Automatic dishwashing relies primarily on mechanical energy, which is a much smaller factor in the cleaning equation for automatic dishwashers. Autodish machines depend more on chemical energy in the form of more effective detergents, on higher wash temperature, and on more time spent cleaning (Figure 1).

The formulation of ADDs is thus completely different from that of a manual dishwashing detergent. ADDs reduce surface tension to ensure proper wetting to penetrate and loosen soil, tie up water hardness minerals that may interfere with cleaning efficacy, emulsify greasy or oily soil, suppress foam, help water to “sheet off” surfaces, and protect delicate items (fine china, inlaid dishware) and metals from the corrosive effects of heat, water, and the cleaning agents of the ADD.

Autodish machines and detergents

Automatic dishwashing (“autodish”) machines can be found in homes around the globe, especially in developed nations and those experiencing economic growth. These autodish machines rely on processes and detergents that differ markedly from those used in clothes washing machines.

Similarly, machine dishwashing is not just an automation of the manual chore done in a sink or tub. Manual dishwashing requires a balance of cleaning, wetting, rinsing, and other processes that are optimized for a specific set of constraints. In contrast, the formulation of an automatic dishwashing detergent (ADD) is designed to address the unique challenges of machine dishwashing.

Although detergents used for manual dishwashing must similarly focus on cleaning performance, other major priorities include skin compatibility, solubility, wetting, and foaming behavior. The formulation of ADDs is thus completely different from that of a manual dishwashing detergent. ADDs reduce surface tension to ensure proper wetting to penetrate and loosen soil, tie up water hardness minerals that may interfere with cleaning efficacy, emulsify greasy or oily soil, suppress foam, help water to “sheet off” surfaces, and protect delicate items (fine china, inlaid dishware) and metals from the corrosive effects of heat, water, and the cleaning agents of the ADD.

Autodish machines

Autodish detergents do not work in
isolation, but act in synergy with the autodish machine, which itself has evolved over the years. Although the technology of autodish machines may be considered relatively mature, innovation helps keep sales booming.

In the manufacture of electrical domestic appliances, production of dishwashing machines is the fastest-growing sector worldwide. Annual U.S. sales grew about 5% to approximately 5.1 million units sold during 1998 and have increased 30% over the past five years, according to the Association of Home Appliance Manufacturers (AHAM) in Chicago, Illinois.

Some of the international sales growth is fueled by entirely new markets opening up in developing nations. As income levels rise, labor-saving “convenience” items become a part of the household, beginning with the more affluent areas.

Still, part of the continuing growth of autodish machine sales comes from within developed countries, as autodish significantly trail the market penetration of clothes washing machines.

“Everyone has a washing machine for their laundry,” said Vincent Croud, manager of the advanced technologies division of Warwick International, Mostyn, United Kingdom. “Not everyone has a washing machine for their dishes.”

In the United States, dishwashing machines are found in approximately 55% of households. In Europe, 33% of households owned a dishwasher in 1997, up from 26% in 1992. This figure is higher in Switzerland, Germany, and some Scandinavian countries, where more than 40% of households own a dishwasher. In Japan, the third-largest market for consumer goods, only 7–8% of households own a dishwasher. That percentage, however, has doubled since 1994.

Although autodish markets exist in Canada and Australia as well, the main autodish machine and detergent markets are spread primarily over the United States and Europe and present a study in contrasts. From the types of food soils to consumer habits and societal trends, the differences are many. Of course, there are some similarities, beginning with basic dish-washer function: spraying a recirculating water reservoir onto dishes and glasses—with detergent added during the main washing process, without it for the rinse cycle. Beyond that basic description, the machines themselves are different down to the basic building blocks: plastic is used more often in the United States, stainless steel in Europe.

One of the more important differences between the autodish machines, however, actually revolves around the water supplied to them. Approximately 60% of the United States has water hardness under 90 parts per million (ppm) calcium carbonate, including the 10% of homes that use a water softening appliance. In Japan, water in 92% of households falls under that level. In contrast, only 1% of homes in Great Britain have a water hardness level under 90 ppm, but 62% have a level over 270 ppm. On average, about 42% of homes in Western Europe have a water hardness level greater than 270 ppm, with 74% of Belgian homes exceeding 270 ppm.

European water hardness levels necessitate a built-in water softener in autodish machines. This component softens water via an ion exchange unit, which must be periodically recharged by the addition of regenerating salt. If consumers forget or do not take the time to regenerate the water softener, washing performance can suffer.

Another difference between the continents is the amount of water used by the autodish machines, and the way in which it is heated. European models are attached to a cold-water inlet line and have a built-in water heater to heat the water to the proper operating temperature of approximately 65°C (149°F). In the United States, autodish machines are attached to a hot-water inlet line and use a built-in water heater to boost the temperature only when needed.

In Europe, the amount of water

Figure 1. Estimates of importance of cleaning factors for machine and manual dishwashing (Source: Henkel KGaA).

(continued on page 233)
used during a wash cycle has dropped to 15–18 liters from 60 liters in 1970. In the United States, the average volume of water is about 30 liters (8 gallons), but the former average inlet water temperature of 60°C (140°F) has slowly declined to 50–55°C (120–130°F) as more energy-conscious consumers turn down their household water heaters.

As the same water heater supplies hot water for bathing, showers, and laundry, the water fed into an autodish machine might be about 45°C (110°F) instead of 50°C (120°F). In addition, the nearest 15–20 feet of water line to the autodish machine may contain cold water, which enters the machine before hot water makes its way in from the water heater.

In Japan, compact countertop dishwashers have been developed to fit compact kitchens. These autodish machines use 14–23 liters of water, with wash temperatures ranging from 30–50°C (85–120°F).

How important is the temperature of the wash water? Although a higher temperature helps the detergent to work more effectively, it also detracts from an autodish machine’s energy efficiency. Heating up the water for cleaning dishes constitutes the greatest energy expense in dishwashing, whether by hand or machine. It dwarfs the energy needed to manufacture the detergent and operate the electronics and equipment in an autodish machine, according to a European study by Henkel. A study by German conglomerate RWE found that machine dishwashers consumed 53% less water than manual dishwashing.

**Machine trends**

The future of the autodish machine, whether in Europe or the United States, may well be determined by current trends affecting dishwasher design.

One current innovation is the development of sensor-based dishwashers. Maytag Corp.’s model uses an optical sensor to measure turbidity in the first rinse cycle, checks the machine’s fuzzy logic system and past usage, and sets the number of remaining wash cycles. Whirlpool Corp. and General Electric Co. make similar sensor-based machines that detect the level of soil in the rinse to determine the number of wash cycles. The impetus behind these machines is to save time and energy by washing only as long as necessary.

Sensor-based washing was the manufacturers’ response to the large number of U.S. consumers who “pre-rinse” dishes before placing them in the dishwasher. With approximately
70% of consumers rinsing off dishes before placing them in the dishwasher, the average cleaning job seen by U.S. autodish machines is far easier than the worst-case scenario represented by the AHAM performance standard. Manufacturers design their machines to achieve a good score on the standard, which tests performance given a generic detergent and a standardized but tough-to-clean food load.

Although sensor-based washers have been marketed over the past two years, the current trend is for such technology to trickle down from the premium machines to the middle-tier dishwashers that cost less. Another possibility in the future is for sensor-based systems that determine the level of dishwashing detergent needed and then prompt automatic dosing systems to add just the right amount.

Another current trend, primarily in response to consumers’ fear of germs, is marketing of dishwashers that are “certified to sanitize.” At least two U.S. manufacturers produce autodish units that have been certified by the National Sanitation Foundation (NSF) International, based in Ann Arbor, Michigan. NSF certification previously had been used mostly for commercial equipment, including the institutional-sized industrial-strength dishwashers used in food service establishments.

The sanitizing cycles require a high, steady temperature, necessitating a greater boosting of the temperature of water coming in from the household water heater. Although this trend may continue, it is difficult to reduce the energy used by an autodish machine that offers high-temperature sanitizing cycles. In the future, “certified to sanitize” may come into conflict with federal regulations to reduce household energy usage.

The U.S. Department of Energy (DOE) has published energy efficiency requirements, in effect since 1994, which are based on a maximum allowable “energy factor,” defined as kilowatt hours per cycle. This statistic does not, however, address the cleaning efficiency of the dishwasher or detergent, since the testing protocol uses clean dishes and no detergent.

According to AHAM, the average energy factor for U.S. dishwashers dropped 50% between 1972 and 1996. That is, operating autodish machines manufactured in 1996 required about half as much energy needed for machines made in 1972.

As early as 1996, DOE could have started a new round of energy efficiency rulemaking on dishwashers, but chose not to do so. The DOE Office of Codes and Standards considers this a low priority, as manufacturers have continued to make dishwashers more energy efficient without tighter regulations, and the energy used by dishwashers is relatively small compared to that used by other regulated appliances, such as clothes washing machines, water heaters, and air conditioners.

Following the lead of European laundry washing machines, autodish machines now fall under compulsory energy labeling in Europe. Labeling with performance and energy data will become mandatory on July 31, 1999. There are no mandatory or voluntary energy efficiency standards attached to this new requirement.

“With labeling now in place, we are starting to look at the possibility of preparing an industry voluntary agreement within CECED (the European Committee of Manufacturers of Domestic Equipment) on dishwashers, similar to that agreed upon for washing machines,” said Stuart MacConnnacher, head of the European technical applications group of the Association of Manufacturers of Domestic Appliances in London, United Kingdom. The European clothes washing machine industry set the precedent when it voluntarily agreed with the European Commission to withdraw the least efficient models from the market.

**ADD formulation**

The autodish machine does not act in isolation, but in synergy with a special type of detergent carefully formulated for the conditions inside the machine. For example, the surfactants that drive the cleaning action in laundry detergents do not have as important a role in ADDs. The surfactants used in ADDs are typically different from those used in laundry detergents, and lower levels are used in ADD formulations.

Although surfactants provide sheeting action to prevent spots or filming, they also may produce foam that reduces the efficiency of the water pump and inhibits the cleaning process. Thus, low-foaming surfactants are required and defoaming agents are often added to combat foam generated by protein soils.

ADDs rely mainly on alkalinity, rather than surfactants, for cleaning. Alkalinity is provided by phosphates, silicates, and soda ash, for better soil dissolution and emulsification. Silicates also protect fine china and dishwashing machine components against corrosion.

Sodium tripolyphosphate (STPP) has been used as the preferred builder in North American ADDs because of its multifunctionality: water hardness sequestration, soil removal, soil dispersancy, and buffering capacity. Use of phosphate is so prevalent that approximately 45% of the STPP manufactured in North America is used in ADDs, despite the fact that ADD production is just one-tenth to one-

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**Autodish detergents rely mainly on alkalinity, rather than surfactants, for cleaning.**

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twelfth that of laundry detergent production.

Although phosphates have been replaced in premium laundry detergents in Europe, the United States, and Japan, laundry phosphate replacements such as zeolites and soda ash have not fared as well in ADDs. Although citrates and polycarboxylates are used instead of phosphates in some markets, such as Japan, these account for 5–10% of ADDs around the globe, according to Harald Magg, a chemist in ADD research and development at Benckiser Productions GmbH, Ludwigshafen, Germany.

In Europe, where ADDs account for 3% of annual phosphorus emissions to the environment, reduction of phosphates in ADDs still seems to be a long-term goal.

"But at the moment, phosphate-free ADD formulations have certain disadvantages compared to those with phosphates," said Christian Nitsch, a chemist in ADD research and development at Henkel KGaA, Düsseldorf, Germany. Performance on bleachable stains, dried-on/baked-on soils, and lime scale-inhibition suffers without phosphates.

Zeolites, frequently used in phosphate-free laundry detergents, are not used by the major ADD manufacturers due to problems with deposition. Zeolites are not water-soluble, so they can act as an abrasive on dishes and leave a residue. In addition, zeolites are more costly than phosphate builder systems, do not perform as well, and there is little regulatory or consumer incentive to push for a phosphate substitute. Another alternative builder, citrate, is not compatible with the chlorine bleach widely used in North American ADD formulations, is inferior in sequestration to phosphate, and is generally more expensive.

Even though phosphates are considered a vital part of ADDs, the maximum phosphorus content in U.S. formulations is limited to 8.7% by many local and state governments. As phosphorus makes up approximately one-fourth the weight of STPP, this limits ADD formulations to 34.8% STPP. In Europe, some countries, such as Switzerland and Italy, have phosphate limitations.

"In general, however, there is a trend toward phosphates in Europe," Nitsch said.

Although polymers are not widely used in phosphate-based ADDs, a reduction in the level of phosphates would create a need to use polymers to prevent the formation and deposition of insoluble calcium phosphates. Acrylic and maleic polymers also can be used, either separately or together as copolymers, to prevent crystal growth of calcium carbonate, reduce growth of crystals already formed, and disperse particulate soils so they do not redeposit on dishes.

Chlorine, pH, and enzymes

"The main difference between European and U.S. autodish detergents is enzymes," Magg said.

According to Magg, a major change took place in the European ADD market about seven years ago, with a move away from metasilicates and chlorine, which were considered corrosive and a safety hazard. Peroxygens bleaches are now used instead of chlorine bleach, and metasilicates have been replaced by sodium carbonate and disilicate.

"Today, 95% of autodish detergents on the market are considered not corrosive," Magg said.

The overall effect has been to lower the wash water pH from an average of 12.5 before the change to the current range of 10.5–11, Magg said. Lower pH also decreases the detrimental effects on glazes and glasses and improves the lifetime of dishes.

European ADD manufacturers found they needed enzymes to combat the performance loss due to a lower pH and removal of chlorine bleach. Proteases and amylases are the most common enzymes used to break down protein and starch soils, respectively. In the United States, however, ADDs already used the lower-pH disilicates, so there has been little push to add enzymes, which can significantly add to the cost of the formulation. Also, enzyme-killing chlorine bleach is still the standard in U.S. formulations, so there has been less incentive to add enzymes at the expense of chlorine.

"Enzymatic ADDs have a different performance profile than chlorine-based detergents," Magg said. Enzymatics work better at lower temperatures, such as 50°C, except on bleachable stains such as tea. The cleaning of starch and proteins, however, is better than that achievable with chlorine-based ADDs.

Peroxogen bleaches such as sodium perborate and percarbonate produce hydrogen peroxide bleach in the wash. At normal wash temperatures, peroxide is not an effective oxidizing agent, so formulators include an activator such as tetraacetyl ethylenediamine (TAED) to create a more effective peracetic acid anion for bleaching.

A more compact system is possible by using a bleach catalyst instead of an activator. Indeed, something good came from Unilever's work on the manganese-based catalyst first introduced in laundry detergent in 1994 and then withdrawn after being linked to fabric damage. Dishes are harder than fabrics, and bleach catalyst technology has been adapted by Unilever and others for use in European ADDs.

One disadvantage of the catalyst technology is that it does not provide biocidal activity. Although chlorine bleach provides this function, peroxogen bleach does not. The addition of TAED not only creates a better bleaching agent but also returns the biocidal activity lost when chlorine is removed from an ADD formulation.

"Water that remains in the machine between washings presents a problem if you do not have a biocide in the formulation," Croud said. "You provide an environment ripe for growing bacteria, and then they get sprayed all over your dishes the next time you run the washer."

Regardless, the use of more peroxogen bleach and a reduction in chlorine bleach would allow formulators more flexibility in introducing enzymes, unique surfactants, and a wider range of polymers. Yet in addition to stain removal, chlorine bleach also helps eliminate water spotting, and does a better job at it than peroxogen bleach does.

Spots are due to protein soils that are washed from dishes and glasses.
and dispersed throughout the dishwasher. The proteins serve as nucleation sites, to which water adheres and dries to form spots. Chlorine denatures proteins, disrupting the spot-forming process. Oxygen bleach does not do this as well, but is compatible with the use of enzymes, and protease enzymes can degrade proteins to reduce spotting.

**Product form**

Although powders still lead in European ADD market share (55% in 1997), tablets, called “tabs” in the industry, have taken the market by storm.

“Tabs are growing and growing, while liquids are constantly decreasing,” Nitsch said. “In countries such as France and Great Britain, however, the liquids maintain market shares.”

Benckiser has tested the waters in the United States as well, introducing ADD tablets nationwide in 1997. Meanwhile, Procter & Gamble test-marketed tablets in 1998 and Unilever has increased the distribution area of its own U.S. tablet within the last six months.

Still, Europe leads the way, with tablets gathering a 35% share of the European ADD market, and over 50% of the market in Germany.

“In one to two years, tabs will make up half the European market,” Magg said.

Germany likewise leads Europe in ADD sales and is the only European country to purchase more ADDs than manual-dishwashing detergents (Table 1). The ADD market for Western Europe (European Union countries plus Switzerland and Norway) was estimated at $945 million in 1996.

Of all the companies selling ADD products, Benckiser N.V., Amsterdam, The Netherlands, stands out in the crowd.

“We are the largest autodish detergent manufacturer in the world,” said Bob Scarella, research and development manager for Benckiser Consumer Products, Greenwich, Connecticut.

Benckiser NV, the household cleaning product subsidiary of Jos. A. Benckiser GmbH, had 1997 sales of $1.77 billion. ADD sales that year leapt 26% to reach $563 million, nearly 32% of the firm’s total. What makes Benckiser’s position more remarkable is that it competes with global megaconglomerates that have substantial detergent pedigrees.

The firm has hitched its wagon to the tablet phenomenon and is enjoying the ride. Benckiser is not the only firm making tablets, however, especially in Europe. Although each company may have its own process, tablets are generally manufactured by blending powdered detergent ingredients with tableting aids, then compressing them. Disintegration in the wash water can be improved by the use of polymeric dispersants, such as cross-linked sodium carboxymethylcellulose.

While the “rapid release” formulation gets ADD ingredients into the wash water quickly, other two-layer or tablet-in-tablet systems can be used to deliver normally incompatible ingredients. This allows enzymes, for example, to be released early in the wash cycle before the bleach is released to do its best work at the highest temperatures. Even though oxygen bleach is more compatible with enzymes, it would begin degrading the enzymes if both ingredients were released at the same time.

A typical European tablet may contain 30% or more STPP, with silicate making up 25% of the formulation. A perborate bleach may make up an additional 15%, TAED activator at 4%, polymer at 3%, and surfactant at 2%. Enzymes and sodium sulfate make up the balance. This sort of enzymatic peroxygen-based European formulation was what Benckiser introduced into the United States for the first time when the company brought out its tablet in 1997. Unilever’s U.S. tablet uses chlorine bleach and no enzymes.

In making ADD tablets, one modification to the typical powder formula is the addition of polymers because, even at 34.8% STPP, the overall detergent dosage is so low (20–25 grams) compared to powders (40–50 grams) that the formulation simply cannot contain enough phosphate to be effective as the sole builder.

Polymer cobuilders are therefore needed in tablets to help keep inorganic scale from depositing on dishes. When insufficient phosphate is included in the formulation, it can be “overwhelmed” and an additional phosphate complex film can form. Acrylic polymers cannot combat this type of film, but “weak acid–strong acid copolymers” can, and are often combined with polyacrylates in order to tackle both kinds of scale.

One potential problem with unitized dose tablets, however, is that, for some consumers, the tablet may provide an underdose or overdose of detergent. The tablet is formulated to provide good cleaning performance on most soil loads in water of average hardness, and thus suits most consumers. In hard water regions within the United States, however, a tablet might not supply enough detergent, but in soft water, the same product might deliver too much and could etch glasses. This can occur even in hard water regions if a household water softener is used, as many older models oversoften the water.

In addition, the “average” soil load in the United States masks the range of possibilities, from the most pre-rinsed almost-clean dishes to those containing week-old food remnants. A unitized dose may contain too much

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**Table 1**

1996 Sales of Dishwashing Products (million US$)

<table>
<thead>
<tr>
<th>Country</th>
<th>Automatic</th>
<th>Rinse aid</th>
<th>Manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>271.9</td>
<td>47.3</td>
<td>260.3</td>
</tr>
<tr>
<td>France</td>
<td>187.3</td>
<td>32.2</td>
<td>300.2</td>
</tr>
<tr>
<td>Italy</td>
<td>117.5</td>
<td>20.6</td>
<td>327.2</td>
</tr>
<tr>
<td>UK</td>
<td>133.4</td>
<td>16.9</td>
<td>217.0</td>
</tr>
<tr>
<td>Spain</td>
<td>45.6</td>
<td>8.3</td>
<td>185.5</td>
</tr>
<tr>
<td>Total</td>
<td>755.7</td>
<td>125.3</td>
<td>1,290.2</td>
</tr>
</tbody>
</table>

Source: Industrieberand Körperlilc:1" und Waschmittel (IKW), 1997
detergent for the first situation, and perhaps not enough for the latter. Powders avoid this type of situation, and are still the most popular ADD product form. In Europe, compact ADD powders with enzymes were launched in 1990. These reduced the dosage of traditional powders by one-third without reducing the bulk density much. By 1995, the market share of all compacts (powder, tablet, and liquid) had passed the 80% mark.

In the United States, enzyme-containing compacts hit the market in 1992, but were not as successful as in Europe. The opposite occurred in Japan, where compacts lead traditional powder ADDs. Enzymatic ADDs are also on the market in Australia and New Zealand.

In the United States, powders still lead with approximately 55% of the ADD market share, but gels hold 35-40% and tablets have already captured a 6-7% market share.

The main advantages of liquid gel ADDs are similar to those of tablets: convenience in dispensing and freedom from powder caking and dust. The formulation of the first liquid ADDs was equivalent to their powder brethren, with the ingredients suspended in a structured liquid matrix. These formulations suffered from inadequate shelf life and needed to be shaken before dispensing the product. Today, liquid ADDs are stable and easily dispensable as a consequence of the use of clays and cross-linked polyacrylates (with a molecular weight over 1 million) for dishwasher cup retention and suspension of insolubles.

It is difficult to formulate gels with sufficient levels of phosphates, so other builders are needed, and polymers are commonly used to help keep scale in check.

"If carbonates are used to bolster the builder role of phosphates, you may get calcium carbonate and leave chalk deposits on your glasses," said Jan Shulman, a research scientist at Rohm and Haas Co., Spring House, Pennsylvania.

In liquid ADDs, sensitive ingredients such as enzymes, nonionic surfactants, and sodium citrate can be oxidized by chlorine bleach. However, peroxygen bleach is not used in liquid ADDs because of its instability in aqueous formulations. Nonaqueous ADDs have been introduced in Europe, however, and can overcome some of these formulation difficulties.

Gels make up 10-15% of the EU market, roughly half the market share of gels in the United States. This disparity could have many reasons, but may relate to different consumer habits.

In Europe, dirty dishes often go into the washing machine direct from the table—without the pre-rinsing habits common in the United States. ADDs in Europe thus have to work harder at cleaning, which may account for the smaller market share for liquid ADDs there. Some feel the liquid formulations lack the performance of their powder and tablet rivals, as it is more difficult to suspend the most powerful ingredients in a liquid base. Gels also rely on chlorine bleach, which can be an unpopular ingredient.

"Northern Europe has a definite negative feeling toward chlorine as a bleach," Croud said.

Future trends
What will the future autodish machine look like? Manufacturers expect consumers to want less interaction with machines, less time involved in loading and unloading, and quieter operation. Manufacturers also are trying to stay one step ahead of energy efficiency legislation by improving machine designs before being required to do so.

In the United States, autodish machine and detergent manufacturers must contend with a changing consumer profile. Families tend to be smaller, spending more time on the go and eating more meals away from home, which means dirty dishes pile up more slowly at home. Two possible outcomes affect autodish: more partial loads being washed or dirty dishes sitting in a dishwasher longer before a full load is washed. The longer dirty dishes sit, the more difficult it becomes to remove some food soils.

At least one manufacturer has approached the dilemma of partial loads by offering a model with two dishwashers in one machine. New Zealand manufacturer Fisher & Paykel makes a "Dish Drawer" model
that squeezes two half-height dishwashers into the space of one.

Dishwasher technology is also expected to follow the current trend of intelligent program control, with the addition of low-temperature programs and overall reduced water consumption. ADDs will be expected to maintain cleaning performance under reduced energy conditions. More of the cleaning burden will be shifted away from mechanical energy, thermal energy, and time, with chemical energy expected to make up the difference.

"Not only will the formulations need to be more powerful, but you may see cleaning agents that are more specific to problem stains," Scarella said.

Yet decreasing the wash water temperature can have multiple negative effects on cleaning: increased deposition of slightly soluble salts, less removal of fatty soils, and decreased activity of oxidizing agents.

Unlike carbohydrate and protein soils, most fatty soils are liquefied by the high temperature wash water in autodish machines and thus can be more easily saponified by the alkalinity present. If wash temperatures are reduced to save energy, removal of greasy or oily soils may become more difficult and require the use of lipase enzymes in the ADD.

The formulation trend in Europe will continue toward low-alkaline ADDs, with phosphates complemented by poly(carboxylates), peroxygen bleach with activator or catalyst, and enzymes, according to Nitsch.

Still, a better version of the non-phosphate detergent may arise if the performance is acceptable and consumers are ready for it. Also, enzymes stable in chlorine bleach may be on the way, providing a way to combine the most effective stain-fighters in the ADD arsenal. Other ingredients may need to be multifunctional if detergent dosages continue to decrease.

"In the future, look for polymers to help facilitate removal of food soils," Shulman said. "If you develop the polymer properly, you can make it have surfactant characteristics."

In Europe, Nitsch expects compact tablets to continue gaining in market share, while powders can be expected to decrease in usage and liquids will hold steady.

"Convenience is important to the consumer, but not at the price of performance," Scarella said. "So you'll see tablets and gels continue to thrive in the U.S. market, but only if their performance meets consumers' expectations."

Europe is also ahead of the United States in the use of rinse aids. In Europe, 90% of autodish machine owners use a rinse aid, compared to roughly 40% of machine owners in the United States.

Rinse aids reduce interfacial tension and the uneven wetting that leads to spots during drying. Used at less than 1 gram per liter of solution, rinse aids usually contain a nonionic surfactant, a complexing agent, and hydroxylates. Not only do rinse aids decrease water spots but they also help dishes and glasses dry more quickly, protect glasses from etching, and even protect plastics.

Use of rinse aids is beginning to pick up again in the United States after having remained flat for several years. Autodish machine manufacturers are supplying rinse aids with new machine purchases, making a greater effort to discuss the benefits and give directions on how to use them, and also educating consumers who call the manufacturers' product hotlines with complaints.

"Rinse aids will become more a part of the dishwashing procedure," Scarella said. He also predicts that detergent booster products and/or water softeners will be used more often in the United States, bringing U.S. consumers a little closer to their European counterparts.

The next frontier for autodish manufacturers, however, may be a step beyond dishes altogether. An automatic machine for the washing and drying of pets was recently awarded a European patent, as described in the December 21, 1998, issue of Chemistry & Industry. The animal is cleaned in a central chamber studded with spray nozzles, and surrounding chambers contain clean water, a selection of soaps and shampoos, a fan and heating elements to dry the animal, and a hose to wash its paws before entering. Labeling requirements and energy efficiency mandates would soon follow, no doubt.