



OMNI TECH INTERNATIONAL, LTD.

# SURFACTANTS

## A Market Opportunity Study Update

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## EXECUTIVE SUMMARY

Surfactants or surface active agents are broadly defined as organic compounds that can enhance cleaning efficiency, emulsifying, wetting, dispersing, solvency, foaming/defoaming and lubricity of water-based compositions.

The annual surfactant demand in the United States is estimated to be 7.7 billion pounds. The largest end use market for surfactants is household cleaning detergents. These are comprised of large volume, lower priced laundry and dishwashing detergent commodity products that account for roughly one-half of the U.S. surfactant market. “Specialty surfactants” are higher-priced, low-volume products used in a broad range of industrial and personal care market applications with annual demand estimated at 2 billion pounds or 26% of the total US surfactant market.

Surfactants are produced from petrochemical (synthetic) feedstocks or oleochemical (natural) feedstocks. U.S. surfactant production is based on 40% petrochemical and 60% oleochemical feedstocks. The basic petrochemical feedstocks are ethylene and benzene which are derived from crude oil and converted to surfactant intermediates ethylene oxide (EO), linear alkylbenzene (LAB) and detergent alcohols. The basic oleochemical feedstocks are typically seed oils - palm and coconut – as well as tallow. Raw material costs for these feedstocks are a prime determinant of surfactant pricing.

The U.S. surfactant market is extremely diverse and includes many primary product manufacturing industries and segments which are described in this report. Surfactants are used in formulated products to provide optimum performance.

The structure of the surfactant supply industry is stratified and complex. It consists of large surfactant manufacturers that produce surfactant raw materials, surfactant producers without a raw material position that typically modify basic surfactants by sulfonation or ethoxylation, smaller specialty surfactant producers and/or formulators and end users that are often focused on specific industries.

It is difficult to estimate the amount of soy-based surfactants being produced because of the supply chain complexity. The largest volume of soy-based surfactants is represented by lecithin. Examples can be found of soy-based surfactants in most of the markets studied. Soybean oil and soy protein are used as the starting materials for surfactants; however, soybean oil is currently the predominate feedstock used in the manufacture of surfactants where soybeans are used.

One thing that is common in the surfactant industry is concern for the environment. This concern ranges all the way from the impact of crude oil supply and demand to the environmental impact of chemicals, energy usage and conservation of resources. The interest in the “cradle to grave” use of products by both governmental organizations and consumers has heightened environmental interests and created a growing trend in more stringent environmental regulations impacting surfactants.

Increasing environmental awareness and the use of renewable resources provide opportunities for the use of soybeans in surfactants through new technologies that are emerging, especially in the field of protein-based surfactants.

## STUDY OBJECTIVES

The main objective of this study is to update the May 1996 report “*Emulsifiers and Wetting Agents – A Market Opportunity Study.*” This study update provides much more surfactant industry background information and summaries of ten primary market segments. The original study analyzed three market segments. A more comprehensive overview is also provided on industry environmental issues, surfactant manufacturers, pricing and emerging surfactant technologies that may provide opportunities for soy chemistry.

Much has changed in the surfactant industry since 1996. Identification of these changes is another objective of this report and discussion of the changes occurs throughout.

The final objective is to provide recommendations for the development and commercialization of soy-based surfactants. The emergence of oleochemical-based surfactants has come a long way since 1996. Unfortunately, most of these surfactants have not involved soy.

### **SURFACTANT INDUSTRY CHANGES 1996 – 2008**

- Much more surfactant industry information is available especially on the internet. However, very little market demand study has been done or published since 2003.
- There has been considerable industry consolidation through mergers and acquisitions among surfactant manufacturers and customers.
- There is growing awareness and interest in renewable-based products by consumers and industrial end users for “Green Products”.
- Increasing environmental and regulatory pressure on petrochemicals
- Major feedstock pricing changes favoring oleochemicals
- The emergence of oleochemical-based biosurfactants
- A gradual emergence of new product and market application opportunities for soy

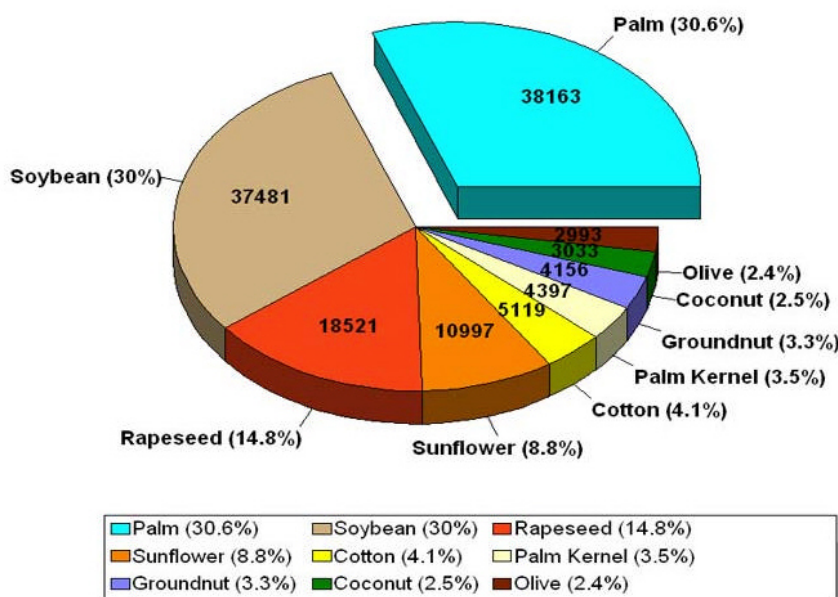
# THE SURFACTANTS MARKET

## OVERVIEW

Surfactants or surface active agents are broadly defined as organic compounds that can enhance cleaning efficiency, emulsifying, wetting, dispersing, solvency, foaming/defoaming and lubricity of water-based compositions.

All surfactants have the same basic chemical structure - a hydrophilic (water-loving) “head” and a hydrophobic (oil-loving) “tail” which is always a long (linear) chain of carbon atoms. Surfactants are made from oleochemical (natural) and/or petrochemical (synthetic) raw materials.

## WORLD SEED OIL PRODUCTION – 2007



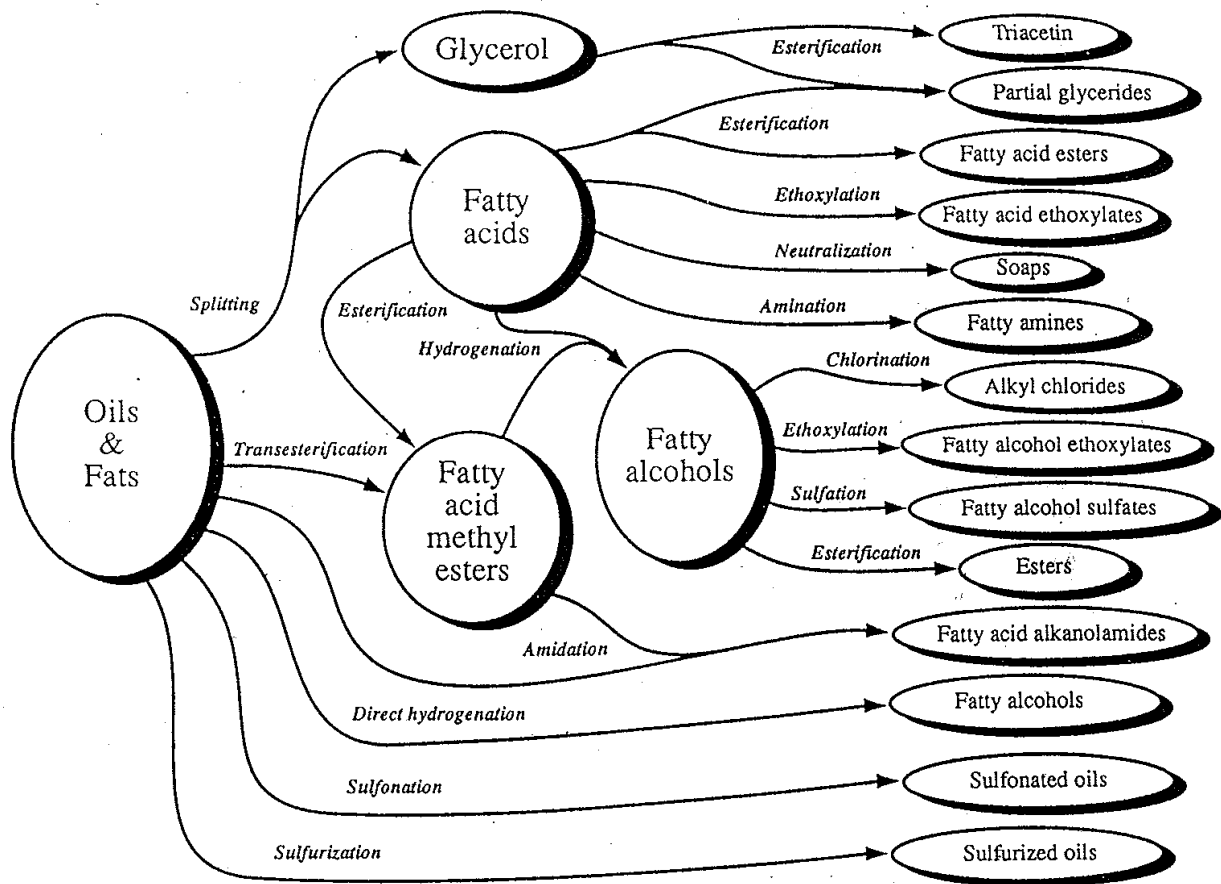
## SURFACTANT FEEDSTOCKS

**Oleochemical / Natural** surfactants are commonly derived from plant oils – coconut and palm oils, from plant carbohydrates – sorbitol, sucrose and glucose or from animal fats such as tallow. Oleochemical feedstock sourcing for surfactants has been changing in recent years. Animal fats have lost ground in favor of vegetable oils, including the growing utilization of soybean oils. Beef tallow has been impacted by mad cow disease concerns while fish oil use has declined due to high oil prices caused by growing antioxidant demand.

**Petrochemical / Synthetic** surfactants are derived from petroleum-based feedstocks, mainly crude oil. The primary synthetic feedstocks are ethylene, benzene, kerosene and n-paraffins. The surfactant industry currently uses roughly equal amounts of “natural” oleochemicals and “synthetic” petrochemicals.

## OLEOCHEMICAL FEEDSTOCKS

Oils and fats can lead to a variety of products as shown below:



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## SURFACTANT PRODUCT TYPES

Surfactants are classified by their ionic (electrical charge) properties in water:

Surfactant Type	Ionic Charge
Anionic	Negative
Nonionic	No charge
Cationic	Positive
Amphoteric	Positive/Negative

## CONVENTIONAL SURFACTANT PRODUCTS BY TYPE

The primary function of a surfactant is to enhance the performance properties of water-based formulations composed of a range of ingredients such as other surfactants, solvents, thickeners, alkalis/salts, chelating agents, foamers/defoamers and fragrances. They are grouped by their ionic charge.

### Anionic Surfactants

- Alkylbenzene sulfonates – detergents
- Fatty acids – soaps
- Sulfosuccinates – wetting agents
- Lauryl sulfates – foaming agents
- Lignosulfonates – dispersants

Anionic surfactants are the largest group accounting for approximately 40% of world production. These products exhibit superior wetting and emulsifying properties and tend to be higher-foaming materials.

### Nonionic Surfactants

Alkylphenol ethoxylates  
Alkanolamides  
Polyglucosides  
Sorbitan esters

Alcohol ethoxylates  
Fatty amine ethoxylates  
Sucrose esters

Nonionic surfactants are the second largest group by volume at about 35%. Demand for these sugar-based products is escalating due to their low toxicity.

### Cationic Surfactants

Imidazolines  
Betaines  
Pyridenes

Morpholines  
Quaternary ammonium compounds

Cationics typically have excellent antibacterial properties, provide good corrosion protection and can be good demulsifiers.

### Amphoteric Surfactants

Imidazole derivatives  
Betaines  
Amine condensates

Quaternary ammonium compounds  
Phosphatides

Amphoterics can behave as a cation or anion depending on pH. These surfactants are “mild” and are increasingly used in personal care products.

## SURFACTANT USES

The largest end use market for surfactants is as household cleaning detergents. These are typically formulated cleaners based on linear alkylbenzene sulfonate (LAS) made from petroleum feedstocks – benzene, kerosene and n-paraffins. The largest producers are Procter & Gamble, Unilever and Colgate Palmolive. These “household cleaning” products are comprised of large volume, lower priced laundry and dishwashing detergent commodity products that account for roughly one-half of the U.S. surfactant market. The rest of the U.S. surfactant market involves “Specialty Surfactants”. The portion of these that are higher-priced, low-volume products used in a broad range of industrial and personal care market applications is estimated at 2 billion pounds, or 26% of the total US surfactant market.

### U.S. SURFACTANT MARKET

#### 2007 DEMAND

<b>MARKET SEGMENT</b>	<b>MILLION POUNDS</b>
Key Markets	
Household Detergents	3,500
Personal Care	800
Industrial & Institutional Cleaners	490
Food Processing	405
Oilfield Chemicals	385
Agricultural Chemicals	270
Textiles	200
Emulsion Polymerization (Plastics)	200
Paints & Coatings	200
Construction	100
	<hr/>
	6,550
Other Markets	
Lubricant and Fuel Additives	615
Metal Working	150
Mining Chemicals	100
Pulp & Paper	75
Leather Processing	30
Other	195
	<hr/>
	1165
Total	7,715



## **MARKET SEGMENT SUMMARIES**

### **HOUSEHOLD DETERGENTS**

#### **OVERVIEW**

The household detergent market includes laundry detergents, dishwasher detergents, prespotters, carpet cleaners and fabric softeners.

This market consumes almost half of the total surfactant demand. For laundry detergents, the primary function of a surfactant is to remove soil from fabrics and to suspend the soil in the wash water. Fabric softeners are either added to the final rinse or as dryer sheets which are used to dry the wet clothes in dryers. Surfactants in dishwasher detergents are used for wetting surfaces to help soil removal. The surfactant level in automatic dishwasher detergents is lower than in hand dishwash detergents to minimize foaming in the dishwasher. The amount of automatic to hand dishwash detergent sales in pounds is almost equal.

The amount of surfactants used in this market area is around 3.5 billion pounds. The percentage breakdown of surfactant usage by market is:

- Laundry detergents - 80%
- Dishwashing detergents - 10%
- Fabric Softeners - 7%
- Other - 3%

#### **MARKET TRENDS**

Household laundry cleaners have an active history of change, and the function of surfactants has changed in the process.

The use of soaps in home laundry products was 99% of the total in 1940 as compared to synthetic detergents. Synthetic detergents were initially developed to replace soap when the supply of edible oils and fats were in short supply. These synthetic detergents were found to have better cleaning properties, especially in hard water, than soaps. By 1960, the trend to synthetic detergents reached about 75% of U.S. consumption. The initial detergents had poor biodegradability and modifications were made so that these products degraded before they entered the water supply in streams, etc. Synthetic detergents account for over 85% of the category today.

The second trend has been the growth of liquid laundry detergent sales at the expense of powders. This trend is more one of convenience as the cost per wash of liquids has been higher than that of powders. The split between liquid and powder detergents was about 50:50 in 1994. The amount of liquid laundry detergent used today is at least 85% of the combined liquid and powder laundry sales in pounds, and it is projected to increase to 90%.

The third trend has been the concentration of liquid laundry detergents which was targeted for 2008. The use of more concentrated (2:1) liquid laundry products has been promoted by Wal-Mart to decrease shelf space requirements, decrease plastics used in containers, decrease usage of water and to obtain savings in shipping costs. Water content reduction in these products ranges from 44% to 60%.

The fourth trend is the current movement to side loading home laundry machines along with lower wash temperatures to save water and energy. In January 2007, the U.S. Department of Energy phased in tougher efficiency requirements for washing machines. New washers are required to use 21% less energy. Much of the increase in Energy Star shipments has been because of the growth of front-loading washing machines. These are usually more efficient than conventional top loaders. The Association of Home Appliance Manufacturers reports that shipments of front loaders grew from 9% in 2001 to 29% in 2006. The market has traditionally preferred top-loading agitator models; front-loading washers made up only 14.5% of all installed units in 2006 while current front-loader sales are reported at about 35% of shipments.

These trends can be summarized as:

- Emergence of synthetic detergents (surfactants) to replace soaps (1950 -1960).
- Liquid home laundry products replace powders (1990 - current).
- Concentration of liquids to save on shipping, container costs and shelf space (2007 - 2008).
- Front loading washing machines that use less water and operate at lower temperatures to save energy (current).

## **SURFACTANT INNOVATIONS**

To satisfy requirements for the front loading home laundry machines along with lower wash temperatures, surfactants for laundry detergents will have to demonstrate low foaming in horizontal-axis machines, be more easily rinsed due to cooler wash temperatures, and provide reduced redeposition of soils with lower volumes of water. The biodegradability of any new surfactant also has to be considered.

In reformulating detergents for cold water, a product requires a surfactant system that solubilizes oily soils in cold water as well as proteases and carbohydrases (enzymes) that work on insoluble dirt residues in cold water. Examples of special surfactants with grease-removal properties are branched-chain narrow-range ethoxylates, ethoxylated amines and alky amidopropylamines. Hydrotropic surfactants such as short-chain alkyl polyglucosides that help solubilize ingredients and provide cleaning are also needed. Finally there is also an opportunity for surfactants that clean well in hard water, cold water and over a wide temperature range.

## **HOUSEHOLD DETERGENT SURFACTANT MARKET**

The total amount of detergents used in the home detergent market is about 13 billion pounds and the corresponding amount of surfactants used is estimated at 3.5 billion

pounds. The market growth of surfactants in the household detergent area is projected at 1-2% per year.

The leader in the US detergent market is P&G with a 55-60% share. The second largest is owned by Vestar Capital Partners which acquired Huish Detergents and the North American business of Unilever to form Sun Products Corporation in 2008. Other players are Henkel and Church & Dwight.

The major categories of surfactants used in household detergents are:

- Anionic
  - Linear alkylbenzene sulfonates (modified)
  - Alcohol ether sulfates
  - Alcohol sulfates
- Nonionic
  - Alcohol ethoxylates
- Cationic
  - Fatty nitrogen quaternaries (fabric softeners)

Major producers, in addition to others listed in this study are:

- Proctor & Gamble (P&G)
- Sun Products Corporation
- Stepan.

Introduction of methyl ester sulfonates into heavy duty laundry detergents is of interest as they perform better at lower water temperatures. Huish, which now belongs to Sun Products Corporation, and Stepan manufacture this surfactant. Production capacity of this anionic surfactant is estimated at 285 million pounds.

## **PERSONAL CARE**

### **OVERVIEW**

The personal care market includes bubble baths, body washers, hand soaps and cleaners, shaving products, hair shampoos and oral care products.

The personal care retail market in the United States is valued at over \$70 billion. The sub segment of this market that is defined as natural products in hair, skin and cosmetics is valued at \$7 billion.

The amount of surfactants used in this market segment is close to 800 million pounds. Surfactants reportedly constitute around 15% of the raw material costs for personal care products.

## **MARKET TRENDS**

Natural products and ingredients remain a big trend in the global cosmetics and toiletries market. Key growth sectors for natural products include baby products, bath and shower products and hair care. Organic products see growth in oral hygiene, deodorants, liquid soaps and skin care.

Consumers are also looking for improved performance in this market segment along with sustainable or “green” products. Companies that are active in these types of surfactants are Sea-Land, Croda, Cognis, Chattem Chemicals, Inc. and Air Products.

Toilet soap bars with high levels of surfactants are projected to decline in volume and be replaced by liquid body washes. The use of lower levels of surfactants in liquid soaps has caused the surfactant growth in this market to level out as bar soap is being replaced with liquid soap for personal care.

Another market that is seeing growth is wipes with surfactants growth at 5-10% per year in that market niche. Surfactant producers see this market as one to provide higher value products with improved profit margins to offset the surfactants that are used in the household detergent area that are more commodity priced.

## **SURFACTANT INNOVATIONS**

The development and commercialization of new surfactants are more prevalent in the personal care area than other market segments in this study. The interest of consumers using personal care products has driven this market. The interest in more environmentally friendly and more natural products has been a big driver in the development of new surfactant products.

Innovations in personal care are aimed primarily at skin and hair care. The types of new products introduced here include naturally derived surfactants based on oat triglycerides that have a composition close to that of the skin, vegetable derived nonionic surfactant to solubilize essential oils and fragrances, and the use of sulfonated methyl esters to formulate a surfactant in a soap bar that reduces drying of the skin,

## **PERSONAL CARE SURFACTANT MARKET**

The total amount of surfactants used in this market is estimated at around 800 million pounds. The market growth of surfactants in the personal care area is projected at 4-6% per year.

The usage of surfactants in this major market is:

- Bar Soaps -20%
- Liquid Soaps/Body Washes -15%
- Hair Care -35%
- Skin Care -20%
- Other -10%

The types of surfactants in personal care are:

- Amphoterics -10%
- Anionics - 55%
- Nonionics - 5%
- Cationics - 30%

Major producers of surfactants in this market, in addition to others listed in this study, are:

- Procter & Gamble
- Stepan
- Cognis
- Rhodia
- Degussa
- Croda
- Lonza

## **INDUSTRIAL AND INSTITUTIONAL (I & I) CLEANERS**

The Industrial and Institutional cleaning industry (I&I) utilizes formulated cleaners in a broad variety of market uses: restaurants, office buildings, hospitals, schools, nursing homes, food processing plants, transportation vehicles – cars, planes, trains, marine, janitorial and general housekeeping and metal treatment and cleaning.

The cleaning products used include general purpose cleaners, floor care and carpet cleaners, disinfectants and sanitizers, laundry detergents, hard-surface cleaners and hand cleaners.

Surfactants are used in I&I formulations for detergency, foam control, bacterial action, coupling ability, rinsability and emulsification.

I&I cleaning products are estimated to represent about 10% of total U.S. surfactant use. In 2007, I&I market surfactant demand was approximately 490 million pounds and growing at a 2.3% annual rate.

The I&I market segments that use the most surfactants in cleaning products are: hard surface cleaning, machine dishwashing, commercial laundries and metal cleaning. The most widely used surfactants in I&I products are:

- LAS – Linear alkybenzene sulfonate
- APE – Alkylphenol ethoxylates
- AE – Alcohol ethoxylates
- Biocidal quats

These product types account for 60% of all surfactants used in I&I cleaners.

## MARKET SEGMENTS

The largest I&I market segment is housekeeping.

1. **Janitorial Products** represent about 40% of the market volume. This involves hard surface cleaners, floor care, disinfectants and hand soaps. This market utilizes the largest volumes of hard surface cleaners that contain low foaming surfactants and solvents to remove fatty soils. These cleaners have become a major market for renewable biobased solvents such as methyl soyate and d'Limonene that offer significant environmental advantages: renewable based, biodegradable, low toxicity and reduced VOCs.
2. **Transportation Vehicles** – Vehicle cleaning generally involves high pressure foaming sprays that contain quaternary ammonium surfactant and spray-on waxes. Hard surface cleaning of commercial fleet cars, trucks, aircraft, trains and ships will require an increased use of safer solvent and specialty surfactant ingredients.
3. **Metal Cleaning** – Parts cleaners degrease and remove scale and the oxides of corrosion. Various immersion and spray cleaning processes utilize solvents, aqueous-based emulsion cleaners and detergents. The use of low VOC, low toxicity surfactants is growing.
4. **Hand Cleaners** – This is a rapidly growing market that requires ingredients that are not harmful to skin. Mild biosolvents such as methyl soyate and amphoteric surfactants are growing in use. Most hand cleaners are waterless.
5. **Food Processing Equipment** – Dairies, bakeries, canneries, beverage and meat packing plants all require the removal of fats and proteins from processing equipment. Typical cleaners are highly alkaline, heated and involve mechanical action. Surfactants provide rinsability, foam control and sanitizing with biocidal detergents or disinfectant.
6. **Commercial Machine Dishwashing** – Surfactants used in commercial dishwashing products are similar to household detergents. Product formulations are concentrate powders, liquids and solid blocks that are chlorine-stable and designed for use in restaurants, hospitals, schools, nursing homes, hotels and office buildings. Leading suppliers are BASF, Ecolab and Johnson Diversey.

## MARKET TRENDS

### Consumer Demand

The I&I market is usually the leading edge for tomorrow's household cleaning products. However, in today's market environment, the consumer is increasingly demanding product changes focused on wellness, safety and sustainability. Consumer awareness has created significant demand-pull for ecofriendly, biodegradable, renewable natural-based and safer products that are cost-effective, convenient and efficient.

### Environmental Issues - Product Safety

Most I&I cleaning products are regulated under OSHA (Occupational Safety and Health Administration) but there is increasing environmental pressure from the Consumer Product Safety Commission (CPSC) and the U.S. EPA (Environmental Protection Agency).

Primary I&I product ingredient concerns involve surfactants and solvents:

<b>SURFACTANTS</b>	<b>CONCERN</b>
NPE (Nonylphenol ethoxylates)	Endocrine disruptors
LAS (Linear alkylbenzene sulfonates)	Sulfates
DEA (Diethanolamides)	Skin cancer in mice
Mineral Spirits	VOCs, Flammability, Toxicity
d'Limonene	VOCs, Flammability, Skin irritation

## MARKETING TRENDS

The I&I cleaning industry is a service business with suppliers that solve cleaning problems rather than just sell products. Roughly two thirds of I&I products move through distributors, janitorial supply companies and food service suppliers. Beyond the major detergent manufacturers – P&G, Unilever and Colgate Palmolive – most industry manufacturers are small or regional with the exception of Ecolab, Johnson Diversey, Clorox and Reckitt Benckiser. Many of these companies have been involved in recent consolidations and brand acquisitions. Some of the leading suppliers of renewable-based cleaners currently are smaller companies such as Spartan Chemical, Maumee, OH with their Soy Strong product line and Acuity Specialty Products, Atlanta, GA with their Zep brand, of 20 soy-based products. These companies, being smaller, can move quickly to develop and launch new green products.

Cleaning product ingredient concerns are increasingly being addressed to provide better resource assistance to formulator/manufacturers of I&I cleaning products. An example is the Clean Gredients Program developed under the direction of the EPA's Design for the Environment (DFE) effort. It is an online database that contains "Modules" for primary formulation ingredients – Surfactants, Solvents, Chelating Agents and Fragrances. Industry manufactures/suppliers of these ingredients list their products with analytical data documenting physical and chemical properties, toxicity test data and EH&S (Environmental Health & Safety) data for each product. Formulators can subscribe to the service and

select ingredients to provide the combination of safety, performance and cost required for any formulated product.

## **FEEDSTOCK COSTS**

I&I cleaning product raw material costs have escalated dramatically since 2003. Surfactant feedstocks are equally based on petrochemicals, mainly crude oil and oleochemical/natural materials, mainly plant oils – coconut, palm and tall oil; plant carbohydrates/sugars – sucrose and glucose or animal fats – tallow and lard. Oleochemical feedstocks did not escalate in price like petrochemicals until 2006 when they began to skyrocket and then retreat. Currently, the highly volatile cost of feedstocks is an industry condition all with which producers of I&I cleaners must contend.

## **PRODUCT INNOVATIONS**

In response to the market trends listed above, the manufacturers of I&I cleaners have implemented significant changes in raw material content, product packaging/delivery and product end use/application methods. Raw material selection options have increased with the assistance of new resources such as the Clean Gredients database. “Green Products” is a universal theme today in the I&I cleaning market. Surfactants based on tropical (coconut, palm) oil-based detergent alcohols are a major industry trend that now accounts for about 60% of world surfactant production (vs. petrochemical alcohols).

Another example of petrochemical surfactant/detergent substitution potential is Stepan Company’s MES (methyl ester sulfonate) based on soybean oil and designed to replace LAS detergents. The use of renewable specialty surfactants to replace conventional petrochemical surfactants is increasing and is often dictated by the purchasing policy of some major chain retailers like Wal-Mart in their commitment to improve the environment.

Another way the producers are minimizing costs and offering customers better product value is through the optimization of multifunctional ingredients. By utilizing the synergism between complimentary surfactants and other ingredients, they are using co-products and blends to custom design product properties, performance and cost for each formulated product.

Innovative product use delivery methods are also being introduced to bring about a paradigm shift from price per pound to cost in use. This is gradually being done with cleaner concentrates that offer reduced product volume usage and lower shipping, storage and disposal costs. This allows for on-site dilution with water, blending, mixing and product application with measured use rates.



# FOOD PROCESSING

## OVERVIEW

The U.S. food processing industry is the largest market for specialty surfactants. The industry is mature and encompasses meats, processed foods, beverages, dairy products, baked goods, candy, snack foods, frozen foods, fats and oils. Food and beverage demand is forecast to grow 1.5% per year supported by population gains, growth in prepared convenience foods, nutrition-conscious consumers and export demand. There are 20 major U.S. food processors that are among the world's largest.

## FOOD SURFACTANT USES

Surfactants provide multifunctional properties for food additives as emulsifiers, dispersants, wetting agents and solubilizers in foods which contain fats and oils such as baked goods, dairy foods, salad dressings, shortenings and margarine.

## FOOD SURFACTANT TYPES

Commodity and specialty surfactants used in food are primarily nonionic esters:

- Nonionics:
  - Mono & diglycerides
  - Fatty acid esters
  - Sorbitan esters
  - Propylene glycol esters
  - Lactylate esters
- Anionics:
  - Sulfosuccinates
  - Lecithin
- Cationics:
  - Quaternary ammonium salts

## FOOD PROCESSING SURFACTANT MARKET

2007 Market Demand (North America)

Nonionics – 355 million pounds

Lecithin – 50

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Total    405    Market growth – 3%

## SURFACTANT FOOD APPLICATIONS

The largest food processing use for surfactants is in bakery products as emulsifiers, dough strengtheners, crumb softeners and texturizers. Dairy products such as ice cream, whipped cream and margarine utilize surfactants to form stable emulsions containing fats and oils. Other major uses include shortenings, salad dressings, peanut butter, cake mixes, toppings and breads.

Surfactant use in food and beverage applications is projected to grow about 3% per year supported by increased demand for processed and pre-prepared foods that often contain specialty surfactants. About 60% of surfactant use is in bakery goods. Emulsifiers are the largest surfactant type often sold as preformulated systems based on glycerides and/or sorbitan esters. Dispersants are another major surfactant type that helps uniform mixing of food additives such as flavors and texturizers

A growing concern in the food processing industry is consumer health and the control of contamination from microorganisms. There is growing use of surfactants as biocides to kill fungi, bacteria, viruses and protozoa that may be present in fresh food such as fruits, vegetables, fish and poultry. Quaternary ammonium salts and ethylene oxide/propylene oxide copolymer sprays are used as antimicrobial washes.

## **LECITHIN**

Lecithins are phospholipid compounds found in all plant and animal organisms but the primary commercial source is the by-products from the soybean degumming process. They are natural anionic surfactants that are widely used in many food applications as emulsifiers in salad dressings and sauces, viscosity reducers and stabilizers in chocolate, anti-spattering agents in margarine, pan release agents in bakery and confectionery products and as wetting agents in instant food powders. Use levels are small, about 0.1% to 2% in foods which is consistent with use levels of synthetic (petrochemical) surfactants. Lecithin use is often combined with synthetic surfactants which, synergistically, allows for lesser amounts of the synthetic products. Of the estimated 405 million pounds per year food use of surfactants in the U.S., about 80% are synthetic and 20% natural. Lecithin is a major contributor to this portion of natural surfactants used in food products.

## **MAJOR FOOD SURFACTANT SUPPLIERS**

- AMD
- Cargill
- Croda
- International Specialty Holdings
- Lambent Technologies
- Kao
- Cytec
- Dow
- McIntyre Group
- Noveon
- Rhodia
- Solae
- Unilever
- Lonza

## **OIL FIELD CHEMICALS**

### **OVERVIEW**

The U.S. oil and natural gas industry consumes a variety of large volume chemicals including a broad range of commodity and specialty surfactants to drill and produce oil, natural gas and coal bed methane. The dramatic increase in crude oil and gas prices has generated renewed interest in enhanced oil recovery (EOR) technologies that involve extensive use of surfactants that must meet demanding down-hole

environmental regulations and performance requirements. Surfactant applications involve well stimulation, drilling/completion, production/refining and pipeline transport. These operations will require an increased use of specialty surfactants that are effective, safer and cause less environmental damage.

## **OILFIELD SURFACTANT USES**

- Emulsifiers/demulsifiers
- Lubricants
- Dispersants
- Corrosion inhibitors
- Foam control agents
- Wetting and suspending agents
- Biocides

## **U.S. OILFIELD SURFACTANT MARKET**

### **SURFACTANT DEMAND 2007**

<b>SURFACTANT TYPE</b>	<b>MILLION POUNDS</b>	<b>MARKET GROWTH</b>
Anionics	135	2.0%
Nonionics	100	1.0%
Cationics & Amphoterics	150	4.0%
<b>TOTAL</b>	<b>385</b>	<b>3.4%</b>

The dramatic rise in oil and gas prices has caused a significant increase in the need for more effective EOR processes and materials. This has stimulated greater market demand for specialty, higher cost surfactants such as cationics and amphoterics that are more costly than nonionics and anionics but perform more effectively. The use of surfactant combinations with other ingredients in formulated oilfield chemical additive products is also a growing trend. Tighter environmental regulation is forcing the use of less invasive products that have lower VOCs, are less flammable, are biodegradable and reduce the large volumes of water required to recover and refine crude oil and natural gas.

## **OIL AND GAS SURFACTANT APPLICATIONS**

Crude oil and natural gas production and refining operations utilize the largest volume of oilfield industrial surfactants. Typical applications involve the use of nonionics as demulsifiers, anionics as defoamers and cationics and amphoterics as biocides and corrosion inhibitors.

Surfactants containing formulated products are also important additives in drilling operations. They are used in drilling muds and drilling fluids to provide lubricity for better flow and pumpability, for foam control, emulsification and to reduce water loss during drilling. Commonly used surfactants include aromatic sulfates, aromatic

sulfonates, lignosulfonates, fatty amine ethoxylates and betaines. They also provide corrosion and biocidal control.

Natural gas and coal bed methane down hole drilling utilizes surfactants for gas well stimulation in foaming systems that provide formation blocking and fracturing with cationic quaternary ammonium compounds. These foamers can reduce water loading, reduce corrosion and increase gas production.

## **CONVENTIONAL OILFIELD SURFACTANTS**

Conventional oilfield surfactants can be produced from petrochemical (synthetic) or oleochemical (natural) feedstocks and can often be interchangeable depending on feedstock costs. Major oilfield surfactants products are:

- Aromatic sulfates
- Aromatic sulfonates
- Alkylphenol ethoxylates
- Fatty amine oxides
- Quaternary ammonium compounds
- Betaines
- Tallow fatty acids
- Tall oil fatty acids
- Lignosulfonates

The use of oleochemical feedstocks has historically been significant - usually based on tallow, tall oil and lignin, a paper process by-product. To a lesser degree, vegetable oil feedstocks have also been used in drilling fluids and corrosion inhibitors.

Some soy-based feedstocks used for oilfield surfactant products include:

- Soybean oil
- Degummed soy oil fatty acids
- Acidulated soy soapstock
- Fatty acid distillates

The high cost of petroleum feedstocks, demanding environmental pressures and a growing demand pull for renewable-based feedstocks to reduce oil imports have all become drivers for the surfactant producers to develop more natural products. Despite the rapid price escalation of vegetable oil prices in 2007 and early 2008, the long-term cost competitiveness of seed oil-based feedstocks should continue to stimulate the development and use of oleochemical surfactants in oilfield applications.

## MAJOR OILFIELD SURFACTANT SUPPLIERS

- Akzo Nobel
- Baker Hughes
- Clariant
- Cognis
- Croda
- Dow Chemical
- Rhodia
- Lonza
- Stepan\*

\*Stepan Company and Nalco launched a new EOR joint venture “Tiorco” to provide oilfield product sales and process technology service

## AGRICULTURAL CHEMICALS

### OVERVIEW

In the U.S., about 60 manufacturers produce surfactants for agrochemical (Ag) markets. These products are sold to more than 100 pesticide manufacturers that formulate their own end-use products and to about 2,000 pesticide formulators that purchase pesticides, solvents and other ingredients from chemical producers. The formulated products then move through a market network of about 250-300 distributors and 8000 dealers. There are then over 1,000,000 custom applicators and growers that actually apply the end product pesticides.

### AG SURFACTANT USE AND APPLICATIONS

Ag surfactants are used as additives primarily in pesticides (herbicides, insecticides, fungicides) and to a lesser degree in fertilizers, animal feeds and soil treatments. When used as a pesticide adjuvant, surfactants provide the following functions:

- **Emulsifier** for the active ingredient in liquid formulations to create stable emulsions and extend shelf life
- **Spreader** or dispersing agent to aid application of the active ingredient
- **Sticking agent** to improve contact of the active ingredient on the crop or weed plant leave surface
- **Foaming aid** to control spray drift during pesticide application

Surfactant use as a pesticide adjuvant is estimated to be 60% for use in herbicides and 40% for use in insecticides and fungicides.

## AG SURFACTANT MARKET

Conventional Ag surfactants typically used have been commodity products due to low cost – nonylphenol ethoxylates (NPE) and ethoxylated fatty amines. Market demand growth has been relatively flat in total with NPEs declining and some specialty surfactant use growing.

Two major new influences have impacted the Ag surfactant market in recent years. The growth in use of glyphosate herbicides (Monsanto's Roundup®) and new generics following its patent expiration has seen an increase in the use of more specialty surfactants – ethoxylated amines and phosphate esters in these glyphosate products to improve their performance. The other major influence is the growth of public environmental concern and regulatory pressure on pesticides. In addition, market demand will slow due to improving agricultural productivity (less planted acreage), increasing global Ag competition (reduced exports) and the rise of organic farming (no pesticides).

Market demand for Ag surfactants will remain relatively flat with modest growth of some specialty cationics and anionics and declining use of commodity nonionics such as APEs due to environmental pressure.

### AG SURFACTANTS PRODUCTS & DEMAND 2007 MILLION POUNDS

Primary Surfactants	Demand
Nonionics:	100
Alkylphenol ethoxylates	
Alcohol ethoxylates	
EO/PO block polymers	
Cationics:	95
Ethoxylated amines	
Fatty amine oxides	
Anionics:	75
Alcohol ether phosphates	
Aromatic sulfonates	
	270
Market Growth: 1% per year	

## **MAJOR AG SURFACTANT MANUFACTURERS**

- Akzo Nobel
- Cognis Corp.
- Dow Chemical
- Harcros Chemical
- Huntsman
- Lambent Technologies
- McIntyre Group
- Rhodia
- Stepan

## **TEXTILES**

### **OVERVIEW**

The overall global fiber demand is 165 billion pounds. The percentages of fibers in this category are:

- Synthetic - 57%
- Cotton - 36%
- Cellulose - 5%
- Wool - 2%
- Silk - <0.5%

The amount of synthetic and cellulose fiber manufactured in the United States is estimated at 15 billion pounds. The amount of cotton processed is estimated at 3 billion pounds.

The textile industry uses surfactants in many of the steps between producing the raw fiber and selling the finished article. Natural fibers are treated or scoured with surfactants in solution to remove oils and dirt in preparation for spinning. Synthetic fibers have oils applied for lubrication needed for spinning. These oils are removed by scouring before dyeing or printing. Sizes are applied for weaving that must be scoured out later.

Surfactants are also used as lubricants and antistats in all manufacturing for processing and in fabric softening. The dyeing processes also require surfactants.

### **MARKET TRENDS**

The United States had 23% of the worldwide share of manufactured fiber in 1987, and this had decreased to 9% in 2007. During that time the market share of Asia increased from 34% to 75%.

Whereas textile production is in decline in the United States, the production of fibers in the United States for other applications, mainly nonwovens, has remained far more stable and is projected to grow at 2%.

Consumer awareness of greenhouse gas emissions, global warming and the carbon footprint may lead to opportunities for the US textile producers. If US producers are more energy or carbon efficient in producing products locally, and if energy costs in long distance shipping from Asia are considered, one may see the possibility of textile manufacturing returning to the United States.

## **SURFACTANT INNOVATIONS**

The textile industry is energy and water intensive. There is a great deal of potential for savings. The dyeing and finishing sector is the largest energy and water consumer in the whole textile chain.

As fiber producers seek to improve productivity, increased line speeds demand increased thermal stability. New surfactant types are being examined to meet these demands.

Producers try to lower their energy costs by using lower temperatures and lowering the amount of water used. To comply with environmental regulations, the surfactants have changed or are changing to meet these requirements.

## **TEXTILE SURFACTANT MARKET**

Natural fibers are treated or scoured with surfactants in solution to remove oils and dirt in preparation for spinning, Synthetic fibers have oils applied for lubrication needed for extrusion and spinning. These oils are removed by scouring before dyeing or printing. Sizes are applied for weaving that must be scoured out later.

Surfactants are also used to as processing lubricants and antistats and in fabric softening. The dyeing processes also require surfactants.

The estimated textile market size for surfactants is 200 million pounds. The growth in this area is projected to be less than 2%. The types of surfactants used are:

- Anionic- 18%
- Cationic – 22%
- Nonionic-60%



# EMULSION POLYMERIZATION

## OVERVIEW

The amount of emulsion polymers produced in the United States is around 5.5 billion pounds. The growth rate of this market is 3-4% per year.

The major polymers produced are styrene-butadiene latex, acrylics, polyvinyl acetate and vinyl-acrylics.

This type of polymerization starts with an emulsion incorporating water, monomer and a surfactant. Emulsion polymerization is used to manufacture several important polymers. Many of these polymers are used as solid materials and must be isolated from the aqueous dispersion after polymerization. In other cases the dispersion is the end product. This dispersion is often called latex. These products are typically found in adhesives, paints, paper coatings and textile coatings.

Surfactants play a significant role in the production and application of emulsion polymers. They control the particle size and distribution which in turn dictates the rheology and viscosity of the final latex.

## MARKET TRENDS

The polymers and latexes from emulsion polymerization are finding increasing acceptance and are preferred over solvent-based products in suitable applications as a result of their eco-friendly characteristics due to the absence of VOCs (Volatile Organic Compounds) or petroleum solvents. Although the coatings are water-based, they still typically contain 5-10% organic solvent to function properly. Solvents are required for durable film formation ("coalescents"), to provide package stability in cold weather ("freeze/thaw stabilizers") and to dilute coatings additives. Industry has been challenged to reduce or eliminate these solvents while still providing economical and durable coatings. To meet the lower VOC regulations, industry has taken several approaches:

- Use of additives that contain little or no VOCs
- Modify film forming polymers so that they need little or no coalescing solvent and/or freeze/thaw stabilizer
- Use of vinyl acetate-ethylene copolymers that form good coating films with little or no organic solvent

## SURFACTANT INNOVATIONS

New emulsifiers have been developed in response to increasing global environmental protection regulations and recommendations to phase out the use of alkyl phenol ethoxylates (APEs). These new products have been designed to meet environmental requirements while providing effective performance in emulsion polymerization.

## **EMULSION POLYMERIZATION SURFACTANT MARKET**

The use of surfactants in the emulsion polymerization market is estimated at 200 million pounds. The usage is split almost equally between nonionic and anionic surfactants.

## **PAINTS and COATINGS**

### **OVERVIEW**

The total amount of coatings shipped in the United States is around 1.32 billion gallons or about 11.6 billion pounds. The industry declined in volume 2% from 2006 to 2007.

The coatings market is segmented as Architectural Coatings (57%), Product OEM Coatings (28%) and Special Purpose Coatings (15%).

The Architectural Coatings market consists of exterior (33%) and interior coatings (67%).

The Product OEM Coatings market consists of many segments. The coatings in this segment are used in automotive, heavy duty trucks, machinery and equipment, wood furniture, appliances, etc.

The five largest markets for Special Purpose Coatings are high performance maintenance, automotive refinish, highway and traffic marking, aerosols and marine.

The major producers of paints and coatings in the United States are:

- PPG Industries, Inc.
- DuPont Coatings & Color Technologies Group
- Sherwin-Williams Co.
- Valspar Corp.
- RPM International, Inc.
- Behr Process Corp.

### **MARKET TRENDS**

The trend in Architectural Coatings is towards the use of more waterborne coatings (82%) than solvent based coatings. As the quality of waterborne coatings has improved, do it yourself (DIY) users and contractors prefer to use these coatings. Restrictions on the amount of solvents through federal legislation and state laws favor the use of waterborne coatings.

Powder coatings, as an alternative to liquids, are used in many coating applications. Growth is slowing as the market for these products matures and companies try to avoid the cost of capital to invest in powder applications. Powder coating represent about 75 million gallons (375 million pounds) or about 6% of the total coatings market.

## **SURFACTANT INNOVATIONS**

Most of the efforts in coating formulation development have been to reduce volatile organic compound (VOC) emissions by decreasing the amount of solvent. This has resulted in new polymer developments i.e. one company bringing out a soybean-oil-based latex alkyd emulsion which meets strict VOC standards for interior coatings. Surfactant developments are also being focused on the reduction of the VOCs from surfactants or to enable the use of less solvent in a coating.

The trend in the paints and coatings market is to develop products with higher performance at the equivalent or even lower price than competitive products. The higher performance tends to decrease the chance of the paint or coating being considered a commodity product.

## **PAINT AND COATINGS SURFACTANT MARKET**

Surfactants act as wetting agents, dispersants and foam control agents. The estimated market size is 200 million pounds. The growth rate for surfactants in this market ranges from 1-3% per year. The usage within these three areas is estimated to be:

- Wetting agents - 25%
- Dispersants - 40%
- Defoamers and anti-foaming - 35%

Nonionic surfactants are neutral and have wider applications in this market for wetting and dispersing. Alky phenol ethoxylates are the largest class of nonionics used, but their use is decreasing as their usage is being regulated. Defoamers are typically polysiloxanes or mineral and paraffin oils. Polysiloxanes offer better compatibility and lower surface tension, while mineral and paraffin oils have a lower price. Anionic surfactants improve wetting and dispersion of pigments.

Major providers of surfactants for this market are:

- Air Products
- Byk Chemie
- BASF Corp.
- Cognis
- Rhodia
- DuPont

## CONSTRUCTION

The primary applications for surfactants in the construction industry are in asphalt, cement and wallboard.

### SURFACTANTS USED IN CONSTRUCTION – 2007 Million Pounds

Product	Surfactants	Million Pounds
Asphalt (Cationics)	Tallow fatty amines	45
	Tall oil fatty amines	
	Imidazolines	
	Lignosulfonates	
Cement (Anionics)	Naphthalene sulfonates	40
	Lignosulfonates	
	Polycarboxylates	
Wallboard	Naphthalene sulfonates	15
	AES	
	LAS	
	TOTAL	100

Market growth: 1.0% per year

### Asphalt

Surfactants are used as emulsifiers in asphalt cement which is the binder that adheres the asphalt to the aggregate. They are typically cationic tall oil and tallow-based fatty amines and imidazolines as well as lignosulfonates.

The asphalt industry is changing rapidly due to severely escalating and highly volatile feedstock costs. Rising crude oil prices have forced refinery product mix upgrading and significantly decreased the availability of bitumen (petroleum-based asphalt). Prices of asphalt cement have, consequently, tripled since 2004. Concurrently, tall oil and its derivatives have also become scarce and expensive. These conditions have created new opportunities for renewable-based products such as BioSpan Technologies' soy-based asphalt cement containing new soy solvent chemistry and recycled plastics such as styrene-butadiene polymers from Styrofoam® and tire rubber scrap.

## **Cement**

Surfactants used in the production of cement are primarily anionics such as naphthalene sulfates, lignosulfonates and polycarboxylates as plasticizers and air entraining agents to control the rate of reaction with water.

## **Wallboard**

Wallboard or gypsum board production primarily utilizes anionics such as naphthalene sulfonates and alcohol ether sulfates. LAS (linear alcohol sulfates) are also used as foam stabilizers in lightweight wallboard products.

# **LUBRICANT and FUEL ADDITIVES**

## **Motor Oil**

The by-products of the combustion process will form sludge and varnish deposits in the engine. Detergents are used in motor oil to aid in removing the deposits. Other surfactants known as dispersants are used to keep the by-products in the oil until the filtration system can remove them.

Surfactants are used in lubricants as detergents and as dispersants. The estimated usage of all lubricants in the automotive sector is estimated at 1.4 billion gallons. The US passenger car motor oil yearly consumption is estimated at 615 million gallons (4.5 billion pounds). The surfactant usage in this category is estimated at 315 million pounds.

Detergents used are magnesium sulphonate, calcium sulphonate, and sodium sulphonate. Dispersants used are typically alkenyl succinimides.

## **Gasoline**

Detergents in gasoline keep the engine clean and can affect emissions. For that reason the United States Environmental Protection Agency has required all gasoline marketed in the United State to contain detergents since 1995.

The US yearly consumption of gasoline is estimated at 142 billion gallons (880 billion pounds). The corresponding surfactant usage is estimated at 300 million pounds.

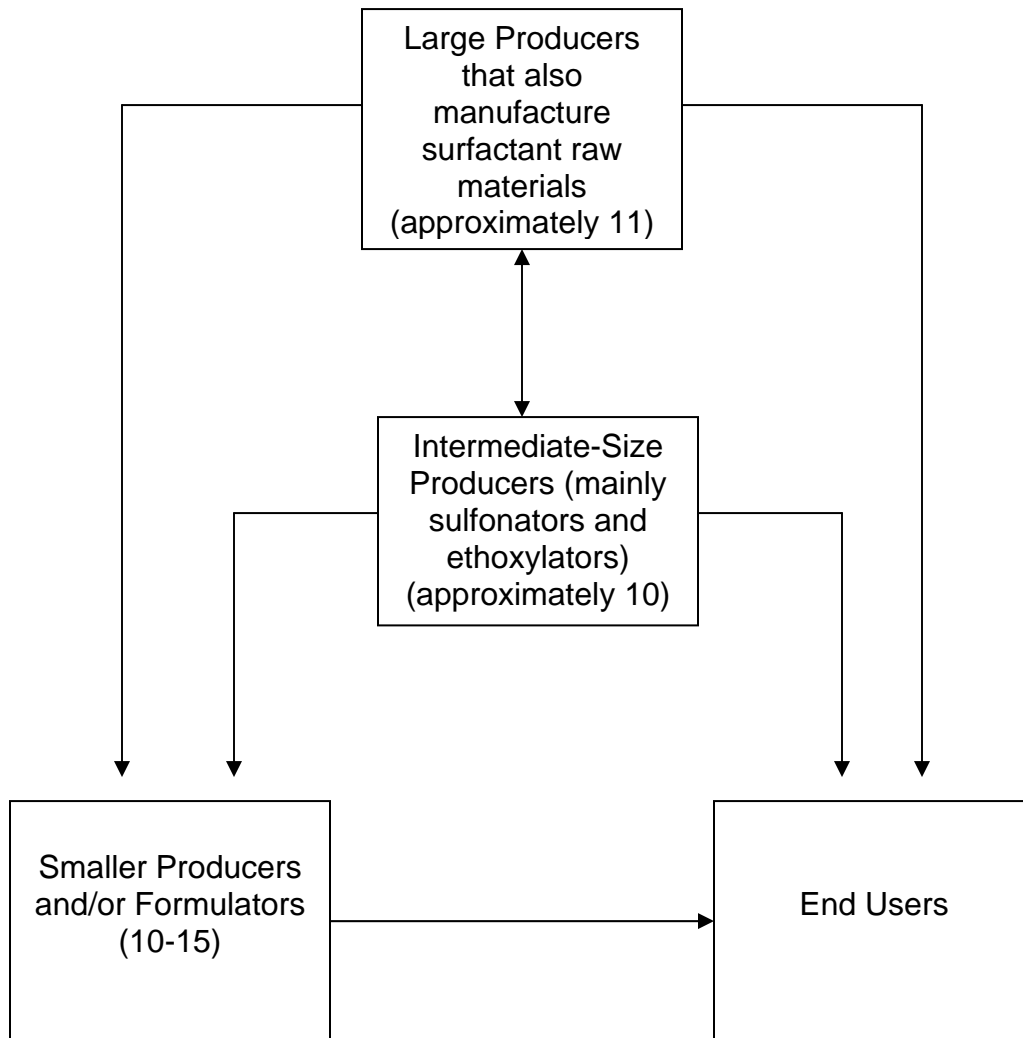
Detergents include polyether amines, polybutene amines, Mannichs and alkenyl succinimides.

# SURFACTANT INDUSTRY MANUFACTURERS

The structure of the surfactant industry is stratified and complex. It consists of large surfactant manufacturers that produce surfactant raw materials, surfactant producers without a raw material position that typically modify basic surfactants by sulfonation or ethoxylation, smaller specialty surfactant producers and/or formulators and end users that are often focused on specific industries.

**FIGURE 1**

## U.S. SURFACTANT INDUSTRY STRUCTURE



The large surfactant producers using petro-chemical feedstocks typically produce ethoxylated commodity surfactants for large volume household detergent customers.

Companies producing surfactants based on oleochemical feedstocks usually have much broader product lines and make more processed downstream specialty surfactants based on sulfonation/sulfation, esterification and amination with nitriles.

Due to difficult industry economic challenges caused by escalating feedstock costs and large manufacturer pricing pressure, the surfactant industry has undergone significant consolidation by acquisitions, divestitures, mergers and joint ventures especially among the smaller specialty producers. This segment is led by large producers with broad product lines and extensive marketing, research and manufacturing capabilities. These companies have grown by acquisition of smaller specialty, niche product producers. The 12 largest producers of specialty surfactants currently supply two-thirds of U.S. demand. This consolidation trend continues with more recent acquisitions, mergers and joint ventures happening on a global scale involving many major companies: Dow bought Union Carbide, Akzo Nobel acquired surfactant businesses from Witco and Crompton. Sasol acquired CONDEA and Cognis Corporation, the world's largest oleochemical manufacturer and part of Henkel, has recently been acquired by PTT Chemicals, Thailand. Elsewhere, Nalco and Stepan recently formed a joint venture "Tiorco" to sell oilfield chemicals and services.

## **SURFACTANT PRODUCT ABBREVIATIONS**

- AE Alcohol ethoxylates
- AES Alcohol ether sulfates
- APE Alkylphenol ethoxylates
- APG Alkyl polyglycosides
- AS Alcohol sulfonates/sulfates
- DFX Diphenylether sulfonates
- EO/PO Ethylene oxide/propylene oxide block copolymers
- LAB Linear alkylbenzene
- LAS Linear alkylbenzene sulfonates
- MES Methyl ester sulfonates
- NPE Nonylphenol ethoxylate

**TABLE 1  
MAJOR BASIC SURFACTANT PRODUCERS**

<b>COMPANY</b>	<b>BASIC FEEDSTOCKS</b>				
<b>Petrochemical-Based:</b>	Detergent Alcohols	Ethylene Oxide	Linear Alkylbenzene	Nonylphenol	Major Surfactants
BASF Corp.		X			EO/PO Polymers
Dow Chemical		X		X	NPE, EO/PO, DFX
Huntsman Corp.		X	X	X	AE, NPE
Sasol N. America	X		X		AE
Shell Chemical	X	X			AE
<b>Oleochemical-Based:</b>	Detergent Alcohols	Fatty Acids	Nitrile-Based Amines		Major Surfactants
Akzo Nobel		X	X		Amines, quats, As, AES, LAS, EO/PO
Cognis Corp.	X	X			AS, AES, AE, esters, APG
Crompton Corp.		X	X		Amines, quats
Degussa Corp.		X	X		Esters, amines, quats
Uniqema		X			Esters, ethoxylates
Procter & Gamble	X	X			Many, captive use
Lonza		X			Amines, quats, esters, ethoxylates, waxes



**TABLE 2  
MAJOR U.S. SURFACTANT PRODUCERS**

COMPANY	SURFACTANT TYPES				PRIMARY PRODUCTS/MARKETS
	Anionic	Cationic	Nonionic	Amphoteric	
Akzo Nobel	X	X	X	X	Fatty amines, fatty acid derivatives
BASF Corp.	X	X	X		EO/PO polymers, specialties
Clariant Corp.	X	X	X		AE, specialties, personal care
Cognis Corp.	X	X	X	X	Cosmetics, Textiles, APG
Croda Inc.	X		X		Personal care
Degussa Corp.	X	X	X	X	Specialties, surfactant blends
Dow Chemical	X		X		APE, DFX, specialties
Harcros Chemical		X	X	X	Specialties, AE, NPE
Huntsman Corp.			X		APE, commodities
Kao Corp.	X	X	X		Specialties – textiles, paper, leather, etc.
Lambent Tech.		X	X		Specialties, AE, NPE
Lonza Inc.		X	X	X	Specialties, biocidal cationics, quats, textiles, personal care, plastics
McIntyre Group	X			X	Anionics
ONDEO Nalco		X	X		Oilfield surfactants, formulated products
Pilot Chem.	X		X		Toll producer of commodity products
Procter & Gamble	X	X			Captive use, consumer products
Rhodia Inc.	X	X	X	X	Specialty products, amphoteric leader
Sasol N. America			X		AE supplier to detergent industry
Shell Chem.			X		Detergent feedstock supplier
Stepan Co.	X	X	X	X	Largest specialty supplier, anionics leader
Tomah Prods.		X	X		Fatty amines
Unilever	X	X			Captive use, consumer products
Uniquema	X	X	X	X	Specialties, broad line

## **SURFACTANT PRICING**

Surfactants are produced from basic petrochemical - “synthetic” and oleochemical – “natural” feedstocks. The basic petrochemical feedstocks are ethylene and benzene which are derived from crude oil and converted to surfactant intermediates, ethylene oxide (EO), linear alkylbenzene (LAB) and detergent alcohols. The basic oleochemical feedstocks are typically seed oils -palm and coconut and tallow. Raw material costs for these feedstocks are a prime determinant of surfactant pricing. In large, commodity surfactant markets such as detergent alcohols, feedstock costs for ethylene vs. plant oils will often determine product composition.

### **Synthetic vs. Natural Feedstocks**

Through the 1990’s, surfactant production was dominated by the use of “synthetic” feedstocks due to low and stable crude oil prices. With the rapid escalation of crude oil pricing beginning in 2003, however, oleochemical-based surfactant production has expanded to support major surfactant feedstock substitution. More recently, strong demand for plant oils in oleochemicals and biodiesel has caused similar price escalation which has reduced the cost advantage for natural feedstocks.

At the time of this writing, raw material costs for both synthetic and natural feedstocks have declined significantly.

This raw material cost competition and resultant feedstock substitution is common to commodity surfactants especially in the detergent industry. Specialty surfactant products are less vulnerable to the impact of rising raw material and energy costs because they are more performance/value driven, command higher prices and create higher producer profit margins.

### **Recent Pricing Trends**

The following pricing summaries demonstrate a major surfactant industry trend toward the increasing utilization of natural, renewable feedstocks which are primarily plant oils - palm, coconut and, most recently, soybean. The rapid price escalation of crude oil, natural gas and derivatives ethylene and benzene beginning in 2003 triggered a major reformulation of many basic commodity surfactants. Alcohol ethoxylates, for example, can be made from natural fatty alcohols rather than synthetic alcohols. Rising raw material costs only reinforced a growing trend toward consumer preference for natural, renewable-based green products.

This feedstock substitution trend was temporarily interrupted during the first half of 2008 when plant oil prices suddenly escalated with gasoline prices and rising biodiesel demand. Later in 2008, however, plant oil prices subsided with crude oil prices due to growing recessionary pressures and declining market demand.

### Feedstock Pricing

Feedstock	2003	2005	4Q07	4Q08
<b>Petrochemical</b>				
Crude oil \$/barrel	22	50	72	43
Natural gas \$/MM BTU	5.00	6.50	7.90	5.80
Ethylene ¢/lb.	.23	.57	.59	.51
Benzene ¢/lb.	.25	.41	.50	.30
<b>Oleochemical</b>				
Coconut oil ¢/lb.	.30	.27	.52	.345
Palm oil ¢/lb.	.32	.185	.50	.255
Soybean oil ¢/lb.	.25	.23	.38	.295

### Surfactant Pricing

Recent pricing for major surfactants and their primary intermediates shown in the summary below documents the strong impact of feedstock costs on commodity surfactants and lesser influence on specialty surfactants.

### Intermediate Pricing

Intermediate	2003	2005	4Q07	4Q08
EO, Ethylene oxide ¢/lb.	.50	.75	.75	.70
LAB, Linear alkylbenzene ¢/lb.		.70	.90	1.05
Detergent alcohols ¢/lb.		.55	.60	.80

### Surfactant Pricing

	2005	¢/lb. 4Q07	4Q08
<b>Commodity Surfactants</b>			
LAS, Linear alkylbenzene sulfonates	.51	.71	.93
AE, Alcohol ethoxylates	.60	.70	.90
AES, Alcohol ethoxysulfates	1.00	1.20	1.47
AS, Alcohol sulfates	1.35	1.50	1.70
NPE, Nonylphenol ethoxylates	.80	1.02	1.40
<b>Specialty Surfactants</b>			
Betaines	2.56		2.72
Fatty alkamolamides	2.50		2.62
Alpha olefin sulfonates	1.49		1.56
Sarcosinates	1.46		1.51
Quaternary ammonium salts	1.24		1.30
Sulfosuccinates	1.24		1.27
Fatty amine oxides	1.17		1.22

## **Oleochemical Surfactant Pricing Outlook (Including Soy)**

Despite wide fluctuations in both petrochemical (synthetic) and oleochemical (natural) feedstock pricing in recent years, the escalation of crude oil prices was most dramatic and had the biggest impact on surfactant pricing. Supply/demand changes, along with other factors such as currency exchange rates and commodity speculation, will continue to influence pricing of surfactants but not to the extent of the stronger influence exerted by 1) the growing U.S. dependence on crude oil imports (now 70% of supply) and 2) growing environmental and regulatory pressure on surfactant manufacturers to use natural, renewable raw materials. As a result, demand for oleochemical-based feedstocks will grow at the expense of petrochemical-based surfactants.

Historically, the oleochemical feedstocks of choice have been palm, palm kernel and coconut oils as well as tallow. Soybean oil, with much greater supply volume and typically lower pricing, has not been used much in surfactant formulations. This has, most likely, been because of the higher level of polyunsaturates. Soy oil contains multiple unsaturates (double bonds) that preclude its use in most conventional surfactant products. The longer carbon chain fatty acids are not as water soluble and, consequently, do not “foam” as well; they can create dark colors when sulfonated and the greater reaction sites reduce the biodegradability of soy-based surfactants.

Methyl ester sulfonates (MES) are anionic surfactants derived from any of these oleochemical feedstocks that have been around for many years but were not produced commercially because they could not compete with low cost petrochemical commodity surfactants. MES is making a comeback with some major manufacturing plants on stream using both palm and coconut oil mainly because of the higher prices of LAB surfactant intermediate. MES is being used as a replacement for LAS in laundry detergents because of 1) higher petrochemical costs, 2) the growing trend to cold washing temperatures and 3) a need for more neutral pH laundry detergent formulations. Growing production capacity in Asia and the U.S. is based mainly on palm oil but Stepan Company operates a coconut oil-based plant in Joliet, IN. Price competition between these seed oils will probably continue but they both produce cost performance competitive surfactants that can replace LAS detergents.

### **Product Performance**

MES surfactants provide better overall detergency in hard and cold water, lower toxicity (mildness), more biodegradability and good compatibility with other detergent additives. The product performance advantages of MES are best optimized by the utilization of C16 and C18 fatty acids from palm, coconut and soybean oil. Unfortunately, soybean oil contains mostly C18 fatty acids and only 11% C16s which are preferred for MES. C18 fatty acids have some aquatic toxicity issues that preclude its use in MES. However, if traditional seed oil pricing returns and soy oil is the low cost seed oil vs. coconut and palm, C16 fractions at 11% content could be isolated and used as a cost-effective MES feedstock.

## SOY-BASED SURFACTANTS and EMERGING OPPORTUNITIES

The use of oleo chemicals, which consist mainly of plant based chemicals, is estimated at 60% of the total amount of petroleum chemicals and oleo chemicals used in surfactants.

The primary plant based materials are coconut, palm, castor, rapeseed and soybean oils, with the majority being coconut and palm oil.

The list below represents a sample of typical uses of soybean based surfactants in selected markets.

1. **Household Detergent.** A biobased dishwasher detergent containing a biobased surfactant from the fermentation of soybean oil and sugars which produces sophorolipids. Name of the detergent is Sophoron™. Manufacturer is Saraya Co., Ltd. located in Osaka, Japan. Website is [www.saraya.com](http://www.saraya.com).
2. **Agricultural Chemicals.** Use of lecithin in soybean herbicide adjuvants. Adjuvants are substances added to the spray tank, separate from the herbicide formulation that will improve the performance of the herbicide. Examples are trade names of Compare™, LI700® and Liberate®. Manufacturer is Loveland Products, Inc. in Greeley, Colorado. Website is [www.lovelandproducts.com](http://www.lovelandproducts.com).
3. **Personal Care.** Non nonionic surfactants derived from soy oil which are used in mild cleaning agents for skin and hair care and a solubilizer for fragrances and oils. Products are Chemonic™SI-63 and Chemonic™SI-7. Products are supplied by Noveon® Consumer Specialties owned by the Lubrizol Corporation of Wickliffe, Ohio. Website is [www.personalcare.noveon.com](http://www.personalcare.noveon.com).
4. **Personal Care.** Condensation product of undecylenic acid and hydrolyzed soy protein. Product is used in hair care and skin care as a cleanser. The product is undecylenoyl soy polypeptide. It is sold by Sinerga Cosmetic Company of Milano, Italy. Website is [www.sinerga.it](http://www.sinerga.it),
5. **Household Detergent.** A liquid laundry detergent that contains a soy-based fabric softener. Product name is Ecos. Manufacturer is Earth Friendly Products of Winnetka, Illinois. Website is [www.ecos.com](http://www.ecos.com).
6. **Agricultural Chemicals/Construction.** Use of ethoxylated soybean oil for surfactants in herbicides and pesticides. An example is Agnique™ SBO-10. This same surfactant is used to treat fly ash for use in concrete. Manufacturer is Cognis GmbH headquartered in Monheim, Germany. Website is [www.cognis.com](http://www.cognis.com).
7. **Oilfield Chemicals.** Use of soy alkyltrimethyl ammonium chloride as a surfactant to recover crude oil in crude oil and water emulsions. Typical trade

names are Arquad® SV-60 PG and Arquad® S-50. The manufacturer is Akzo Nobel headquartered in Amsterdam, Netherlands. Website is [www.akzonobel.com](http://www.akzonobel.com).

8. **Textiles.** Use of sulfated soybean oil as a textile lubricant. Product is Actrasol™ OY-67. Manufacturer is Georgia Pacific Corp. headquartered in Atlanta, Georgia and owned by Koch Industries. Website is [www.gp.com](http://www.gp.com).
9. **Paints & Coatings.** Use of sulfated soybean oil in paints and coatings. Product is Actrasol™ OY-75. Manufacturer is Georgia Pacific Corp. headquartered in Atlanta and owned by Koch Industries. Website is [www.gp.com](http://www.gp.com).
10. **Food Processing.** Use of lecithin to provide emulsification properties in foods with high-viscosity, reduced –fat, high moisture and/or flavor-sensitive applications. Typical products from Archer Daniels Midland, headquartered in Decatur, Illinois, are Yelkin® lecithin, Ultralec® lecithin and Beakin™lecithin. Website is [www.admworld.com](http://www.admworld.com). Other uses for lecithin can be found at [www.soynewuses.org](http://www.soynewuses.org).

The above uses of soybean-based products are examples of both the soybean oil and the soy protein as the starting materials for surfactants. Soybean oil has been the principal feedstock used in the manufacture of surfactants from soybeans.

## **EMERGING TECHNOLOGIES FAVORING SOY-BASED SURFACTANTS**

The emerging technologies that may affect the increased usage of soy-based surfactants in the future are:

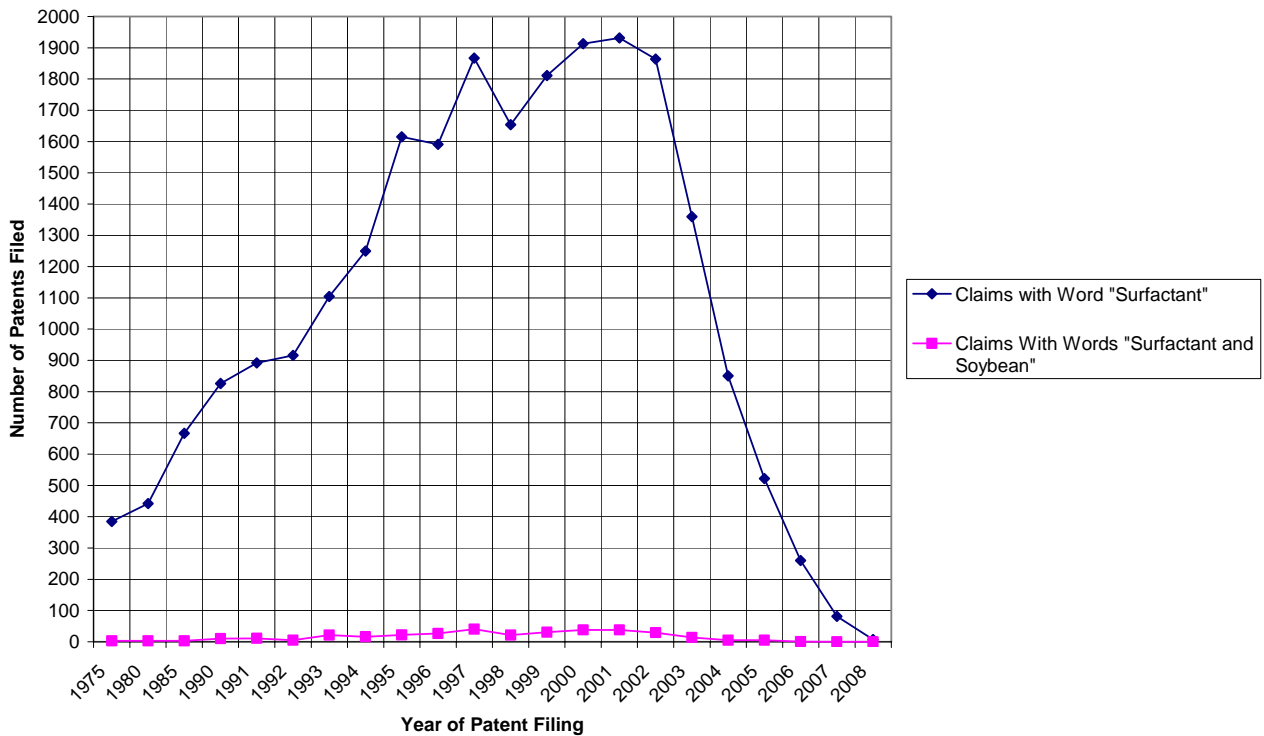
1. Increased knowledge in enzymatic processes which are related to fermentation to produce surfactants.
2. Increased knowledge in the area of protein-based surfactants to provide functionality is not currently available today. Soy oleosin surfactants were studied by the University of Southern Mississippi. Three soy oleosin emulsifiers were identified, two lipoproteins and one vacuole protein, that were “100 times more efficient wetting agents than conventional surfactants” and highly biodegradable. These soy proteins also emulsify best in highly alkaline systems such as detergents, household and industrial cleaners. This feasibility study was completed but no further application development work was done. Further application work holds good potential.
3. Increased knowledge of the oil content to produce fatty acid components with less unsaturation.

4. Process improvements in processing technology of producing surfactants by using micro fluidizer technology to prepare more stable nanoemulsions.
5. Separation technologies to produce products with fewer impurities to increase potential product applications, especially in food and personal care. Cargill has developed a new fluid membrane separation process that can produce clear lecithin for these applications.

The United States Patent database was analyzed to evaluate the number of patents filed from 1975 to present. The word “surfactant” and the words “surfactant and soybean” were searched in the patent claims. Notably the peak year for these patent applications with the word “surfactant” in the claims peaked in 2001 at 1,931 patents and has decreased drastically since then. A similar pattern is seen with claims having the words “surfactant and soybeans” with a peak of 38 patents for each year in 2000 and 2001.

These trends and emerging technologies suggest that there is room for innovation using soy-based surfactants.

**Number of US Patents Filed in Specified Year  
(with word "surfactant" or words "surfactant and soybean" in the claims)**



# ISSUE ANALYSIS

## ENVIRONMENTAL AND REGULATORY ISSUES

### ENVIRONMENTAL REGULATION

The surfactant industry is facing challenging environmental, regulatory and consumer pressure on the production, exposure, packaging, handling, transporting, use and disposal of its products. Surfactant product protection and safety is regulated by the U.S. EPA and other federal, state and local agencies regarding product toxicity, flammability and volatility. In addition, surfactants used in food processing applications are regulated by the Food and Drug Administration (FDA) and surfactants with biocidal claims must be registered under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).

Other environmental regulations impacting surfactant suppliers and end users include the Clean Water Act, the Clean Air Act, the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA) and the Occupational Safety and Health Administration (OSHA) standards. More recently, a number of consumer product certification organizations have influenced product environmental acceptability – Clean Gredients, Green Seal, EPA’s Design for the Environment Program, EcoLogo, Eco-Label, GreenGuard, Nordic Swan and EcoCert. Also, the impact of the European REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) program is growing.

### THE “GREEN” PRODUCT MOVEMENT

Throughout the surfactant industry, there is significant new consumer market driven demand for natural, renewable-based products that are more environmentally friendly. Consumers and major retailers of surfactant-containing products want “wellness” and “sustainability” in addition to product performance. This new influence has come on strongly in the last two years, on top of concern for rising raw material and energy costs and the growing requirement to have cleaning products “certified” as safe.

This new market driven influence has resulted in some major purchasers of surfactant-containing products banning specific surfactants. In 2006, Wal-Mart North America began phasing out a list of suspect chemicals including APE (alkyl-phenol ethoxylates). Cintas Corporation, a major industrial launderer, banned NPE (nonyl-phenol ethoxylates) detergents in 2008 and Levi Strauss began a ban on NPE use. Many producers of formulated cleaning products have responded to these initiatives by eliminating APEs from their products, replacing the surfactants with natural, renewable oleo-based products such as methyl ester sulfonates (MES) from soy or palm oil or seed oil-based alcohol ethoxylates. Major cleaning product manufacturers - JohnsonDiversey, Ecolab and Reckitt Benckiser - have phased APEs out of their formulations.



## **SURFACTANT PRODUCTS OF CONCERN**

- LAS – Linear alkybenzene sulfonates. There is a general health concern about surfactants containing sulfates that has increased demand for renewable-based substitutes especially in large commodity detergent products.
- NPE, APE – Nonylphenol ethoxylates, alkylphenol ethoxylates. These compounds have long been suspected “endocrine disrupters” that cause reproductive disorders in aquatic life forms and potentially in humans. They are major commodity industrial surfactants that have been thoroughly studied and banned in much of Europe although not in the U.S.
- Diethanolamides (DEA) – These commodity nonionic surfactants are typically based on oleochemical fatty acids and have been shown to cause skin cancer in mice.
- Tallow fatty acid-based surfactants – There is some concern over possible health risks from “mad cow disease” that has caused some reformulating of surfactants to vegetable-based raw materials.

The environmental and health issues described above, coupled with severe price volatility of feedstocks, especially crude oil and natural gas, have resulted in a significant response by the surfactant industry. The emerging trends include corporate consolidation as smaller specialty producers are acquired by larger firms, a growing demand for renewable-based products that are safer and less environmentally damaging, a renewed emphasis on R&D to produce value-added differentiated products, an increased use of surfactant blends to create better cost-performance and the introduction of concentrate cleaners to reduce costs, boost cleaning performance and reduce the environmental imprint of products in terms of energy consumed and packaging disposal.

## **UNMET SURFACTANT MARKET NEEDS**

While the ten markets that are explored in detail along with five other market segments that are mentioned in this summary are very diverse; they do hold one thing in common, and that is the concern for the environment.

This concern ranges all the way from the impact of crude oil supply and demand, environmental impact of chemicals, energy usage, conservation of resources, etc. The end result is some form of consumer awareness in these issues. The consumer in this case is all through the value chain from the manufacture of chemicals, formulators of products, retail outlets, and to the final consumer.

In addition to this value chain to the consumer, an interest in the “cradle to grave” use of products by both governmental organizations and non-governmental organizations has

heightened environmental interests and created a growing trend in more stringent environmental regulations impacting surfactants.

Nowhere is this more evident than in the household detergent market. This market has progressed through many changes.

- Emergence of synthetic detergents (surfactants) to replace soaps and reformulation for biodegradability (1950-1970).
- Liquid home laundry products replace powders (1990-current).
- Concentration of liquids to save on shipping, container costs, and shelf space (2007-2008).
- Front loading washing machines that use less water and operate at lower temperatures to save energy (current).

The current changes in washing technology will require surfactants that operate at lower temperatures and use less water for rinsing among other requirements.

These trends that concern the environment also impact industrial and institutional cleaners.

Consumers of personal care products want products that are mild on their skin and hair along with being good for the environment. Knowledge of the chemistry of skin and hair will create more scientific approaches to formulating products in this area. Renewable-based surfactants offer good potential here.

As users of petrochemicals seek alternatives to crude oil-based feedstocks through other alternatives such as coal, etc., opportunities exist for surfactant use in extracting crude oil from oil reservoirs that have been difficult to remove.

This same concern for the environment can also be seen in the trend to lower solvent usage and lower VOCs in paints and coatings, industrial and institutional cleaners, adhesives, paint strippers and many other formulated products. Surfactants must also meet these environmental standards and regulations.

## **BARRIERS TO MARKET ENTRY**

Oleochemical-based surfactants have historically utilized coconut oil, palm oil and tallow more than soybean oil. The basic chemistry of soybean oil has not been a deterrent for surfactant use, although the higher levels of unsaturated fatty acids in soy (C18) can affect water solubility and oxidative stability versus the other oleo feedstocks. Pricing and availability of these raw materials are still the primary drivers of raw material choice. Soybean oil has not been widely available in Europe; this may have influenced surfactant products that excluded soy.

Environmental and regulatory standards are becoming more stringent. Based on specific end use markets, surfactant products and formulations in which they are used must meet aquatic and human toxicity testing requirements as well as biodegradability standards.

Product registration of surfactants and their formulated products is now required by the EPA in the U.S. and REACH in Europe. This can be a time consuming and costly process.

Another potential marketing issue involves the use of GMO soybeans and the consumer perception of product safety concerns. Although this is not a problem at this time, future development efforts involving soy-based surfactant products planned for use in the food or personal care markets should consider the use of GMO soybeans and their potential impact on demand for the end product.