

**COMPETITIVE IMPLICATIONS OF ENVIRONMENTAL REGULATION:  
IN THE  
LAUNDRY DETERGENT INDUSTRY**

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U.S. EPA Cooperative Agreement #CR824410-01

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Report prepared for:

Office of Policy, Planning and Evaluation  
U.S. Environmental Protection Agency  
Washington, D.C. 20460

The Management Institute for Environment & Business  
June 1996

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## **INTRODUCTION**

Laundry detergent is used in millions of households around the world to remove soils and stains from fabrics. Although soap has been used since ancient times to wash laundry, the first commercial detergents were not produced for household use until just after World War II. In the following years, the production of laundry detergent grew rapidly into a worldwide industry, mature in developed countries, but still expanding in developing regions. By the mid-1990s, the industry had become extremely competitive. The primary method available to manufacturers to gain market share was the introduction of new or reformulated products. Manufacturers competed primarily on performance, cost, and environmental attributes. (Chynoweth, 1993)

## **INDUSTRY STRUCTURE**

### **Product**

The primary function of laundry detergents is removing soil particles from fabric. Laundry detergents are produced in two major types of formulations: powder and liquid. Powders are generally more effective in removing clay and ground-in dirt, while liquids work well on oily soils. Both powders and liquids are used in automatic washing machines and also in washtubs and sinks. After the laundry has been washed, the washwater is emptied down the drain, and sent into the municipal water treatment system.

Laundry detergents comprise one category of the several different types of cleaning preparations manufactured and sold worldwide. Laundry detergents are generally classified under the broader category of soaps and detergents, which includes bar soaps, fabric softeners and bleaches as well as household surface cleaners and dishwashing detergents. Laundry detergents represent the largest piece of this segment.

Detergent formulations vary considerably from region to region for several reasons. First, manufacturers are extremely sensitive to consumer preferences for fragrances, mildness, etc., which typically vary across cultures. For example, Japanese consumers tend to prefer much milder detergents than those demanded by U.S. consumers. Second, the types and operating temperatures of washing machines are different in different countries, requiring specific detergent formulations to achieve proper foaming and cleansing activity. Finally, water supplies vary regionally in their hardness, or metallic content, which affects the performance of surfactants. To satisfy these various demands, the laundry detergent industry operates in a primarily regional fashion.

Detergents are comprised of four major types of ingredients: builders, surface active agents (surfactants), additives, and fillers. Surface active agents, or surfactants, perform the actual task of removing soil from the fabric. They work through the action of their hydrophilic (attracting water) and hydrophobic (repelling water) molecules. One end of the surfactant attaches to soil particles and the other end to water, drawing dirt out of clothing to be rinsed away. Surfactants also reduce the surface tension of water, causing droplets to spread and thoroughly wet fabric surfaces. In the 1990s, the most commonly used surfactant was linear alkylbenzene sulfonate (LAS), accounting for 45% of the commodity surfactant market. LAS is made from benzene and kerosene, which are derived from petroleum.

Builders are used to soften hard water, and allow surfactants to perform more effectively and efficiently. Phosphates had been widely used as builders since 1947. Comprised of condensed or complex phosphates and sodium, the most common phosphate used by the detergent industry was sodium tripolyphosphate

(STPP). STPP softens water by sequestering calcium and magnesium ions, enhancing the detergency of surfactants and preventing the redeposition of soil particles onto fabric.

Additives enhance the detergent, providing fragrances, bleaches, stain removers, optical brighteners, and fabric softeners. Fillers are used to dilute the detergent for convenient usage, water for liquid formulations, and sodium silicate for powders.

Enzymes are also used to enhance performance. Although they primarily function as stain removers, enzymes perform other functions, such as protecting cotton fibers. Enzymes are natural proteins produced by plant or animal organisms which break down other proteins, fats, or starches. Proteases are enzymes that attack protein-based stains, such as egg. Lipases break down fat-based stains such as butter. Amylases are enzymes that attack starch-based stains such as gravy. Cellulases are enzymes that protect fabrics from fiber damage (i.e., "fuzz" or "pills" on fabric surface) from repeated washing. Enzymes are considered environmentally benign, and even beneficial, as they supplant synthetic chemicals use.

The primary production methods for powder detergents are spray-drying, agglomeration, and dry mixing. Spray-drying involves spraying a mixture of liquid and dry ingredients through nozzles to form small droplets, which then fall through a current of hot air and form hollow granules as they dry. (*Soaps and Detergents*, 1994) In agglomeration, dry raw materials are blended with liquid materials by rolling or mixing. Dry mixing is used to blend primarily dry raw materials, although small quantities of liquids may be added. (*Soaps and Detergents*, 1994)

Liquid detergents are produced through both batch and continuous blending processes. In the typical blending process, dry and liquid ingredients are combined and blended to a uniform mixture using in-line or static mixers (*Soaps and Detergents*, 1994).

### **Market Dynamics**

In the U.S., laundry detergents are classified as a segment of the soaps and detergents industry (SIC 2841). In 1993, sales of laundry detergent represented over 76% of this segment, or approximately \$4.2 billion.

In 1991, detergents sold for \$.40-\$.60 per pound at the manufacturer level. Raw materials costs accounted for about half of this amount, or \$.20-\$.40 per pound. (Verbanic, 1991) In the decade ending in 1993, annual growth of total U.S. detergent shipments averaged 2.4%. (Mullin, 1995)

In 1993, the Western European market for laundry detergent totalled approximately \$7.62 billion (Graffmann, 1994). Eastern Europe represented a major growth opportunity for the laundry detergent market. Demand for detergents was expected to grow quickly in Hungary, Slovenia and the Czech Republic, and at a somewhat slower rate in Poland, Slovakia and Croatia.

In 1992, the Japanese market for laundry detergent totalled approximately \$1.5 billion. (Leikhim, 1994) Between 1986 and 1992, detergent sales grew in Japan at an average of 5.5% each year, due largely to the introduction of super-concentrated detergents. (Tsumadori, 1994)

In addition to Eastern Europe, Latin America and China represented the most rapidly growing markets for laundry detergent. From 1990 to 1993, yearly growth in laundry detergent sales ranged from 4% in Mexico to 15% in Argentina. By 1993, market penetration of automatic washing machines into Mexican households was at 65%, and at 40% for all of South America. (Leikhim, 1994) About 1.61 million short

tons of detergents were sold in China in 1991. This volume was expected to reach 2.5 million tons by 1995, and 3.7 million tons by 2000, more than doubling the market in less than ten years (Novo Nordisk, 1994).

In the mid-1990s, the mature laundry detergent markets of the U.S., Western Europe and Japan were experiencing an average of approximately 2% annual growth. Worldwide, the growth rate was closer to 5 or 6%. Sales of laundry detergent were closely aligned with the market penetration of automatic washing machines.

### **Threat of New Entrants**

In Japan, although the market share held by supermarket brands was negligible, the lower-priced detergents were causing concern among established detergent manufacturers. Makers of lower-priced detergents hoped to convince customers that their detergents, while more expensive, produced better results. However, large manufacturers realized they could not ignore price completely, so many companies like Kao, Lion and P&G no longer put suggested retail prices on their detergents (*Nikkei Weekly*, 6/5/95).

In the U.S., private label manufacturers gained ground. In 1993, they held only 3.2% of the market, but sales grew 11.3% that year. By 1995, private label sales still accounted for just 6% of detergent sales. Many consumers did not believe that private labels had the same quality as national brands, and aggressive marketing by the larger producers kept the private label detergents in line. However, corporations such as Wal-Mart, which was the biggest customer for P&G's Tide, introduced Ultra Clean in 1995, a private label product in direct competition with Tide. It was a concentrated powder in a box of the same shape and size as Tide's traditional package, yet was available at a much lower price (*Chemical Marketing Reporter*, 1/16/95).

### **Leading Supplying Nations**

#### United States

In 1995, the U.S. market was dominated by three laundry detergent manufacturers: P&G, Lever Brothers, and Colgate-Palmolive. Collectively, these three controlled an estimated 84% of total detergent market share, with P&G as a clear market leader with 54% share. Lever Brothers followed with 23%, and Colgate-Palmolive a distant third with 7% (Gerry, 1993).

*The Procter & Gamble Company* Procter & Gamble (P&G) introduced the first synthetic household laundry detergent, Tide, in 1946 in the U.S. In 1991, Tide was still the leading brand in the U.S.; the powder formulation represented 22% of the U.S. laundry detergent market and Liquid Tide another 8.5%. Other P&G brands sold in the U.S. included Cheer, Bold 3, and Era.

The company was also a leading producer outside the U.S., maintaining a 17% volume share of the world detergents market ("Unilever", 1993). P&G was the market leader in Europe, controlling 20% of the market, and also commanding 15% of the Japanese market.

In 1993, P&G's laundry/cleaning sales accounted for 33% of the company's total sales, or over \$10 billion. Industry analysts attributed P&G's dominance in laundry detergents to three factors: 1) P&G marketed more products in the laundry detergent category than other producers; 2) the company was highly

aggressive in its marketing and advertising; and 3) the company was frequently first to market new, reformulated or line-extended products (Gerry, 1993). 4) P&G also benefitted from having the longest history in the market; it marketed its first detergent, Tide, in 1946.

*Colgate-Palmolive Company* U.S.-based Colgate-Palmolive had fabric care sales of \$7.14 billion in 1993, representing 19% of total sales. Colgate-Palmolive's brands included Fab and Dynamo. The company derived 65% of its sales from outside the U.S. and Canada. The company had captured 8% of the European market, and a 7% volume share of the world market for detergents.

### Europe

The European market was more fragmented than in the U.S. or Japan. Major producers of laundry detergent in this region included P&G, Lever Europe, Henkel and Colgate-Palmolive, accounting for 66% of detergent sales in Europe (Unilever, 1993).

*Unilever PLC/NV* Unilever, an Anglo-Dutch company, was the world's second largest consumer products company manufacturing non-durable goods. In 1994, the company had worldwide sales of \$45.4 billion, with \$10 billion in detergents. Unilever led the world detergents market, with a 20% volume share (Unilever, 1993). About 45% of the company's detergent sales were generated in Europe through its subsidiary Lever Europe. Unilever products included all', Surf and Wisk.

*Henkel KGAA* Henkel was Germany's fourth largest chemical company, and a major European producer of detergents. The company's detergent and cleanser sales totalled \$ 2.63 billion in 1993, or 31% of total sales. Henkel controlled 16% of the European detergent market, and 5% of the world market. In 1994, Henkel commanded a 47% market share in Germany, and was the only producer other than P&G to increase its market share for Europe as a whole.

### Japan

Similar to the U.S. market, the Japanese market was extremely concentrated. Kao, the market leader with a 55% share, Lion, with 25%, and P&G, with 15%, collectively controlled 95% of market share. Nippon Lever (the regional subsidiary of Unilever) controlled 2.8% ("Detergent Producers", 1992).

*Kao Corporation* Kao, a privately-held Japanese company, had 1994 sales of \$6.93 billion. The market leader in Japan, Kao controlled 55% of the domestic market, and 3% of the world market. Owing primarily to a slowdown in domestic sales growth, the company was looking to expand its international presence. However, initial efforts to penetrate the Australian market, seen as a trial run for entry into the U.S. and European markets, were largely unsuccessful (Mullin, 1993). The Australian market at the time was dominated by Colgate-Palmolive and Unilever which posed fierce competition. Kao hoped to have 10% of the market by 1995. In 1994, however, Kao captured less than 3% of the Australian market. In other markets, though, Kao fared better. Kao was particularly well-positioned for the detergent markets in Taiwan, Thailand, and Malaysia (*Chemical Week*, 1/27/93).

Suppliers to the industry provided the raw materials necessary to create laundry detergents. These materials included both commodity and specialty chemicals. Major suppliers to the industry were Witco, Stepan, Hoechst, Texaco, Shell, Vista and Huntsman. Other suppliers were subsidiaries or business units of the manufacturers themselves, such as Crosfield (a Unilever subsidiary based in the U.K. with U.S. headquarters in Joliet, IL), Henkel and Procter & Gamble.

## **ENVIRONMENTAL, HEALTH & SAFETY PRESSURES**

### **Environmental Risk Analysis**

For several decades, the home laundry detergent industry had experienced pressure from environmental, health and safety concerns in its product content, energy consumption, substance safety and packaging.

#### Product Content

The greatest environmental challenge to the detergent industry was the use of phosphates as builders. Phosphorus, the primary component of phosphates, is a nontoxic element which acts as a nutrient for plant life. The overabundance of phosphorus in the environment was believed to be a contributor to advanced eutrophication of thousands of water bodies throughout the world as early as the 1960s. Eutrophication results from an overabundance of nutrients such as phosphorus in aquatic systems. Highly elevated nutrient levels cause an overgrowth of algae, which consumes all oxygen in the water, asphyxiating fish and other aquatic life.

Industry players maintained that detergents were not the primary culprits of eutrophication, constituting no more than 20% of phosphate input to surface water. Sewage, farm and industrial wastes were pinpointed as the principal sources (*C&EN*, 2/7/94). Nevertheless, environmental pressures to eliminate phosphates were successful in spite of controversial industry positions.

Also of concern was phosphate substitute nitrotriacetic acid (NTA), known to cause cancer in animals as well as combine with metal ions in drinking water to elevate the risk of birth defects.

Detergent surfactants too posed environmental problems. Again in the 1960s, observers noted that the introduction of synthetic surfactants led to persistent foaming on rivers, in sewage treatment works and around sewage out-falls. This was caused by the slow rate of surfactant biodegradation. Surfactants were under further environmental attack as they were derived from petroleum, a nonrenewable resource.

In the later part of the decade, the U.S. public feared health threats from detergent enzymes. Workers directly involved in enzyme manufacturing developed severe cases of asthma and other respiratory ailments from inhaling airborne enzyme particles. To avoid negative outcomes, U.S. companies which utilize enzymes, such as P&G, voluntarily suspended U.S. production.

#### Energy Consumption

Three types of energy were consumed in the process of washing laundry: chemical, mechanical and thermal. Chemical energy was provided by detergent ingredients. Mechanical energy was generated by the action of the automatic washing machine or human effort. Thermal energy was required to heat washwater to an appropriate temperature (*Soaps and Detergents*, 1994). The amount of energy consumed per washload was closely tied to the temperature at which the clothing was washed, as well as the length of washing time and the volume of water required. Higher temperatures required more thermal energy than lower temperature washes. Products designed for cold water washes required less thermal energy, but potentially increased the need for chemical energy.

The Department of Energy wanted to implement new efficiency standards to take effect in 1999. The legislation would have required lower water temperature settings on hot water heaters to reduce energy

consumption. This will result in lower wash temperatures for washing machines. Detergent manufacturers would have to reformulate detergents to be effective in cold water (*Chemical Marketing Reporter*, 1/16/95).

### Packaging

Packaging was a less sensitive issue than content in the detergent industry, but the industry was not immune to the pressure felt by all consumer good sectors to reduce plastic and paper packaging. Packaging concerns focused primarily on the amount of packaging used to contain detergent products, and on the recycled content of the packaging used.

## **Environmental Regulation**

### Phosphate Bans

#### *United States*

In the U.S., the first bans passed against the use of phosphates occurred in the early 1970s. The first wave of states to impose bans were Connecticut, Indiana, and New York. Several localities in Florida, Illinois, Maine, New Hampshire, Ohio, and Wisconsin were also early movers. Other counties and states continued to enact bans through the 1980s and 1990s. In 1995, approximately 17 states had bans in effect, covering about 42% of the U.S. population. These bans made distribution complicated for manufacturers.

#### *Europe*

In Europe, bans on phosphates appeared at the national level. Switzerland and Norway passed total bans on phosphate use. Regions of France, Germany and Italy enacted strict local bans. Finland, Sweden, Denmark and the Benelux countries set voluntary limits for manufacturers.

#### *Japan*

During the late 1970s and early 1980s, local ordinances banning phosphates were enacted in the Shiga and Ibaraki prefectures of Japan. In response, Japanese firms reduced their use nationwide. By 1984, 98% of all laundry detergents sold in the country were phosphate-free.

#### *Rest of the World*

In 1995, phosphates remained unbanned and still widely used in Latin America and other developing regions. They were also used in industrial applications and in dishwashing detergents.

### Packaging

#### *United States*

Several states in the U.S. passed laws mandating specific levels of recycled content in paper and plastic packaging. In 1991, California passed a bill requiring rigid plastic containers to be recycled at a 25% rate or to be reusable, refillable, or source-reduced at a 10% rate. Oregon approved a bill in the same year requiring containers to achieve a 25% recycling rate or have 25% recycled content by 1995, and also

called for mandatory coding of plastic containers. In 1993, Florida put a one cent advance disposal fee on containers that were not recycled at a 50% rate.

Thirty-nine states mandated use of the triangular "chasing arrows" voluntary resin identification system for plastic containers. The system was originally designed by the Society of the Plastics Industry. In 1994, environmental groups in California, Washington and Colorado unsuccessfully attempted to ban the sorting codes on the basis that they misled consumers to believe that code-bearing plastics were recyclable. The plastics industry helped to defeat the bills through its push to modify the code in 1995. (*Plastics Engineering*, 6/95)

### *Europe*

The German government also passed legislation to reduce packaging waste. They issued a mandatory \$.03 deposit for all beverage, soap and detergent containers. By 1995, 80% of packaging materials were to be collected and recycled, and 80% of the plastics must be reprocessed.

### Substance Safety

After the U.S. Surgeon General issued a report in the early 1970s suggesting that phosphate substitute nitrotriacetic acid (NTA) was a carcinogenic compound, U.S. detergent manufacturers agreed to phase out its use in domestic production. In 1980, the U.S. Environmental Protection Agency reviewed and subsequently denied a citizens' petition to ban manufacturers' use of the substance. In 1986, New York became the only state to pass a ban. However, this action effectively prohibited the use of NTA by U.S. manufacturers such as P&G, owing to the inefficiency of producing state- specific formulas (Hall, 1995).

## **INNOVATION IN RESPONSE TO ENVIRONMENTAL PRESSURES**

Phosphate bans and packaging regulation, in addition to demands for less-packaged, space-saving detergents, fostered innovation in detergent manufacturing. And, while pressure to reduce energy consumption was not a primary driver of detergent innovation, it afforded manufacturers of cold-water detergents the ability to market the new formulations' energy-saving benefits.

### **Surfactants**

During the mid-1990s, the market shifted away from linear alkylbenzene sulfonate (LAS) usage. Several factors contributed to this trend. First, enzyme usage was steadily increasing and LAS was incompatible with enzymes when LAS was used at content levels over 10%. Secondly, alcohol-based surfactants were widely supplanting LAS because they were milder. In addition, emerging types of surfactants siphoned demand from LAS.

### Sugar-based compounds

Surfactant alternatives consisted primarily of carbohydrate-based or sugar-based compounds. Owing to their excellent biodegradability and safety profile, sugar-derived surfactants had been seen as substitutes for surfactants suspected of having adverse effects on the environment and whose use had been partly restricted. Henkel was the first to develop a compound, *alkylpolyglucoside* (APG), for use in laundry detergents. Henkel first introduced APG into its Le Chat laundry detergent in France in September 1989. Subsequently, Henkel introduced a line of carbohydrate-based surfactants called *Glucopon*.

In 1994, P&G replaced LAS in its U.S. liquid detergents, including Liquid Tide, with its newly patented *N-methyl glucosamide*. The new compound was developed by P&G, and manufactured by Hoechst in Bavaria. P&G also developed a new formulation for its Ariel Futur brand, which contained a sugar-based surfactant. P&G Europe declared, "This is not a product we have developed just for its environmental impact. It has superior performance, particularly in the removal of grease and stains." (Milmo, 1995).

## Ultras

The single largest development in the laundry detergent industry through the 1990s was the introduction of concentrated product formulations or "ultras." Ultras were characterized mainly by a reduction in chemical and filler content. These concentrates were made available first in powders, then in liquids.

Powdered ultras were first introduced in Japan by Kao in 1987. The product was marketed on its space-saving qualities, extremely important for space-constrained Japanese homes. The leading ultra manufacturers in Europe were P&G and Lever which both introduced products in 1989. Henkel introduced a concentrate in 1990 as "Dixan 2000". In the U.S., powdered ultras were introduced in 1991; liquids followed the next year. In 1991, Lever Brothers introduced powdered ultras for its detergent brands. In 1992, P&G completely switched to liquid ultras for its line of eight detergents. Church & Dwight introduced Ultra Fresh powder in 1991 and Arm & Hammer liquid in 1992. Colgate-Palmolive had the first super-concentrate on the market -- Fresh Start Powder, but it waited until 1994 to introduce a line of ultra liquids.

In 1993, P&G's line of ultras comprised 27% of the liquid detergent market. Colgate-Palmolive had 2.6% of the market with its Fab Ultra liquid. In the powdered market, Procter & Gamble's line including the most-successful brands Tide and Cheer, controlled 43.6%. Lever Brothers had 8.6% with its Ultra Surf and Ultra Rinse brands. Church & Dwight had 5.5% of the market with its Arm & Hammer Ultra Fresh brand and Colgate-Palmolive commanded 3.3% with its three ultras for the Fab, Ajax and Fresh Start brands.

Lion Corp. (Japan) reformulated versions of its brands in 1995 so only 20 grams of the new formula were needed per 30 liters of water, compared with 25 grams for conventional products. The new Lion brands came in a 1.2kg pack, compared with the 1.5kg size of previous boxes. Using smaller packages resulted in annual paper savings equivalent to 170 million sheets of paper.

Kao Corp. (Japan) followed with similar condensed versions of its brands, and the concentrated formula was better at absorbing calcium ions in tap water, thereby improving its cleansing efficiency. It also contained a protein-dissolving enzyme.

In trying to improve performance while cutting energy consumption and achieving higher densities in powder products, Lever Brothers developed a new product in the U.K which used a sodium percarbonate-based bleaching system as well as a new zeolite builder. The new formula required 30% less volume than conventional compact powders and used 15% less chemicals. The manufacturing process eliminates the need for dry spraying towers, reducing the consumption of energy by 80% and saving 200 liters of water per ton of detergent (*Chemical Marketing Reporter*, 1/16/95).

P&G was developing a new product for the U.S. market in 1995 called Ariel Futur, a super compact powder, which contained a sugar-based surfactant and also avoided the use of dry spraying. The company claimed that the detergent reduced chemicals content by 25%, achieving with 1.5 kilograms of detergent

what an existing product could do with 2 kilograms (*Chemical Marketing Reporter*, 1/16/95).

## **Enzymes**

The world's largest enzyme manufacturer was Novo Nordisk which controlled 50% of the global market in 1995. Other leaders were Gist-Brocades (The Netherlands) which stopped producing industrial enzymes for detergents in 1993. It sold its industrial enzyme business to Genencor International (Rochester, NY) in 1995. With the addition of Solvay Enzymes (Belgium) these three companies each had 10% of the market in 1992.

### Proteases

Proteases were the first enzymes used in laundry detergents. The first protease was developed by a Swiss company, Gerbruder Schnyder, in the early 1960s. However, Novo Nordisk A/S, based in Denmark, quickly followed with the introduction of *Alcalase*, a protease. Within five years of its initial introduction, P&G, Lever Brothers and Colgate-Palmolive had all incorporated *Alcalase* into product formulations.

### Lipases

In 1988, Novo introduced *Lipolase*, the first lipase designed for laundry detergents. The company simultaneously applied for approval of production from both the Danish and Japanese governments. Because *Lipolase* was a genetically engineered substance, Novo anticipated a lengthy review process by the Danish government. The Japanese government, however, approved the substance in four months. Lion Corporation, the second largest Japanese manufacturer, immediately entered into an exclusive supply arrangement with Novo. Although *Lipolase* was viewed as expensive at \$7.50/lb, it was thought that Lion had seized this opportunity to steal market share from rival Kao. (Pedersen, 1988) Introduction into European and U.S. markets followed during 1990-1991.

Novo was the only enzyme producer to offer a lipase until 1991, when Genencor introduced its *Lumafest* enzyme in Europe.

### Cellulases

Novo created a proprietary cellulase for Procter & Gamble called *Carezyme*. P&G introduced *Carezyme* into Tide liquid in March 1994, boasting of the detergent's ability to keep "clothes looking like new." Novo also developed and marketed *Celluzyme*, a cellulase almost identical to *Carezyme*, but available to the rest of the industry.

## **Builders**

The most common substitutes used for sodium tripolyphosphate (STPP) were zeolites, naturally-occurring minerals containing silicon. Zeolite A, the most common form of zeolites used in laundry detergent, is a hydrated sodium aluminum silicate. Like STPP, zeolite A captures calcium ions present in hard water. However, zeolite A is not effective on magnesium, and so must be combined with a number of other ingredients in order to approximate the effect created by STPP. There was a general perception that their performance had yet to meet the standard of STPP which was cost-effective and performed well as a builder. As a result, laundry detergents in the U.S. still consume about 40 million pounds of STPP per year (*Chemical Marketing Reporter*, 1/24/94)

Major producers of zeolites included PQ Corporation (Valley Forge, PA) and Ethyl Corporation (Richmond, VA). PQ, a privately held company, had sales of \$450 million in 1994. Ethyl was the largest domestic producer of detergent grade zeolites, with 1993 sales of \$1.73 billion. A record high output of 370,000 million tons of zeolites were produced in 1992. During that year, two new producers, Crosfield (Joliet, IL) and J.M. Huber (Edison, NJ), entered the market.

Sodium citrate was used in conjunction with zeolite A as a co-builder in powder formulations and as a builder in liquid detergents. Sodium citrate is a naturally-based ingredient converted from citric acid, commonly sourced from sugar beet.

In 1992, the demand for sodium citrate had been growing in excess of 50% annually. Major producers of the substance included Haarmann & Reimer (a British-based subsidiary of Bayer), Jungbunzlauer (Austria), Hoffman-LaRoche (Switzerland) and Archer-Daniels-Midland (U.S.). Analysts speculated at the time that the rising price for sodium citrate, which ranged between \$.87-\$1.93 per kilo in 1992, might slow the growth in demand (Milmo, 1992).

Rhone-Poulenc (France) introduced a new builder in 1995 called Naabion, which dissolved more quickly than other builders. It reacted very quickly in the wash to capture calcium and magnesium ions, thereby enabling the surfactants and the enzymes to more rapidly. This reduced washing time, which cut down on energy consumption (*Chemical Marketing Reporter*, 1/16/95).

Rhone-Poulenc was also developing techniques to cut down detergent waste through a controlled-release system to ensure that surfactants started operating only when they were close to the stains on fabric.

Crosfield had a new zeolite which had smaller and denser particles with a calcium uptake rate 50% faster than its conventional zeolite. This enabled it to operate well at lower temperatures and to shorten wash times.

## **Packaging**

In response to regulatory and consumer demands, the industry made significant reductions in the amount of paperboard and plastic used for packaging. In 1990, P&G began Downy Refill, a small paper-based carton using 75% less packaging material. Dial Corp. (Phoenix, AZ) introduced the Bag-in-Box concept for its liquid detergent Purex the same year. An outer box contained a plastic pouch holding two gallons of detergent. This reduced the volume of plastic waste by 75% over standard plastic containers.

In March 1994, P&G introduced the first polyethylene refill bag for powders. Refill Tide and Cheer in resealable polybags filled to a basically square form that allows them to be easily stacked on shelves. They were constructed of laminated polyethylene film including recycled high-density polyethylene (HDPE). The film helped to keep moisture away from the detergent which reduced lumping and caking. The bags contained 80% less packaging than comparably-sized cartons, and they diverted 18 million pounds of raw packaging from landfills annually. They were made of at least 25% post-consumer recycled material, and are 100% recyclable as low-density polyethylene (LDPE).

The Flexible Packaging Association (FPA) in Washington, D.C. awarded its third annual Green Globe Award for environmental achievement to Paramount Packaging Corp. (Chalfont, PA) for the Tide and Cheer refill bags.

It had been hard to convince consumers that small packages of concentrated formulas had the same value

as larger ones. Lever Brothers planned to withdraw its one-quarter cup packaging and re-introduce its half-cup formula due to market pressure. Church and Dwight was the only major liquid detergent manufacturer still committed to the one-quarter cup packaging, yet they only had 3% of the detergent market (*Soaps Chemical Cosmetics Specialties*, 1/95).

Upon switching to the use of recycled materials in their containers, Lever Brothers and P&G both included up to 35% post-consumer HDPE in the construction of their plastic bottles. By 1992, however, post-consumer content inflation had set in, with Lever's refill bottles reaching 50% and P&G's Downy refill modified to use 100% post-consumer HDPE (*Green MarketAlert*, 10/93).

### **Regional Formulas**

Ecover, a Belgian detergent manufacturer with 1992 revenues of 3.38 billion BF (exchange rate for 9/26 was .0338), began to develop product formulations tailored specifically to regional water supplies. For the city of Amsterdam, Ecover introduced a laundry detergent that eliminated 12% of the ingredients in the standard formula. For the Pacific Northwest, where the water is unusually soft, Ecover planned to eliminate up to 30% of the ingredients used in its standard detergent formula.

## **COMPETITIVE POSITIONING OF INNOVATORS**

### **Cost Structure**

The industry movement toward innovative surfactants and the development of ultras reduced raw materials usage and costs.

P&G's detergent formulation using the sugar-based surfactant N-methyl glucosamide reduced the chemical content of the product by 25%.

Henkel's alkylpolyglucoside (APG) allowed manufacturers to reduce the number of surfactants kept in stock and could be used at lower active levels. Both of these qualities represented real cost savings for laundry detergent manufacturers.

Concentrated versions of detergents eliminated fillers, such as water and sodium silicates, to make formulas smaller. This in turn reduced the costs of production to manufacturers by lowering raw materials, packaging and transportation costs.

Additionally, changes in the production process resulting from the movement to ultras allowed manufacturers to switch from dry-spraying to other, lower cost methods of detergent production, such as agglomeration.

### **National Market**

#### Phosphates

Major suppliers of phosphates included FMC, Olin, Occidental Chemical and Albright & Wilson. FMC Corporation Phosphorus Chemicals, which had 1993 sales of \$180 million, was a subsidiary of FMC Corporation. Olin Corporation had 1994 sales of \$2.66 billion. Occidental Chemical Corporation, a

subsidiary of Occidental Petroleum Corporation, had sales of \$4.681 billion in 1994. Albright & Wilson Americas Inc., a subsidiary of Tenneco Inc., had 1993 sales of \$914 million.

As a result of the legislation banning phosphates, the phosphate supply market contracted significantly. Firms had to produce two different versions of their products and rearrange distribution systems accordingly. Thus, distribution efficiency became increasingly difficult (Kemezis, 1993). This caused firms to remove phosphate from entire brands, even from those products distributed in regions where phosphates were permitted. In 1993, P&G removed STPP from its Tide brand, the last major household brand sold in the U.S. to contain phosphates. This left only a few minor brands to be marketed in the U.S. containing phosphates, generating demand for approximately 40 million lbs. a year (Coeyman, 1994).

In 1991, two leading producers of phosphates, Olin and Occidental Chemical, exited the market entirely. This move resulted in the elimination of 30% of U.S. capacity. In addition, the remaining producers cut back production. By 1992, only FMC Corporation was still selling to the home laundry segment of the detergents market. The company hoped to build up its Mexican market, bolstered by NAFTA (Kemezis, 1994). Other firms exclusively concentrated on the institutional and industrial and automatic dishwashing markets. Prospects for export of phosphates were poor, as manufacturers continued to phase out the substance from products, and sufficient local capacity existed overseas. These firms did not attempt to innovate.

### **World Market**

In general, only regional markets for laundry detergents were susceptible to foreign entrants (e.g., Japan's move to Thailand; U.S. marketing in Canada; European cross-marketing). Consumer preferences for fragrance and other characteristics differed substantially around the world, precluding detergent formulas from being marketed on a truly international scale.

Detergent ingredients, however, were more suitable to international trade. Surfactants and enzymes could be flexibly used in a multitude of detergent formulations.

The contraction of phosphate production, as illustrated in the chart below, led to increasing centralization of detergents production in Europe (Milmo, 1992).

<b>Country</b>	<b>% of laundry detergents containing phosphate</b>
Switzerland	0
Norway	0
Italy	0
Germany	0
Austria	0
The Netherlands	0
Belgium	10-20
Denmark	50-60
Sweden	50-60
Finland	50-60
France	70
Spain	75
Greece	85-90
Portugal	85-90

Overall, the world market in the 1990s was shifting toward concentrated detergents, enzymes and innovative surfactants.

### **Country Competitiveness**

#### United States

Concentrated detergents, first created in Japan, took root in the U.S. by the late 1980s. By the 1990s, key detergent makers had ultra detergent lines.

Although Belgian detergent manufacturer Ecover had penetrated niche markets (i.e., regional and eco-friendly shoppers), the top companies were not threatened by outsiders.

U.S. competitiveness was hampered in enzyme manufacturing, however. The public concern that erupted over enzymes in the late 1960s in the U.S. drove enzyme production in Europe, where concerns were nonexistent. There, product reformulation continued and leading producers gained a steep advantage that U.S. manufacturers were not able to overcome.

In the mid-1980s, P&G reintroduced enzymes into U.S. detergents to improve product performance, relying on European suppliers. The newly-formulated detergents were successfully marketed on "new,

improved" qualities. To compete with P&G, others re-formulated detergents with enzymes, further strengthening the market for European-producer enzymes. Ultimately, P&G began to introduce its own enzymes, such as its distinctive cellulase designed to protect fabrics.

## Europe

As noted, after the discontinuance of enzyme production in the U.S., European manufacturers continued to develop safer and higher-performing enzyme formulations.

Although initially, major enzyme supplier and Danish company Novo Nordisk suffered a major drop in sales, falling from \$86 million in 1969 to \$60 million in 1970, it gained ground over the next decade and a half.

In 1995, Novo Nordisk was the dominant firm in the overall industrial enzyme market, controlling approximately 50% of the \$1 billion world market (DiCorpo, 1995). Competitors in the industrial market included Genencor International, Gist-Brocades, and Solvay Enzymes. In 1987, Novo controlled 70% of the U.S. detergent enzyme market and Gist-Brocades commanded most of the remaining market share (Savage, 1987). Novo Nordisk's 1993 detergent enzyme sales were \$230 million, 11.5% of the company's total sales (Flynn, 1994).

Genencor International was Novo Nordisk's chief competitor in the detergent enzyme market. The company was a privately-held joint venture of Cultur Oy (Finland) and the Eastman Kodak Company. The company In 1993, Genencor International had total sales of \$150 million. In 1995, the company bought Gist-Brocades' detergent enzyme business.

## Japan

Japan led the Asia/Pacific region in detergent innovation and was the leading market for compact powder and liquid detergents. Growth in Japan was extremely rapid; in 1987 only 8% of the detergents marketed in Japan were concentrates. By 1990, super-concentrates accounted for 80% of the powdered market and 72% of the total market. Japan was a relatively restricted market, given trade barriers; Kao and Lion controlled more than 60% of the market. Japan's innovation with ultras, however, did not provide it with a first-mover advantage in non-Asian markets, since other markets were largely invulnerable to foreign competition.

Kao initiated a move towards 100% natural oleochemical surfactants in response to demand for natural rather than synthetic surfactants. While most compact brands of detergent use conventional surfactants such as LAS, new compacts were introduced in 1991 by Lion Corp. that used another surfactant which allowed for high concentrations compared to LAS. As a result, the new compacts contained half the surfactant compared with LAS-based compact. The new surfactant, methyl ester sulfonate (MES) could be manufactured from renewable resources, it was biodegradable, and had a high tolerance to calcium found in hard water. Water tended to be softer in Asia, so less builder was required, and the proportion of surfactant to builder was high in the region compared with the West. Use of phosphate builders in Japan was not restricted by law but had been voluntarily removed; all detergents were phosphate-free.

In 1995, the market for super-concentrates was saturated and Kao focused expansion efforts on Thailand where washing preferences were more similar than in larger, more foreign markets. The likelihood for gaining ground in the U.S., for example, was limited by differing washing preferences. Unlike in the U.S.,

Asian consumers sought high-foaming, low-temperature washes.

Enzymes were well suited to the Japanese tendency to wash clothes in low temperatures. In addition, the high cotton content of clothes made cellulases very effective. Enzymes targeting specific soils, such as proteases to remove soil from shirt collars, were being bioengineered by Kao.

### **Buyer Market Position**

During the early and mid-1990s, detergent raw materials suppliers were primarily concerned with providing ingredients to allow concentration of detergents and mildness. Due to the constant product reformulation which occurred in the laundry detergent industry, suppliers needed to anticipate manufacturers' needs, and be able to supply effective ingredients at little or no additional cost. In order to accomplish this, many suppliers formed research partnerships with manufacturers. This arrangement allowed suppliers to work closely with manufacturers and to develop new materials over a several year period.

### **Substitution Rate of Technology**

#### Surfactants

Detergent manufacturers switched to LAS from branched alkylbenzene sulfonate during the 1960s in response to concerns that the branched version was not as readily biodegradable. However, in the mid-1990s, BAB was still commonly used throughout Latin America and other developing regions.

In 1991, there were only two U.S. suppliers of LAS: Vista and Monsanto. Vista's production capacity was 490 million lbs. and Monsanto's 350 million lbs. for the U.S. market in 1991 (Verbanic, 1991). Several years later, Huntsman Chemical bought two chemical lines from Monsanto, LAS and Maleic anhydride, which together represented \$200 million in annual sales. Vista Chemical Company, a private company, had 1993 sales of \$700 million.

The world market for LAS in 1993 was estimated between 3-3.5 billion lbs. World usage was expanding at 2.5-3.5%, although this growth was not uniform. Demand in Japan, for example, was declining, and the European market was experiencing about 1% growth. In regions like Eastern Europe and China, LAS demand was growing at an annual rate of 6-7% ("Soaps and Detergents", 1990).

In the 1990s, LAS was increasingly replaced by carbohydrate and sugar-based surfactants. For example, Henkel's APG (an LAS substitute) production capacity in 1994 was 50,000 million tons, sourced from a plant opened in 1992 in Cincinnati, OH. In 1995, Henkel brought a second plant on line in Dusseldorf. This surfactant possessed unique qualities expected to provide Henkel with a "powerful competitive tool in the battle for market share," ("Henkel", 1994) as it was sourced from renewable, natural resources, and it was mild.

Henkel hailed another LAS substitute *N-methyl glucosamide* as a "major move" for P&G, and a "demonstration that it (carbohydrate-based surfactants) works." (Breskin, 1995)

#### Builders

As the phosphate market declined, production of zeolites grew. In 1993, however, demand for zeolites

remained flat in the U.S. This phenomenon was due largely to a major pricing war that made liquid products more attractive to consumers, pulling market share away from powders based on zeolites. J.M. Huber exited the market that year. However, as the chart below illustrates, demand growth for detergent zeolites was expected to continue to rise through 2000. Industry projected growth to 500,000 million tons by the end of the century.

### Enzymes

In 1994, market penetration for proteases was 75% in the U.S., 95% in Europe and 95% in Japan. Future growth for proteases was expected to come primarily from the Latin American, Chinese, and Southeast Asian markets, in sync with the growth in detergent demand (DiCorpo, 1995). Proteases sold for about \$3.35 per pound.

Between 1992 and 1994, the market for detergent lipases was estimated to range between \$10-30 million (Singletary, 1992). In 1994, market penetration for lipases was 25% in the U.S., 50% in Europe, and between 15-20% in Japan.

Cellulases did not penetrate the market as deeply, although P&G found success in its proprietary enzyme Carezyme. P&G credited the introduction of Carezyme as "one reason brands like Cheer outperformed the market." (Flynn, 1994)

### Ultras

Ultras caught on very quickly; by 1989, 80% of the Japanese powder market had converted to ultras. By 1995, compact powders represented 88% of the U.S. powder market; 100% of the Dutch market; just over 50% of the German and Austrian markets; and just under 30% of the Spanish and Italian markets. In Japan, compact powders represented 90% of the total laundry detergent market, powder and liquid combined (Graffmann, 1994).

### Packaging

In 1995, P&G maintained its position as the sole producer of resealable polybags for powders. The relative success of the product was not divulged by the company owing to the limited period of time it had been on the market.

### Regional Formulas

In 1993, Ecover predicted that its detergent designed for Amsterdam would capture 10% of the city's market. In the following two years, Ecover did not aggressively pursue its strategy of differentiation through regional market-specific products. Nor did competitors appear to follow Ecover's lead in regional formulas.

## **EFFECT OF ENVIRONMENTAL INNOVATION ON INDUSTRY**

### **Ripple Effect**

Innovative surfactants increased performance standards in the detergent industry. Witco's market manager for detergents recognized the move toward alternatives as a "big development . . . It was very remarkable.

That doesn't mean that P&G is abandoning LAS, but this is a major brand and they were willing to look at new materials, an alternate surfactant. This is not an isolated incident, it shows that the industry is willing to investigate alternative materials for commercial products. In the past, it would have been considered too costly." ("Surfactants and Detergents", 1995) Vista, however, characterized the formulation as "very limited." (Breskin, 1995)

According to Joel Houston, a leading industry consultant, sugar-based surfactants were "part of a step change in detergent formulations which appears to be raising performance standards for laundry products." ("Surfactants Keep", 1995)

The early Japanese development and success of ultras spurred the efforts of others. In order to preempt a move by Kao into the European and U.S. markets, other manufacturers introduced their own concentrated formulas in the late 1980s and early 1990s. In these regions, ultras were marketed to end-users less on their compact size than on the environmental benefit generated through detergent concentration and the resulting reduction in packaging and raw material use. Particularly in Europe's environmentally aware market, these attributes proved attractive to the average consumer. In addition, trade customers appreciated the reduced use of shelf space.

The move to ultras increased the pressure on manufacturers to examine each ingredient used in a formulation. Because equal or improved performance had to be achieved with less volume, each raw material had to provide as much "bang for the buck" as possible.

The re-introduction of enzymes into U.S. detergents, marketed on their "new, improved" qualities, spurred other manufacturers to use copycat technology in order to match P&G's product performance.

### **Supporting Industries**

The enzyme market continued to grow rapidly through the mid-1990s. In 1988, the world market for detergent enzymes was approximately \$124 million, with \$50 million markets in both the U.S. and Europe, and a \$24 million market in Japan. The detergent enzyme market grew 10% in 1994. This rate was expected to slow during 1995, although overall tonnage produced would grow 10-15%. By 1995, the world market had reached \$400 million. Although the volume of enzymes produced continued to grow, falling prices kept market growth in check. (DiCorpo, 1995)

Market growth was expected to be fueled by several factors. First, the continued trend toward concentrated products made enzymes attractive to manufacturers, since enzymes are extremely effective in small quantities, and therefore prove extremely useful in attempts to improve detergent performance while using fewer and fewer ingredients. Second, enzyme use benefited from a positive environmental image. As manufacturers looked more closely at the environmental impact of their raw materials usage, a naturally produced protein offered a benign and effective alternative to synthetic chemicals. Third, producers continued to attempt to make up for the loss in cleaning ability due to the elimination of phosphates, and enzymes offered a method of improving performance. (Singletary, 1992) Finally, as concern for energy consumption drove appliance manufacturers to design machines which operated at colder temperatures, detergent manufacturers needed to reformulate products accordingly. Enzymes proved effective at colder temperatures.

### **SUMMARY**

With the advent of the modern environmental movement in the early 1970s, the detergent industry increasingly came under attack on environmental, health and safety grounds. Following the outcry over unsafe enzymes, the industry was pressured to find innovative ways to eliminate hazardous product content, promote the reduction of energy use and consume less plastic and paper packaging while improving cleaning performance and cutting costs.

The marketplace for detergents was increasingly competitive in many dimensions. Ultras and re-fill bags were environmental winners. One manufacturer, Lion, saved the equivalent of 170 million sheets of paper annually in reduced packaging for its ultra products. P&G's compacts reduced the chemical content by 25%. Re-fill packaging in the mid-1990s won the Green Globe Award for environmental achievement.

Although ultras were also successful in enhancing detergent performance (e.g., Kao's ultras were better at absorbing calcium ions in tap water), enzymes proved highly valuable for their superior performance in removing stains and protecting fabrics, as well as for their non-toxicity.

Environmentally-inspired process innovation contributed to the competitive dynamics of the detergent industry as well. Rhone-Poulenc's builder dissolved faster, reducing washing time and thus saving energy. Likewise, Lever Bros.' manufacturing process eliminated the need for dry-spraying towers, affecting an 80% reduction in energy use.

Without a doubt, environmental pressures had emerged as a driving force in the detergent industry as echoed by industry analysts, producers and suppliers. Performance, cost, and environmental attributes were consistently linked together as minimum standards for product reformulation. As Richard Hall, Environmental, Safety Manager at P&G stated, "Materials have been rejected from formulations because of environmental concerns. We try to do a good job on the front end. One environmental mistake can cost a whole lot of money," (Hall, 1995).

## SOURCES

- Breskin, Ira. "Consumers Resist Increased Liquid Concentration." *Chemical Week*, January 25, 1995.
- Chynoweth, Emma. "Cleaning Up with Novel Detergent Know-How." *Chemical Week*, October 13, 1993.
- Coeyman, Marjorie and Paul Kamezis. "P&G Reformulates Away from STPP." *Chemical Week*, January 19, 1994.
- "Detergent Producers in Japan." *Market Share Reporter*, 2nd ed 1992.
- DiCorpo, James A. "Global Visions: Detergent Additives Manufacturers are Turning to Reformulation and Globalization in an Attempt to Maintain Profit Margins." *Chemical Marketing Reporter*, January 16, 1995.
- Flynn, Julia. "Novo Nordisk's Mean Green Machine." *Business Week*, November 14, 1994.
- Gerry, Roberta. "Ultra Detergents Continue Very Big." *Chemical Business*, January 1993.
- Graffmann, Heinz-D. "Product Trends in European Detergent and Cleaner Market." *Proceedings of the 3rd World Conference on Detergents: Global Perspectives*. Champaign: AOCS Press, 1994.
- Hall, Richard (Proctor and Gamble). Personal Interview. 13 July 1995.
- "Henkel -- Going for Growth." *ICC Stockbrokers Research Reports*, January 18, 1994.
- Kemezis, Paul. "Zeolite Producers Claim Record Gains in 1992." *Chemical Week*, January 27, 1993.
- "Phosphates Fight to Hold Position as Zeolites Hope for an Encore" *Chemical Week*, January 26, 1994.
- Lafley, A.G. "Leading a Changing Industry Into the Twenty-First Century." *Proceedings of the 3rd World Conference on Detergents: Global Perspectives*. Champaign: AOCS Press, 1994.
- Leikhim, John W. "Progress and Change: Industry Drivers in the Americas." *Proceedings of the 3rd World Conference on Detergents: Global Perspectives*. Champaign: AOCS Press, 1994.
- Milmo, Sean. "Expanding Family: the European Market is Digesting the New Compacts, and Soapers Now Eyeing Product Differentiation." *Chemical Marketing Reporter*, January 27, 1992.
- "A New Generation: European Detergent Manufacturers are Gaining Strength from New Technologies and Improved Formulations." *Chemical Marketing Reporter*, January 16, 1995.
- Mullin, Rick. "Japan's Market Under Pressure." *Chemical Week*, January 27, 1993.

-----"New Hard Driver: Mild Performance." *Chemical Week*, April 19, 1995.

"Novo Nordisk exec high on China market prospects; Lars Rebien Sorensen." *Chemical Marketing Reporter*, June 6, 1994.

Pedersen, Alfred, Shoto Ushio and Susan Jones Ainsworth. "Novo Fights the Washday Blues." *Chemical Week*, July 27, 1988.

Savage, Peter. "Three Companies Team Up in a Biotech Venture." *Chemical Week*, July 8 1987.

Singletary, Lynda. "Molecular Modeling Refines Genencor's Lipases." *Chemical Marketing Reporter*, May 4, 1992.

*Soaps and Detergents*. New York: The Soap and Detergent Association, 1994.

"Soaps and Detergents: New Opportunities in a Mature Business." *Chemical Week*, January 31, 1990.

"Surfactants and Detergents News." *INFORM*, January 1995.

"Surfactants Keep Steady Course." *Chemical Week*, January 25, 1995.

Tsumadori, Masaki. "Soap and Detergent Trends in Asian and Pacific Countries" *Proceedings of the 3rd World Conference on Detergents: Global Perspectives*. Champaign: AOCS Press, 1994.

"Unilever -- Recovery, Cost Reduction and Organic Growth." *ICC Stockbroker Research Reports*, May 21, 1993.

Verbanic, Carl. "Detergent Makers Show Battle Colors." *Chemical Business*, January 1991.