FIG. 3. Photograph (40X) of sebum soil submersed in 1% 8-60 ethoxylate showing "roll-up" (as evidenced by formation of liquid droplets on the soil surface).

Removal of solid sebum from soft surfaces. Detergency tests were performed for comparison with hard-surface soil removal data. Tests were performed at 68 F using both 0.1% and 1% surfactant concentrations.

The relative detergency performances of 8-60 and 12-60 ethoxylates are shown in Table 4. Although the 8-60 ethoxylate has been shown to be superior in penetrating solid sebum soil under static conditions, the 12-60 ethoxylate clearly gives better detergency performance. This is particularly evident at the 0.1% concentration, where differences in surface activity become important. (The 12-60 ethoxylate is more surface active and therefore concentrates more at the soil-water interface.)

Similar tests were performed using 12-55, 12-60, 12-70 and 12-80 ethoxylates to determine the effect of HLB on sebum detergency. Results (Table 5) show that in contrast to what was observed with the soil-

TABLE 4

Detergency Performance of 8-60 and 12-60 Ethoxylates on Sebum Soils

Surfactant	Surfactant concentration	Cloth	% Soil removal
8-60	1%	Cotton	97.3
12-60			99.0
8-60	1%	Permanent	94.0
12-60		press	94.8
8-60	0.1%	Cotton	13.7
12-60			86.3
8-60	0.1%	Permanent	1.7
12-60		press	81.1

TABLE 5

Detergency Performance of 12-55, 12-60, 12-70 and 12-80 Ethoxylates on Sebum Soil

Surfactant	Surfactant concentration	Cloth	% Soil removal
12-55	0.1%	Cotton	87.4
12-60			89.8
12-70			95.2
12-80			94.2
12-55	0.1%	Permanent	78.6
12-60		press	82.1
12-70			92.6
12-80			94.0

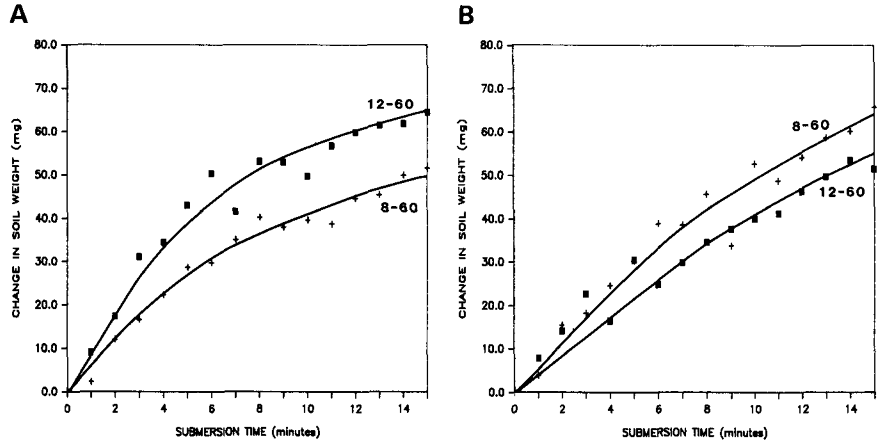

FIG. 4. Soil-submersion curves for 8-60 and 12-60 ethoxylates obtained with sebum-soiled cotton (A) and permanent press (B) swatches (68 F, 1% surfactant).

submersion tests, a higher degree of ethoxylation appears to aid sebum detergency.

To examine the effect of substrate, soil-submersion tests were repeated using sebum-soiled cloth swatches instead of sebum-soiled aluminum coupons. Both cotton and permanent press swatches were submersed in 1% 8-60 ethoxylate for 0-15 min. All swatches were allowed to air-dry for 24 hr prior to determining their change in soil weight. Results (Fig. 4A and 4B) again show soil weight increases with increasing submersion time, but they also demonstrate that penetration rate is substrate dependent. On cotton cloth, the 12-60 ethoxylate penetrates more rapidly than the 8-60 ethoxylate. On permanent press cloth, the opposite is observed. These results suggest that the degree of penetration observed for a surfactant depends upon both its ability to maximize contact with the soil and its ability to penetrate solid soils.

$$\begin{array}{c}\text{Surfactant}\\ \text{performance}\end{array} \; \alpha \; \left[\begin{array}{c}\text{Amount of surfactant}\\ \text{in contact with soil}\end{array}\right] \cdot \left[\begin{array}{c}\text{Ability of surfactant}\\ \text{to penetrate solid soil}\end{array}\right]$$

The model presented above offers one explanation as to why penetration rate appears to be substrate dependent. The ability of a surfactant to penetrate and swell solid sebum adhered to a hard surface depends both on its ability to concentrate at the soil/water interface (first term) and its ability to penetrate solid soils (second term). When surfactant concentration is high (e.g., 1%), plenty of surfactant is available, so the second term becomes more important to penetration. This is why at a 1% concentration the 8-60 ethoxylate was observed to penetrate sebum faster than the 12-60 ethoxylate even though it is less surface active.

In contrast, when surfactant concentration is low, it is reasonable to assume that the first term in the model equation becomes more important to penetration. Consequently, penetration would depend more strongly on the ability of the surfactant to concentrate at the soil/water interface.

With a cloth substrate, the ability of the surfactant to wet the substrate also affects the amount of surfactant that comes in contact with the soil by increasing the area of the soil-water interface (first term). This results in an overall increase in surfactant penetration because more surfactant is available to take part in the penetration process. (This is important, as a cloth substrate yields a substantially greater surface area than hard surfaces.) This is why the 12-60 ethoxylate penetrates sebum/cotton more rapidly than the 8-60 ethoxylate. It is better at wetting the cloth, so more surfactant is available for penetration at the soil/water interface. In contrast, on permanent press cloth (a more hydrophobic substrate), neither surfactant has the edge in substrate wetting. Consequently, the second term becomes more important and the opposite trend is observed.

Keep in mind that the synthetic sebum used in this study may not accurately represent natural sebum soil. These studies were performed without the addition of particulate matter which normally would accompany naturally derived soil. In addition, it has been reported that natural sebum exists in an emulsified state (9). The presence of particulate matter and emulsifiers would certainly affect soil removal.

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