INFORM

Stirring Up Innovation

Environmental Improvements in Paints and Adhesives

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INFORM, Inc., is a nonprofit environmental research organization that examines business and municipal practices that threaten our environment and public health; assesses changes business and government are making to improve their performance; and identifies new business strategies and technologies moving the United States toward an environmentally sustainable economy. INFORM'S research currently focuses on strategies to reduce industrial and municipal waste and to preserve air and water quality.

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Preface

It is surprising, in this era of increasing knowledge about multiple threats to our environment and health, to recall that within many of our lifetimes risks widely known today were either unrecognized or simply accepted as the price of progress. Lead, for example -in gasoline, in house paints, and in residential plumbing - was a virtually unchallenged fact of life until the 1960s. Society has also accepted a burgeoning world of insecticides, agricultural pesticides, and consumer products containing toxics, with little understanding of the threats generated by toxic chemicals used in manufacturing and in many of these products.

Today, public awareness of these and other health and environmental hazards is growing exponentially. Federal and state laws and regulations govern, restrict, and sometimes ban hazardous chemical products; some provide economic and other incentives to change. Consumers scrutinize labels that didn't exist a few years ago and run their water taps longer to "get the lead out." More and more companies keep a weather eye to the evolving environmental mores of society and the tightening strictures of government and marketplace.

Whether in response to existing law or in anticipation of regulation still on the horizon, out of a true sense of stewardship or in quest of commercial gain, or for all of these motives, sectors of US industry are finding new ways of doing and making things to avoid the risk of harm to human health and the environment.

Stirring Up Innovation: Environmental Improvements in Paints and Adhesives examines the process of change in two industries whose products pervade our daily lives. Paint surrounds us: protecting, coloring, hiding, enhancing, marketing. Our books, cartons, furniture - and even critical sections of our airplanes - are held together by adhesives.

Besides the seven companies examined in detail for these case studies, INFORM identified more than two dozen that had taken steps to develop safer products. Our research sought insights on many factors leading to innovation: What did the companies see as the perceived dangers of continuing to do business as usual? What motivated innovation? What hurdles had to be surmounted? What regulations helped or hindered progress? What other factors, such as performance, price, consumer resistance to change, contributed to or detracted from successful innovation? What lessons may be drawn by corporate and government decision-makers about ways to promote corporate environmental innovation?

The number of companies scrutinized in this report, though not large, proved sufficiently broad to offer some lessons to others who are or may soon be on the verge of change. Those who may doubt the will or capacity of companies to respond to environmental challenges may be heartened by some of our findings - toxic solvents removed from paints, adhesives that will permit more recycling of books and cartons, coatings that eliminate the hazards of removing old lead-based paint, and more.

Stirring Up Innovation focuses on one type of change - product change -toward more sustainable ways of living and doing business. It does not address broader questions of sustainable commerce, such as whether all uses of these products are necessary. But these companies are taking steps that deserve to be evaluated and recognized as part of the process of essential change.

Joanna D. Underwood
President, INFORM

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Chapter 1: Introduction

This report presents the results of an **INFORM** study of seven companies that have recently introduced, or are in the process of introducing, environmentally enhanced products in the paint and adhesives industries. It is based largely upon interviews with company officials, supplemented by references to scientific, trade, and popular literature. Reference numbers appear in parentheses, e.g., (3); the corresponding list of references begins on page 111.

Goals of the Study

This study has four principal goals:

- To bring into focus the key environmental concerns associated with the use of paints and adhesives, and the responses of legislators, regulators, and consumers to those concerns.
- To illustrate the kinds of innovations that the paint and adhesives industries are introducing to address those environmental concerns and meet regulatory and customer requirements.
- To describe the regulatory and market environments in which the case study companies operate, and the relevant features of their internal organization.
- To identify characteristics of corporate policy, the marketplace, and environmental regulations that encourage or discourage the introduction to commerce of products that are more environmentally benign.

With clarification of the factors that help or hinder environmental innovation, policymakers in both the public and private sectors can creatively weigh options that may speed the "greening" of the US marketplace. With specific examples of the innovations that are being made by manufacturers of paints and adhesives, other companies may be motivated to develop and introduce other environmentally enhanced products that will be commercially successful.

What is an Environmental Innovation for this Study?

Industry can take many different actions that reduce the environmental problems related to the manufacture and use of paints and adhesives. These range from "end-of-pipe" control and treatment of pollutants, the traditional way of reducing manufacturing emissions and waste now recognized to be the least cost-effective approach, to the more environmentally sound and cost-effective management of industrial operations that avoids the generation of pollutants in the first place. With regard to products, approaches involve redesign to eliminate or reduce waste or contamination. This study addresses the environmental improvements through changes in the products that industry produces, rather than improvements in the processes for making those products.

For the purposes of this study, an environmental innovation is a product that reduces harm to the environment, relative to competing materials, and that is new to the marketplace. Environmental enhancements are defined broadly. They include the following classes of change in the product:

- Design for *reduced content of chemicals that may*

be *toxic* to human beings or animal or plant life, may contribute to ozone depletion, greenhouse gas formation, smog, acid rain, and the eutrophication' of surface waters, and may cause fire and explosions.
- Design to *reduce releases* of damaging materials to the environment (e.g., encapsulation), whether those materials are contained in the product itself or in another material.
- Design to *facilitate reuse and recycling* of the product, or incorporate recycled materials.
- Design to *decrease energy consumption* required for its manufacture, use, or disposal.
- Design to requirefewer *nonrenewable resources,* or fewer natural resources overall, for its manufacture and use.
- Design to require *minimal space or treatment* for safe disposal.

Environmentally innovative products need not address only an environmental problem caused by paints or adhesives themselves, but may also address a problem caused by products on which paints or adhesives are used - for example, a paint that increased energy efficiency by insulating painted surfaces. As defined in this study, they must be *new to a particular market.* Innovations might include:
- Completely new chemistry for a class of products.
- Application of technology developed in one area to another, either within a class of products such as paints, or from another class of products.
- Reintroduction of an older technology that had fallen into disuse.

Why Study Paints and Adhesives?

Why focus on paints and adhesives? Earlier research by **INFORM,** in *Tackling Toxics in Everyday Products* (2), showed paints and adhesives to be among the more common sources of potential exposure to toxic chemicals from everyday consumer products. This finding is buttressed by a database of the chemical constituents of household products compiled by the US Environmental Protection Agency (EPA) (3). Moreover, paints and adhesives pervade everyday life. They are found in numerous common commercial products and are ubiquitous - in the yellow stripe down the middle of the road, on refrigerators and automobiles, on the walls and floors of our homes, and even in our cereal boxes.

Among the constituents of paints and adhesives that give rise to the greatest concern are solvents and heavy metals.* Each of these broad classes of chemicals has members that are associated with significant toxic effects. For example, both lead and mercury are known to be toxic to the nervous system, with young children particularly sensitive to these adverse effects (4,5), while cadmium can cause major kidney damage if it accumulates to a high level in the body. Lead is also suspected to be a carcinogen (cancer-causing chemical).

The effects of solvents range from inducing dizziness and drowsiness to permanent nervous system, liver, or bone marrow damage. A number of solvents that have been used in paints are either known to cause cancer in human beings (e.g., benzene), or are strongly suspected of causing cancer (e.g., methylene chloride trichloroethylene). Some glycol ethers, widely used as solvents in water-based paints, are suspected of causing birth defects.

Further, in addition to direct toxic risks, paints and adhesives contain chemicals that can indirectly cause environmental damage in a number of ways. Among their component chemicals are a class of compounds, known as volatile organic compounds (VOCs), that can contribute to smog formation and depletion of the stratospheric ozone layer.

Because of the various risks that they pose, paints and adhesives have recently been the focus of public concern and legal and regulatory activity. In response, US industry has begun to introduce new, and possibly safer, ways of designing and manufacturing both paints and adhesives. This report examines what industry has done thus far. It seeks to identify ways to encourage progress in environmental improvement and remove obstacles to environmental innovation, both inside business and in the world of government and public action. It does not address other questions of sustainable commerce - for example: Are all uses of these products really necessary? Would a nail or screw make more sense than adhesives, in certain applications? Does furniture need to include a foam that requires adhesives? Are there protective and decorative approaches that are environmentally friendlier than paint?

To raise these further questions, however, is not to slight the important incremental steps toward improvement of existing products that continue to be in demand.

Notes

1. Eutrophication: excess nutrient levels that accelerate algal growth, which may lead to depleted oxygen needed by fish, and the eventual conversion of the water body into a marsh.
2. These are more likely to be found in paints, where they are used as pigments, corrosion inhibitors, and preservatives, than in adhesives.

Chapter 2: Findings and Conclusions

Overview

Paints and adhesives are everywhere, and serious environmental problems are associated with their use. They are among the more common sources of exposure to toxic chemicals from everyday consumer products. The key areas of concern follow:

- Toxic heavy metals such as lead, mercury, and cadmium, found in pigments and additives, can damage the nervous system and kidneys and may cause cancer.
- Toxic chemicals contained in solvents, long the major component in many paints and adhesives, can cause cancer, birth defects, nervous system damage, and other serious health problems during application, the product's life, and disposal.
- Their volatile organic compounds (VOCs) contribute to formation of smog, with its accompanying respiratory damage.
- Long-lived chlorinated organic compounds in some products can damage the stratospheric ozone layer and allow devastating ultraviolet light to reach the earth's surface; they also threaten water quality, human health, and wildlife.

Responding to increased public concern and legal and regulatory scrutiny, the paints and adhesives industries have introduced a number of innovative products that address these environmental problems. INFORM researchers have surveyed the literature on such innovations and identified some two dozen companies. (See Chapter 5 and Table 5-l). INFORM conducted interviews with and submitted questionnaires to officials of seven companies that have introduced such environmental innovations, in order to gain insights into the types of factors that promote or hinder such innovation. The case study companies are:

Ciba-Geigy Corp. (Ciba), Hawthorne, NY
Devoe & Raynolds Co., Louisville, KY
The Glidden Co., Cleveland, OH
Hüls America, Inc., Piscataway, NJ
Miles, Inc., Pittsburgh, PA
National Starch and Chemical Co., Bridgewater, NJ
Swift Adhesives, Downers Grove, IL

Findings

INFORM found that the seven case study companies were addressing environmental problems with innovations that ranged from eliminating the use of toxic chemicals to facilitating the recycling of paper. The innovators were responding to a wide variety of governmental and corporate motivations. But all encountered an array of regulatory and market impediments.

The Innovations

The innovations, devised for both broad use and specialized niche markets (See Chapter 5 and Case Studies) include:

- Organic chemical replacements for toxic heavy metals used to inhibit corrosion or prevent the growth of slime and barnacles on ships and other marine-based structures. [Ciba]
- Low-solvent, water-based paints that can replace solvent-based paints in applications demanding high gloss and durability. [Devoe & Raynolds]

- Paints that are completely free of added solvents and have no measurable VOC content. [Glidden]
- Paint colorants with no VOCs that eliminate the use of a toxic chemical, ethylene glycol. [Hüls America]
- A system of polymers that allows bridges to be repainted without the need for hazardous operations to remove toxic lead paint. [Miles]
- Adhesives that allow more paper products (such as books and corrugated cardboard boxes) to be recycled into new paper. [National Starch and Chemical]
- Adhesives for foam, such as that used in some furniture, that eliminate the use of a solvent known to contribute to depletion of stratospheric ozone. [Swift Adhesives]

Motivations

INFORM found that a wide variety of governmental and corporate considerations motivated these innovations and contributed to their entry into the market. (See Chapter 5.)

Regulatory Factors Promoting Innovation

Federal and state environmental regulations have proved to be a strong driving force for innovation. Some regulations directly affect companies in the paints and adhesives industry, such as the Resource Conservation and Recovery Act (RCRA), the Federal Food, Drug, and Cosmetic Act (FFDCA), the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and regulations of several states in compliance with the Federal Clean Air Act.

Regulation in some cases did not directly affect the innovating companies but created new needs for their customers, leading the case study companies to introduce innovative products to meet those needs. Or regulations in a specific market area, such as California or Germany, may influence a company with national or international marketing goals to bring its products into compliance with the regulated market's requirements rather than forfeit doing business there.

Federal government reporting and labeling requirements provide especially strong motivation for change, as companies are not eager to advertise hazards on their labels and in their public reporting.

Corporate Factors Promoting Innovation

Several of the case study companies indicated they were pursuing an explicit corporate agenda of environmental responsibility.

Others were focused on market opportunities that only coincidentally related to environmental concerns. All were driven by the expectation of commercial success, even if not in the short term.

Managerial flexibility and openness to change in the companies fostered innovation, as did collaboration between marketing and research staffs and greater decision-making autonomy among corporate divisions.

Impediments to Change

If some government and corporate factors in the modem paints and adhesives marketplace are fostering innovative solutions to environmental problems, INFORM found that others just as clearly are impeding innovation. (See Chapter 5.)

Regulatory Obstacles to Change

The stringent review facing new chemical products is seen by some companies as placing them at an unfair disadvantage with existing products that had entered the market in a less demanding regulatory environment and that are unlikely to be subjected to review under modem standards in the near future.

Negotiations between government and business over new regulations tend to focus on individual companies rather than entire industries. This may lead regulators to underestimate the true innovative capacity of the industry at large.

Corporate Obstacles to Change

The market tends to resist change even when economic as well as environmental advantages are promised. In some cases, resistance to new products reflected the combination of a cost disadvantage for the new product and skepticism regarding the seriousness of the environmental problem being addressed.

In other cases, traditional work patterns and industry rigidity in testing procedures and specifications acted as barriers to products that offered significant economic as well as environmental advantages.

Environmentally innovative products have proven unlikely to succeed if their performance is not perceived to be at least on par with the conventional products they seek to replace.

Conclusions

The findings of these case studies, while based on too small a sample to be definitive, suggest a number of policies that government and business could implement to foster further environmental innovation.

Regulatory Initiatives

The regulatory process could more broadly include manufacturers, their suppliers, their customers, and the industry's innovators, in order to better evaluate the potential innovative contributions of firms at many stages of the product life cycle.

To avoid stifling innovation and penalizing new products by regulating them more stringently than existing products, a new regulatory scheme could maintain state-of-the-art review of new products while keeping a regulatory eye on existing products. For example, regulations could analyze new products that serve a similar function and apply current knowledge about those products to the regulation of existing products as well.

To encourage more innovation, regulators could stress public reporting and product labeling requirements in devising regulatory mechanisms.

Corporate Initiatives

To overcome market resistance, producers of innovative products could make greater efforts to educate existing and potential customers about the economic as well as the environmental advantages of adopting new product designs and formulations.

Innovators may wish to ensure through testing, marketing, and demonstration that the new product performs its principal task at least as well as the existing products more familiar to customers. This would help overcome customer preconceptions that environmentally innovative products perform poorly.

Businesses offering innovative products can educate their trade customers that taking advantage of such products can yield significant benefits in the regulated marketplace. Innovators can encourage business customers to shed preconceptions about new products and evaluate costs from a broad perspective, rather than simply comparing prices of products with very different features.

Regulators can work with businesses and environmental leaders to create a more fair and representative playing field by properly defining the full environmental and public health costs of products. They can devise strategies for incorporating those costs into the product rather than have them remain as external costs.

Chapter 3: An Environmental Perspective

A Brief Primer on Paints and Adhesives

Paints

Although their actual chemistry can be extremely varied and complex (6-9), most paints can be described as consisting of four principal components:

- Pigments, which give the paint its color and ability to hide the underlying surface. These are generally in the form of finely ground powders.
- Binders or film-formers in which the pigment particles are dispersed, and which bind the pigment to the painted surface.
- Thinners or solvents, which are used to keep the paint in a liquid state during application, and to otherwise aid in the application of the paint.
- Additives, a broad class of ingredients subsuming a variety of functions not covered by the three primary components described above. Additives may be corrosion inhibitors, biocides, flattening agents (which reduce the gloss of the paint), and flow enhancers for easier application, et cetera. Some of the properties of additives may also be imparted to the paint by the pigments or film-formers themselves.

Paint thinners are generally intended to evaporate following application, or to react chemically with the binder, so that the applied paint consists of pigment, binder, and some additives.

Within this general framework, there is a multitude of possible mixtures, reflecting different types and amounts of pigments, binders, additives, and solvents, which can yield radically different paint products. For example, the two most common household paints, alkyd ("oil," or solvent-based)' and latex paints differ completely with regard to the chemistry (and even the physical form) of their binders. In the former case, a true solution of resin in solvent exists, while the latter are actually aqueous suspensions of finely-ground polymers. The physical and chemical composition of paints varies even more when the diversity of paint applications is considered. Some paints, for example, can be applied in solid form (powder coating) and cure (dry) with exposure to light and/or heat.

Another way to classify paints is by drying mechanism. Some cure simply by solvent evaporation (known as "lacquer drying"), others by absorption of oxygen from the air, and still others from within the paint by chemical reactions that may be catalyzed by additives or even by light. More detailed specification of alternate paint chemistry could extend for pages.

The market for paint products and related coatings can be divided into three primary components: architectural coatings, product coatings, and special purpose coatings. Each of these industry sectors in turn contains a number of subdivisions and includes a wide range of paint formulations and uses. All, however, can be distinguished by the general conditions that affect patterns of paint use.

Architectural Coatings

The most familiar category of paint products, architectural or trade-sales paints, comprises roughly half of the total US market for paints, by volume. It includes interior and exterior building paints, as well as paints for furniture and home repairs. Many specialized products also exist within this broad category, such as floor paints, or industrial maintenance coatings, which differ from the general run of architectural paints in ways that reflect the special requirements of their intended use (e.g., high resistance to abrasion or solvents).

Product Coatings

Another major market for paints consists of product coatings, or original equipment manufacturer (OEM) use. This includes such familiar products as household appliances and automobiles, and smaller, more specialized uses.

Special Purpose Coatings

This is the most heterogenous category, consisting of paint uses that do not readily fall into the two previous categories - such as marking traffic lanes on roadways, refinishing of automobiles or other equipment, and protection of steel structures such as highway bridges.

Economic Aspects of Paints

Annual sales of paints in the US market exceeded $12.2 billion in 1992, representing approximately one-third of the worldwide market.* Of this total, $5.1 billion represented architectural coatings, $4.3 billion OEM coatings, and the remaining $2.8 billion special purpose coatings. These dollar figures represented nearly 1.1 billion gallons of paint. (10-12) Sales to the architectural market represented 562 million gallons, with 334 million gallons of product coatings and 170 million gallons of special purpose paints (10). Nearly 60 percent of sales of architectural paints (285 million gallons) were for residential applications (12).[3]

Nearly one half of the content of paints in the US market is represented by solvents (5 billion pounds out of a total of 10.8 billion pounds). Of the remainder, resins account for 2.4 billion pounds, pigments 1.2 billion pounds[4] and additives 180 million pounds. "Other chemicals" account for 2 billion pounds (13). It has been estimated that 25 percent of all hydrocarbons used as solvents (293 million gallons in 1992) are used in paints and coatings (10).

There are nearly 1,400 companies in the paints and coatings industry, of which 626 (44 percent) have 20 employees or fewer. In a 1991 survey, 35 percent of the responding companies reported sales of less than $5 million per year, 21 percent reported sales between $5 million and $20 million per year, while 39 percent reported sales in excess of $20 million per year (14).

Adhesives

If the variety of paints and coatings makes a simple characterization difficult, the variety of adhesive substances makes it nearly impossible. There is not even agreement on what materials are adhesive; an adhesive is simply defined as a substance capable of holding materials together by surface attachment (15). That same substance, if applied to a single surface only, may be called a paint or coating. The only other requirements noted are that the adhesive must be capable of wetting the surface to which it is applied, at least for an instant, and that it be used in a relatively thin layer, so that it forms a joint capable of transmitting stresses.[5] Adhesives are widely used throughout industry, with special emphasis in the bookbinding, forest products and furniture (e.g., plywood and laminates), construction, automotive, aerospace, electronics, and packaging industries (16).

Economic Aspects of Adhesives

The size of the adhesives and sealants market is almost as difficult to describe as the chemistry of adhesives. One recent source describes the world market as $13 billion per year, with the US share at 40 percent, but also describes the US industry as $7.4 billion (which would represent 54 percent of the market). The top 10 US manufacturers had a 1992 market share of 34 percent, with no manufacturer controlling more than 7 percent of the market. Waterborne adhesives represent more than half of the market, with solvent-based adhesives accounting for 13 percent, hot melt for 18 percent, and 18 percent classified as "other." Nearly 30 percent of adhesives are used for packaging (17).

Environmental Concerns

The three main environmental concerns affecting paints and adhesives are:

- The toxicity and other health hazards posed by their ingredients.
- The contribution of their chemical constituents to smog formation.
- The potential of chemicals released from paint to cause stratospheric ozone depletion.

As the particular concerns differ for chemicals that are commonly found in paints and those that are common in adhesives, they will be discussed separately. An additional issue that involves both paints and adhesives is their role in facilitating or impeding the reuse and recycling of end-use products, as opposed to premature disposal.

Paints and the Environment

The two primary considerations in public, regulatory, and industrial concern over paints have been the release of volatile organic compounds (VOCs) from paints during the curing (drying) process, and the presence of toxic chemicals, used as pigments or additives, that may be released to the environment[6] either while the paint is being applied, when it is in place, or during removal and disposal of damaged paint.

Volatile Organic Compounds (VOCs)

What are VOCs?

VOCs have been identified as a significant problem for the environment. They not only pose toxic hazards but threaten to increase ozone where it is undesirable (in the lower atmosphere, or troposphere'), and to destroy it where it is needed (in the upper atmosphere, or stratosphere*). How can any class of chemicals pose such diverse risks?

The answer, quite simply, is that most chemicals fit the basic definition of a VOC. The only clear positive requirement is that the chemical be organic (i.e., contain carbon) and have the potential to vaporize (this depends upon temperature and atmospheric pressure). Most regulatory authorities' do not even specify a particular criterion of volatility.[10] They may make explicit reference to photochemical reactivity," but this also tends to be nonspecific.

Because a key concern over VOCs is their ability to participate in photochemical reactions (discussed below), most regulatory authorities have employed a very general definition, and then excluded those chemical compounds that are not known to participate in photochemical reactions. Table 3-1 (at the end of this chapter) presents compounds that have been excluded from classification as VOCs by various regulatory authorities. Many of the compounds that are excluded from oversight on this basis, however, are explicitly regulated as ozone-depleting substances (see below).

As can be seen from Table 3-1, the overlap in definition by different authorities is less than complete. Functionally, the VOC content of any substance is determined by measuring the total volatility of the material (i.e., its vapor pressure under specified conditions), and then correcting for the contribution of water vapor.[12] Depending upon the particular compounds present, and their affinity for water, this can lead to rather variable results.

Where do VOCs Come From?

Some VOCs are produced by vegetation, and these natural VOCs participate in the photochemical reactions that generate tropospheric ozone and smog (discussed below). Human activities, however, produce an abundance of VOCs that dwarf the natural generation of these compounds and play a dominant role in the generation of smog (18,19). Table 3-2 shows the results of a study by the Georgia Institute of Technology on the VOCs with the highest concentrations at their urban site (20). As can be seen from the table, only two of the top 35 are of natural origin.[13] Moreover, because urban areas are host to many sources of nitrogen oxides that react with VOCs to form smog,[14] and because many human beings are exposed, a given amount of VOCs in these areas creates greater problems than it would in a rural setting.

Regarding the human-made VOCs, the scientific literature differs on both the amounts released to the atmosphere and the relative contributions of different sources (19). Among the prominent sources are fossil fuels used in transportation and industry (2 1) and solvents used in paints, coatings, and commercial products and as cleaners (22). A 1985 study estimated that 40 percent of human-made VOCs came from transportation, 32 percent from various solvent emissions, and 28 percent from industrial activities and fuel combustion (19). More recently, EPA estimated that the contribution of industrial emissions to total emissions of non-methane VOCs has increased steadily from 21 percent in 1940 to 46 percent in 1990 (23). Between 1970 and 1990, the portion of these emissions attributable to surface coating operations has remained at approximately 25 percent. This would indicate that paints and coatings are responsible for at least 11 percent of VOC emissions, *without* counting the contribution of architectural coatings for residential use. The values on production cited above suggest that residential paint use could contribute as much as another 5 percent of total emissions.

How do VOCs Contribute to Smog Formation and Lower-Atmosphere Ozone?

Briefly, sunlight can catalyze a series of chemical chain reactions between various VOCs and oxides of nitrogen, which are emitted plentifully from combustion sources such as automobile engines; the process produces ozone at each of several reaction steps. Also formed are various organic and inorganic acids and a series of carbonyl compounds (such as formaldehyde). Some of these compounds participate in subsequent reactions that also give rise to ozone. Different VOCs vary in the extent to which they participate in these smog-forming photochemical reactions in the troposphere. While some are highly reactive, others are relatively unlikely to lead to ozone or smog formation. Smog is the complex, visible mixture produced by this entire family of photochemical reactions. A recent report by the National Academy of Sciences (19) offers a detailed and thorough discussion of the photochemistry of tropospheric ozone generation and smog formation.

Ozone: A Growing Health Threat

Research into the toxicity of ozone has been going on for some years, and the human health implications of increased tropospheric ozone are well established (24). Limits on occupational exposures were established by the American Conference of Governmental Industrial Hygienists (ACGIH) as early as 1946, and effects from outdoor air pollution were reported in 1967. Concern over the health and environmental damage caused by ozone has led to its being one of only five chemicals[15] for which National Ambient Air Quality Standards (NAAQS) have been set by the EPA; the original NAAQS for ozone was set in 1971.

Ozone is irritating to the air passages of the lung during acute exposures. Prolonged or repeated exposures to elevated ozone levels have been shown to decrease lung capacity and to cause decreases in lung tissue elasticity that reduce the lung's ability to exchange oxygen and carbon dioxide. Effects can be produced with exposures as short as five minutes, and become increasingly more severe as exposure duration continues (24). Persistent inflammatory changes in the lungs have been noted at levels commonly encountered in urban air, and levels of ozone that occur regularly in southern California have been associated with premature aging of the lungs (25).

Most regulatory standards are based upon data from short exposures, but health effects have been found to be time-dependent and high levels of ozone in urban air may persist for hours. As a result, scientists are concerned that current standards may not fully protect public health (24). Moreover, there is little evidence of progress in controlling this pollutant. According to the United Nations Environment Programme (26) average tropospheric ozone levels have been increasing by approximately 10 percent per year.

Toxicity Concerns Arising from Paint Solvents

Ozone formation is not the only potential threat posed by paints to human health and the environment, although much of their regulation - VOC regulations in particular - is addressed to this concern. Table 3-3 presents those hazardous (toxic) air pollutants, listed in the recently amended Clean Air Act, that are used as solvents in paints or adhesives. As noted, many are also included in the list of toxic chemicals subject to reporting to the US EPA's Toxics Release Inventory (TRI) when emitted from an industrial facility. Some of these chemicals are known, probable, or possible human carcinogens, while almost all have documented non-cancer toxic effects, ranging from temporary narcosis[16] or irritation to permanent neurological damage.

Toxic Pigments and Additives in Paint

For almost as long as there has been paint, metals have been used as pigments or additives. The purposes have ranged from aesthetic (e.g., chromium compounds provide for brilliant yellows) to practical (lead, chromium, and cadmium are excellent inhibitors of corrosion when applied to metal in paint). More recently, as waterborne paints came into widespread use, some formulators added mercury in order to inhibit the growth of bacteria and algae that would ruin the paint.[17] The toxic hazards of these metals have been known for decades (centuries, for lead), but the realization that their use in paint carried significant risks to human health and the environment has been more recent (27), and has led to efforts to limit this use. These efforts were originally focused on paint used in dwellings but now encompass a broader range of applications.[18]

Paints for Steel Structure Maintenance: The Threat of Lead

A particular concern regarding lead, a toxic heavy metal, in paint involves the maintenance of outside steel structures such as highway and railroad bridges. Because of its ability to inhibit corrosion of steel (such corrosion involves significant safety hazards as well), lead has long been a key component of the paints used to maintain these structures. In recent times it has become apparent that continued use of these paints will lead to unacceptable environmental contamination. Many states (and other organizations concerned with maintaining steel structures) are seeking substitutes (27).

Unfortunately, the attempt to replace lead paints for maintaining existing structures poses a dilemma. Lead-based paint jobs can be easily repaired by removing paint from small damaged areas and repainting with more lead-based paint. Paints without lead, however, do not generally adhere properly to the remaining old lead paint. This has meant either continuing to use lead-based paint for maintenance, or completely removing all paint from the structure.

Complete removal of lead paint from a large steel structure, using such traditional methods as abrasive blasting, usually leads to excessive lead contamination of the nearby environment (27). When containment structures have been used to prevent this general contamination, paint removal workers have been exposed to unacceptable levels of lead (27). In either event, abrasive blasting to remove lead from large structures has led to the generation of very large quantities of lead-contaminated hazardous waste.

Antifouling and the Concept of Controlled Toxicity

Sometimes the entire purpose of paint is to be toxic to certain non-human life forms. Such is the case for antifouling paints, the most familiar examples of which are the red paints on the bottom of ships and the blue or green paints used on pleasure craft.‘” These paints are designed to slowly release into the water a toxic metal that will prevent the growth on the hull of a variety of organisms, ranging from slime to large barnacles (28). Such growth creates significant resistance to water flow, reducing speed and increasing fuel consumption.

A significant advance in the effectiveness of these paints was achieved in the 1970s by the use of alkyltin compounds[20] as the toxic agents (28). These tin compounds greatly increased the service life of a coat of paint.[21] Major savings resulted, as the cost of putting a ship in drydock for repainting represents the most significant expense relating to the use of antifouling paints (29). Unfortunately, by the end of the decade a large number of scientific studies indicated that the alkyltin paint formulations were not only preventing fouling but were also releasing enough tin into coastal waters to damage populations of aquatic organisms in areas with heavy boat use (28). Because tin does not degrade, but remains in the aquatic environment for years, continued use of these paints posed a serious risk of ecological disaster. Accordingly, all formulations except those demonstrated to have low rates of tin release were banned.[22] The bans, while effective in protecting the aquatic environment, substantially removed the antifouling advantages of the tin-based paints.

Paint Disposal Issues

Eventually, nearly every painted object will have to be recycled or disposed of. This might occur within days or weeks in the case of a package, or only after decades or even centuries for a steel bridge. In addition, paint that has been removed from a surface - in preparation for recoating, for example - and paint that has not been applied within its working life must be reprocessed or disposed of. Waste disposal practices, such as landfilling, can lead to groundwater contamination as toxic chemicals leach out of the wastes. Alternative technologies, such as incineration, have been found to release to the atmosphere toxic chemicals, particularly heavy metals such as lead and mercury that are not destroyed by incineration or captured effectively by pollution control equipment on incinerators (30). Recycling can lead to excessive concentrations of these toxic chemicals in the recycled paint. The fact that disposal of paints containing toxic materials presents intractable problems has led to increased pressure to eliminate these toxic materials.

Adhesives and the Environment

Adhesives contain many of the same chemicals as paints and raise some of the same concerns, particularly with regard to solvent evaporation, VOC release, and toxic risks from solvents. Other solvents used in adhesives, in addition to those identified as toxic or smog-forming, are associated with other environmental problems, particularly the depletion of stratospheric ozone.

The Chemistry of Ozone Depletion

As noted above, not all substances that are VOCs from a chemical perspective participate in the atmospheric reactions with oxides of nitrogen that lead to ground level ozone formation; consequently, they have been excluded from VOC regulations. Unfortunately, this lack of reactivity can itself lead to environmental problems of another sort. Some chlorinated VOCS[23] are extremely persistent in the environment, because they do not become involved in reactions in the lower atmosphere (troposphere); instead, they eventually migrate upwards into the upper atmosphere (stratosphere).

Conditions in the stratosphere are far different from those in the troposphere. Ozone is a serious health threat in the troposphere; in the upper atmosphere, by contrast, it plays a vital role in capturing ultraviolet light (UV) which can have devastating effects on both human health and the environment if it reaches the surface.[24] The chlorinated VOCs that are unreactive in the troposphere break down under the intense UV conditions of the stratosphere, releasing chlorine that serves to deplete ozone.[25]

Table 3-4 presents a list of five groups of ozone-depleting chemicals (the groups correspond to a set of reduction mandates, discussed below). The chlorofluorocarbons (CFCs or freons) are perhaps the best-known ozone-depleting chemicals. Because these compounds are very unreactive under tropospheric conditions, they have a number of desirable properties, including lack of flammability and (for many but not all) minimal toxicity. This has lead to widespread use, not only in refrigeration (perhaps the best known use), but as aerosol propellants, foam-blowing agents, and general solvents.

Though less well-known than CFCs, halons[26] carbon tetrachloride and 1,1,l -trichloroethane (also called methyl chloroform) are also significant sources of ozone depletion. Because of its high toxicity, carbon tetrachloride use in the US is largely limited to a role as a chemical feedstock. In contrast, 1,1,l -trichloroethane, because of its low flammability, is widely used as a solvent, particularly in adhesives, where low solvent flammability and minimal toxicity are important concerns. It has been estimated that 1,l,1 -trichloroethane causes 15 percent of atmospheric chlorine buildup (3 1).

The Impact of Adhesives on Solid Waste Management

Adhesives are used in a bewildering array of products, from paper envelopes to automobiles and airplanes. In recent years, they have come to supplant mechanical fasteners ranging from staples to bolts in many applications, where they offer a stronger and more uniform bond (16). Increasingly, synthetic polymer adhesives are also replacing traditional materials derived from plants and animals - vegetable oils or horse hooves, for example.

As concern increases over the need to manage products throughout their life cycle, and particularly to reuse and recycle products rather than prematurely disposing of them, the widespread use of synthetic adhesives raises a number of issues. In durable goods, the excellent bonding properties that make adhesives desirable may interfere with product disassembly. In more ephemeral materials, particularly paper packaging, the adhesives may interfere with the ability to recycle the paper content.

Legislative/Regulatory Initiatives Addressing Environmental Concerns

The environmental concerns associated with paints and adhesives have provided the impetus for a series of federal and state legislative and regulatory initiatives. Laws and regulations in foreign countries may also have a significant impact on the practices of those US companies serving markets that are international in scope.

Federal Initiatives

The Clean Air Act and its Amendments

One of the major features of the Clean Air Act (CAA)[28] was the establishment in 1970 of primary National Ambient Air Quality Standards (NAAQS) for six major air pollutants, including ozone and lead. NAAQS are maximum allowable concentrations of these contaminants, as measured over a specified time period. Many areas, primarily urban, had and continue to have pollutant levels in excess of NAAQS; these are designated as "nonattainment" areas, and are further categorized into six classes, ranging from "marginal" to "extreme."

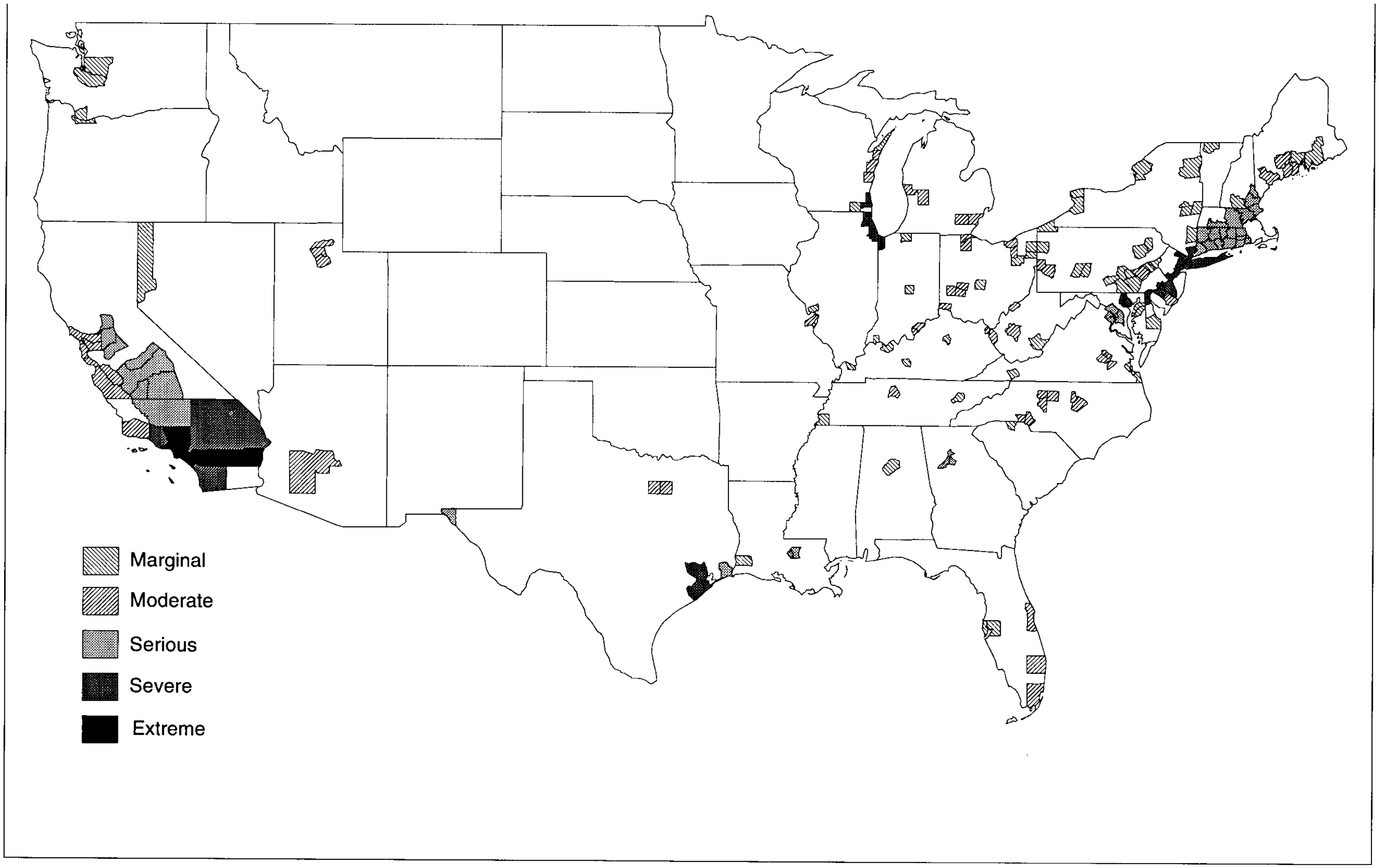
In cases of nonattainment, the states are charged with the responsibility of instituting measures to bring the areas into compliance with the federal standard; each state produces a State Implementation Plan (SIP), which must be approved by EPA. Schedules are set for compliance with NAAQS, depending upon the severity of the nonattainment. When the CAA was reauthorized and amended in 1990, many states had failed to reach their goals, and new compliance schedules were implemented, ranging from three to 20 years. In addition, the more severe the nonattainment, the more inclusive the list of regulated sources of ozone precursor chemicals such as VOCS.[29] If a state is in noncompliance and lacks an approved plan, it faces the loss of federal transportation funding. Currently, more than 100 areas and 400 cities and towns are out of compliance with the ozone provisions of the Clean Air Act (32). Figure 3-l depicts these areas on a map of the United States.

Six states, as part of their implementation plans for controlling ozone under the law, have instituted controls on the VOC content of paints, either statewide or those used in designated nonattainment areas (described below). (Lead use in paints would fall under this law primarily because lead becomes suspended during abrasive paint removal. This process is unlikely, however, to cause the widespread air contamination that is regulated under the Clean Air Act.)

Regulatory Negotiations for Architectural and Industrial Maintenance Coatings

In late 1990, under the Negotiated Rulemaking Act of 1990 and the CAA, EPA convened a negotiated rulemaking committee to address the VOC content of paints for architectural or industrial maintenance (AIM) uses. This committee included eight con-

Figure 3-1: Ozone Nonattainment Areas, 1989-1991, pursuant to the Clean Air Act, 1990



sumer representatives, three representatives from environmental groups, 18 representatives from the paint industry, one labor representative, five representatives of state governments, one EPA representative, and one Federal government observer. The committee attempted to develop a nationwide consensus strategy for regulating the VOC content of these paints.

On July 30, 1993, the committee reached a tentative understanding on a regulatory framework, and EPA thereafter issued a draft paper for comment. The framework includes five principal components:

- A three-stage VOC emission reduction plan that calls for reductions in VOC content of 25 percent from 1990 levels by 1996, 35 percent by 2000, and 45 percent by 2003.[30]
- A fee that companies will be required to pay if they do not meet requirements and the industry overall has not met the 2000 or 2003 targets.
- Performance evaluation checkpoints:
  - AIM coatings manufacturers must register with EPA and submit inventories in an industry-wide survey for compliance verification every year, especially for the reduction target years of 1996, 2000, and 2003.
  - Each company is to be evaluated after the 1996 standards to determine the impact of the 1996 standards on coating performance in each of the major coating categories.
  - An advisory committee to EPA is to report the findings of the survey and performance evaluations.
  - After evaluation, EPA can advise or take other action if "adequately performing products are not available."
- A two-year extension for small companies. (The size definition, based on annual sales, has not yet been finalized.)
- Either an exemption status for specialty coating categories that are manufactured in extremely small quantities, or a special Table of Standards for these coatings.

Yet to be addressed and clarified are the quantity, criteria, and activities that result in fees, the means of conducting performance evaluations, possible exemptions for zero or low VOC products, means of addressing new acquisitions by companies, and finalization of a method for calculating corporate average emissions. Category definitions, administration, and labeling requirements are not included in the framework because they were either discussed earlier or may require further discussion. Among the issues of continuing concern are the use of a company-specific 1990 baseline (which would penalize companies that had made reductions earlier), the fee system, and the certification of performance. Further, a group of small manufacturers, under the aegis of the Alliance of Local and Regional Manufacturers (ALARM), has protested that the proposed scheme favors large manufacturers, which are able to invest more funds in developing low-VOC products.

Regulation of Air Toxics

One of the distinctive features of the CAA amendments of 1990 is the inclusion"' of a list of 189 Hazardous Air Pollutants, subject to revision by EPA; EPA must set emission standards for the various sources of these pollutants. As can be seen from Table 3-3, at least 50 solvents used in paints or adhesives are to be found among these 189 chemicals. Thus, facilities that are regulated under this section of the law may be concerned with the contribution to their emissions that comes from either production or use of paints and/or adhesives.

The Montreal Piotocol and Title VI of the Clean Air Act

In response to concern about the global environmental threat posed by depletion of stratospheric ozone, industrialized nations have instituted bans on nonessential uses of CFCs. In 1987, 71 nations, including the United States, signed the Montreal Protocol, to take effect in 1989; the protocol committed the signatories to freeze consumption[32] of five CFCs at 1986 levels by July 1989, to freeze three halons by 1992, and to begin reductions in consumption. Subsequent meetings led to an agreement, incorporated into Title VI of the 1990 Clean Air Act, to completely phase out the specified substances by the year 2000, except for 1,1,1-trichloroethane, which was to be phased out by 2002. In early 1992, President Bush accelerated the US timetable, calling for a complete phaseout of all Class I substances (those in Table 3-4, plus 1,1,1-trichloroethane), by the end of 1995.

The Lead-Based Paint Poisoning Prevention Act

The hazards of exposure to lead in residential paints were addressed in the 1971 Lead Based Paint Poisoning Prevention Act, amended in 1973 and 1976. The 1973 amendments defined lead-based paint as any paint containing 0.06 percent lead, reflecting the assumption that an ingestion of 300 micrograms per day or less of lead would not lead to toxicity. The 1976 amendments directed the Consumer Product Safety Commission (CPSC) to determine whether a level of lead in paint higher than 0.06 percent, but less than 0.5 percent, was safe. Because CPSC determined that data were not available to support such a determination, the 0.06 percent standard has remained in effect; it applies to all paint manufactured after June 22, 1977.

The original Act provided for programs to abate lead contamination in houses. Yet, as of 1988, the Department of Housing and Urban Development determined that 52 percent of US housing still contained lead levels in excess of safety standards, although, of the estimated 57 million homes harboring lead-based paint, less than 7 percent posed an exposure risk to young children. The federal prohibitions on use of lead-based paint apply to those architectural paints for interior residential uses, as well as to paints for toys, furniture, and food-related utensils.

RCRA and Waste-Related Hazards

The Resource Conservation and Recovery Act (RCRA), passed in 1976 as an amendment to the 1965 Solid Waste Disposal Act and 1970 Resource Recovery Act, was itself amended in 1984 (the Hazardous and Solid Waste Amendments). One of the key features of RCRA, as amended in 1984, is a ban on the land disposal of various classes of waste, including liquid wastes with 500 milligrams per liter of lead (banned as of July 1987). In 1990, EPA issued regulations on land disposal (the “third third” regulations) (33), requiring treatment prior to land disposal of any waste that contained water-soluble toxic constituents.[33] Many wastes generated by removal of lead-based paint require treatment under this standard.

In addition to RCRA’s regulation of the disposal of removed lead paint as waste, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund) and the Clean Water Act specify that waste lead from paint removal must be prevented from being released to the environment. Under these statutes, any releases of lead-contaminated wastes (including removed paint) in quantities greater than 10 pounds must be reported (34). The requirements of RCRA and CERCLA have made proper disposal of lead paint wastes much more expensive.

Protecting Workers from Lead Exposure

The Occupational Safety and Health Administration (OSHA) sets standards to control exposures to toxic chemicals in workplace air. These standards affect not only toxic solvents that may be released, for example, in the course of manufacturing or applying paint, but also chemicals such as lead. Construction work was covered by a less stringent standard than that for in-factory work prior to 1993, but OSHA recently extended to the construction industry the Permissible Exposure Level requirements on lead exposure; this will significantly affect such tasks as removing lead from bridges, lessening the economic advantage of spot removal by requiring the same level of precaution as for structure-wide removal.

State Initiatives

States have initiated a variety of measures to control VOCs and toxic chemicals in paints and adhesives, in some cases to meet requirements of federal law (e.g., State Implementation Plans under CAA) or on their own authority. These regulations will affect not only customers of paints and adhesives within a state, but also any supplier who wishes to operate in that market. While for some products it may be desirable to produce a specialized variant to meet state requirements (the modification of cars specifically to meet California emissions requirements, for example), in the usual case a supplier has a choice of either modifying its entire product line to fit state specifications, or abandoning the market in that state.

Nonattainment Areas and Local VOC Control

INFORM has identified six states (Arizona, California, Georgia, New Jersey, New York, and Texas) that have issued regulations on the allowable VOC content in paints or adhesives, either statewide or for designated nonattainment areas. Tables 3-5 and 3-6 present, respectively, the regulations of the six states affecting the VOC contents of paints and of industrial coatings. While the states vary somewhat with regard to which specific architectural coatings are regulated, by and large (with the exception of Texas), they regulate the same coatings, and have established comparable standards. The distinctive pattern of Texas regulations may reflect the extensive presence of petrochemical facilities in many of the areas covered by the regulation. There is less consistency for industrial surface coatings, with New Jersey and New York regulating more kinds of coatings, and with Arizona regulating aerospace coatings not covered by other states. This may, again, reflect the industries that are prevalent in the areas covered by regulation.

In **Arizona,** regulations on the VOC content of architectural and specialty coatings have been established by Maricopa County (which contains the metropolitan Phoenix area). The county regulations[34] limit to 250 grams per liter (2.1 pounds per gallon) the VOC content of flat and non-flat architectural coatings manufactured after July 13, 1990. In addition, a range of specialty coatings, if manufactured after July 13, 1991, have specific limits ranging from 2.1 pounds per gallon for traffic coatings to 3.5 pounds per gallon for industrial maintenance coatings. Lacquers are allowed to contain 5.7 pounds of VOCs per gallon.

In **California,** with its longstanding problem of smog and ozone, particularly in the southern part of the state,[35] controls are in place that affect not only vehicles (such as the longstanding requirement for additional auto pollution control devices and the recent initiatives to promote cleaner burning fuels and electric vehicles), but also numerous consumer and industrial products and processes. For example, as of January 1, 1993, it became illega1[36] to sell consumer products in California, including (but not limited to) air fresheners, architectural coatings, various cleaners for automobile use, household sealants and caulking compounds, and paints, if those products contained any of the ozone-depleting substances listed in Groups I, II, IV, or V in Table 3-4; these restrictions also apply to five hydrochlorofluorocarbons (HFCs), which are sometimes used as CFC substitutes.

In addition to the specific prohibition on products that contain these ozone-depleting substances, California sets limits on the VOC content of a wide variety of consumer products, including household adhesives. More specific regulations, including those on paints and coatings, are primarily the responsibility of the state's Air Quality Management Districts.

These districts issue specific local regulations for defined areas that form a part of California's State Implementation Plan. For example, in the South Coast Air Quality Management District,[37] the goal is to reduce total VOC emissions by 45 tons per day. This has required the state to address items ranging from commercial dry cleaning to the use of charcoal lighter fluid and certain deodorants. Rules designed to limit VOC releases from paints and wall coverings to a total of 4.5 tons per day specify limits on VOC content (35). Currently, architectural coatings are limited to 250 grams of VOCs per liter of paint (roughly two pounds per gallon).[38] The Bay Area Air Quality Management District[39] also restricts VOC content to 250 grams per liter.[40]

Georgia's Rules for Air Quality Contro1[41] regulate emissions of VOCS[42] While these regulations apply statewide, sources in 13 counties that emit less than 15 pounds of VOCs per day are exempt. For paints and adhesives, these regulations apply primarily to materials used in industrial operations. They range from a low of 1.2 pounds of VOCs per gallon of electrophoretically[43] applied automotive primer to 15.1 pounds per gallon for sprayed automotive topcoats.

New **Jersey's** Bureau of Air Pollution Control regulates VOCs.[44] The rules provide formulas for calculating allowable VOC content for surface coating and graphics arts applications, as well as in various industrial operations. Architectural coatings have limits ranging from 0.8 pounds of VOCs per gallon of bituminous pavement sealer to 7.1 pounds of VOCs per gallon of fire retardant coating.

In New **York,** a similarly wide range of products and processes is subject to VOC regulation in the New York City metropolitan area. For architectural surface coatings, total allowable VOCS[45] vary with the nature of the coating, from 200 grams per liter (1.67 pounds per gallon) for mastic texture coatings to 730 grams per liter (6.1 pounds per gallon) for clear shellac.

Texas regulates VOC emissions from surface coating processes in the Beaumont/Port Arthur, Dallas/Fort Worth, El Paso, and Houston/Galveston areas.[46] The listed processes are primarily industrial (e.g., coil coating, furniture coating), but the regulations are not limited to listed processes. Specific emissions limits include 2.2 pounds per gallon (260 grams per liter) for non-flat and flat latex paints, 3.5 pounds per gallon (420 grams per liter) for interior alkyd paints, 4.0 pounds per gallon (480 grams per liter) for exterior alkyd paints, and 4.5 pounds per gallon (540 grams per liter) for epoxy paints.

Northeastern States Ban Heavy Metals in Paints

Under the leadership of the Council of Northeast Governors (CONEG),[47] 16 states have mandated the removal of heavy metals from paints. The model legislation (36) imposes a limit of 600 parts per million[48] of cadmium, hexavalent chromium, lead, or mercury in paints within two years of the effective date, decreasing to 250 parts per million in the third year and 100 parts per million in the fourth year. Table 3-7 presents the adoption and initial compliance dates for each of the 16 states that have adopted the model legislation and the three states in which such legislation is pending.

Overseas Legislation & Regulation

Just as state regulations affect any firm with a national market, foreign regulations affect the operations of multinational companies. Three areas of regulation appear likely to influence the paints and adhesives industries in the near future: air regulation, packaging regulation, and eco-labeling requirements.

Clean Air Regulations

By 1991, 23 countries had signed the 1979 United Nations Economic Commission for Europe's Convention on Transboundary Air Pollution, committing them to reduce VOC emissions 30 percent by 2000[49] (38). Specific implementing regulations are left up to the signatory countries, and appear still to be under development in many countries. The degree of control on paints and adhesives (as opposed to transportation, for example) may vary from country to country.

Germany's regulatory apparatus is similar to that of the United States, with regulations both at the federal level and by the states *(Länder).* Länder designate investigation areas and smog areas, and federal regulations affect responses to smog at each of three intensity levels. When the second level is exceeded, traffic restrictions are implemented; when the third level is exceeded, industrial activities are suspended (37). It is also expected that these VOC commitments will affect the coatings industry in the signatory countries; German regulations already specify maximum VOC emissions for coating operations.

Packaging Control Regulations

The packaging regulations that took effect in Germany in 1992, and may be adopted by other European Union (EU) members, are expected to encourage the development of more recyclable packaging. These market-based regulations give companies the option of either accepting their packaging material back from their customers or, as most companies have done, forming and participating in a recycling consortium, known as the Dual System; packages judged acceptable are marked with a recycling symbol known as the "green dot." The Dual System collects packaging materials from consumers and grants the green dot to companies.

Thus far, the program has been struggling with a superabundance of plastics products that it has collected, far in excess of its apparent recycling capabilities. The system has recently revised its fee structure in an effort to better reflect the true costs of recycling different types of packaging. This can be expected to provide incentives to develop more easily recycled packaging and to provide disincentives for packages made of multiple, inseparable materials or materials with adhesives or coatings that interfere with recycling. Germany's regulations and program are analyzed in detail in INFORM'S 1994 report, *Germany, Garbage, and the Green Dot: Challenging the Throwaway Society.*

Eco-labeling Requirements

The European Union has adopted a voluntary environmental labeling scheme. "Eco-labels" will provide a general description of a product's environmental effects. France has taken the lead on the standards for paint labeling. Once these criteria are approved through the EU, manufacturers may but are not required to apply to have their products certified for the EU eco-label. Products that do not meet the standard may still be marketed. While the procedures used to develop such labels have engendered much controversy in the international scientific community, guidelines for a paint eco-label were to be released in 1994 (38).

Consumer Demand for Environmentally Improved Paints and Adhesives

Direct regulation of producers of paints and adhesives is not the only factor driving environmental improvements in these products. Other types of regulation are indirectly stimulating change, as well. For example, the regulations on the disposal of wastes containing lead, noted above, may significantly decrease demand for lead-based paints, as commercial consumers of paints must consider not only the cost of purchasing the paints, but also the eventual costs of removing and disposing of them. Similarly, if an industrial plant that paints its products is required by regulations to decrease its total VOC emissions, it may determine that the easiest way is to seek low-VOC paints from suppliers; these suppliers in turn may seek alternatives from resin formulators, who in turn may seek low-VOC alternatives to their way of doing business.

Customer Demand - Industrial Consumers

Large industrial consumers of paints and adhesives are beginning to exert pressure on suppliers of these materials to decrease the content of VOCs and other toxic or environmentally damaging materials. When setting up plants for its new Saturn line of automobiles, for example, General Motors made an explicit commitment to purchase the most environmentally acceptable materials available (39). More recently, the three major US automakers, operating under the US Council for Automotive Research (USCAR), announced a joint program to develop low-emissions systems for painting cars (40). Few paint manufacturers interested in supplying the automobile paint market can afford to ignore such an initiative.

Even if paints and adhesives are not used to a large extent in producing goods at a plant, there may be incentives to minimize the VOC content of the materials that are used to maintain the plant itself, such as architectural and industrial maintenance paints. A company that is near its regulatory limits on VOC emissions may not be able to accept the additional emissions caused by maintenance activities. Alternatively, use of low-VOC paints inside industrial buildings may help to meet OSHA standards for exposure to workers, or minimize the downtime caused by keeping workers outside of a freshly painted work area.

Customer Demand - End Users

Industrial consumers are not the only source of pressure for environmentally improved products. **INFORM** researchers, checking local public libraries, located six books published since 1989 that gave consumer advice on environmentally preferable products (41-46). These contain suggestions on paints that ranged from using water-based instead of solvent-based paints, to recommending specific brands of non-VOC or plant-based paints. That these books may reflect real market pressures is suggested by the fact that, for the two for which sales figures were available, one had sold 800,000 copies, and the other in excess of 5 million copies.

Nor is consumer pressure limited to books. Two environmental labeling organizations are now operating in the United States.[50] Both of these, Green Seal and Scientific Certification Systems (SCS), have focused on environmental concerns affecting paints. Green Seal's practice is to issue a peer-reviewed standard for a class of products, and then to license a label designation for paints that meet that standard. The paint standard was issued in May 1993 and specifies maximum VOC content for interior and exterior, flat and non-flat coatings, as well as listing 25 chemical compounds that must not be used in ingredients, and requiring that lead is not used in the paint can.

SCS does not write standards, but rather certifies specific claims, as well as certifying that the claim is environmentally significant. At present, SCS does not certify paints as low VOC, but only as VOC-free. This entails a measurement of less than 1 gram per liter by gas chromatography/mass spectroscopy.[51] SCS also employs a broader definition of VOCs than that specified in federal regulations.

At present, neither labeling organization addresses the environmental characteristics of adhesives. Green Seal, however, has circulated a draft standard for adhesives (as well as a separate standard for sealants and caulking compounds). This standard specifies that the sealant not be formulated with VOCs in excess of 20 grams per liter, nor with any aromatic solvents, borax, formaldehyde, halogenated solvents, or compounds of mercury, lead, cadmium, or hexavalent chromium. As in the case of paints, the standard also establishes requirements for the adhesive's packaging.

Notes

1. The term "alkyd," denoting a combination of alcohol and acid, refers primarily to synthetic resins that came to substitute for natural oils (e.g., linseed oil) in the 1930s and 1940s.
2. The market in western Europe is nearly as large.
3. Estimates of paint sales in both dollar and gallon terms vary somewhat between sources.
4. 900 million pounds of pigments are represented by Titanium dioxide, a white pigment widely used because of its good hiding power. A 1982 estimate by EPA (published in 1990) indicates that approximately 9 percent of pigments contained lead or chromium compounds (47).
5. There are at least four theories as to what defines an adhesive. Perhaps the clearest approach to classifying adhesives is by their mode of application and setting; curing or setting mechanisms include many of the chemical reaction types described for paints. Among these are cooling of a thermoplastic material, evaporation of a solvent or carrier, in *situ* polymerization, and pressure-sensitive adhesives.
6. Including the environment inside buildings.
7. The troposphere extends from the ground's surface to a height of 6-10 kilometers (3-6 miles).
8. The stratosphere extends beyond the troposphere to a height of 50 kilometers (30 miles) above the earth's surface.
9. Regulatory definitions of VOCs from a variety of sources can be obtained by contacting **INFORM.**
10. California does classify VOCs on the basis of their vapor pressure at 20°C.
11. Participation in chemical reactions that are influenced by light, such as the formation of smog.

12. Test methods are given in Appendix A of 40 CFR Part 60.
13. At least twelve of these compounds are reported to be used in paints or adhesives.
14. See the discussion on ozone formation in the following section.
15. The others are carbon monoxide, lead, nitrogen dioxide, and sulfur oxides. There is also a NAAQS for particulate matter (dust).
16. Narcosis: stupor or unconsciousness.
17. This was not generally a problem in earlier solvent-borne paints, as the solvents were sufficiently toxic to preclude the growth of microorganisms.
18. The concern over lead-based paint in dwellings is continuing, given the long history of use of lead paint and the fact that paint is generally covered over, rather than removed. This means that older housing stock may have a significant amount of lead on its walls.
19. They are also important in many situations where water is being used in industry (for example, in cooling at power plants). While the following discussion is phrased in terms of ships, it applies equally to industrial uses of these paints.
20. These are chemical compounds that combine hydrocarbon groups with tin, increasing the tendency of the toxic tin to be absorbed by living organisms.
21. Because these paints work by releasing the toxic chemical, they eventually "wear out," having too little toxic chemical content to inhibit the growth of marine organisms.
22. Earlier copper-based formulations, less effective than the original tin formulations, are also available.
23. That is, chemical compounds that incorporate both carbon and chlorine.
24. Including an increased incidence of melanoma, cataracts, and immune-system damage, as well as damage to crops and other vegetation.
25. This is a highly simplified discussion. The scientific consensus on the role of these chemicals in ozone depletion is overwhelming, despite the criticisms of some politicians and pundits. (48,49)
26. These are bromofluorocarbons, with atmospheric chemistry similar to that of CFCs. One major use is as a fire extinguishing agent.
27. Because of its low cost, carbon tetrachloride is used in a wider range of applications in the developing world.
28. (Public Law 159,42 USC. 7401-7626) The law was originally passed in 1955, and amended in 1963, 1965,1966,1967,1970,1974,1977,1981 and 1990. The 1970 amendments provided for the establishment of NAAQS.
29. Reductions are required by sources emitting the following quantities of ozone precursors:

    100 tons of precursors per year in marginal and moderate areas

    50 tons per year in serious areas

    25 tons per year in severe areas

    10 tons per year in extreme areas

    Moderate to extreme areas of nonattainment have six years to reduce their emissions by 15 percent. They must then reduce them 3 percent each year after that. (50, p. 125)
30. Based either on a standard table of emissions, or as a corporate average VOC emission (CAVE).
31. In section 112.
32. Defined as the amount produced plus the amount imported, minus the amount exported.
33. The presence of toxic constituents is measured by the "toxicity characteristic leaching procedure."
34. Rule 335 for architectural coatings and rule 336 for industrial coatings.
35. In 1989, air quality in Los Angeles was deemed by the state to be unacceptable on more than 180 days.
36. Under Subchapter 8.5, Article 2, Section 2.
37. Comprising the greater Los Angeles urban area (Los Angeles, Orange, and Riverside Counties, and westem San Bernardino County).
38. Under Rule 1113.
39. Constituting the greater San Francisco metropolitan area (Alameda, Contra Costa, Marin, Napa, San Francisco, and Solano Counties, and southern Sonoma County).
40. Regulation 8, Rule 3.
41. Chapter 391-3-1.
42. Contact INFORM for Georgia's definition of VOCs.
43. Electrophoretic application: the use of electric charge to enhance the adhesion of paint particles to a (metal) surface. Widely used in painting automobiles by immersion in tanks of paint.
44. Under Chapter 7:27, Subchapter 16.
45. As specified in Part 205. Part 228 specifies applicable limits for various industrial operations.

46. Under Section 115.421
47. The Council includes the governors of nine states in the Northeast. A Source Reduction Council operating under CONEG auspices included representatives from industry and environmental groups, and produced model legislation for packaging materials.
48. That is, 600 parts of the regulated material in each 1 million parts of the paint.
49. The selection of the base year was left to the discretion of the individual country, to avoid penalizing those with early achievements. Germany's base year is 1988 (37).
50. Unlike the situation in the EC, these organizations are private (nonprofit), and have no government authority.
51. This analytical technique is far more sensitive and accurate than that specified in EPA regulations.

Table 3-1: Chemicals Excluded from Definition as Volatile Organic Compounds (VOCs) by Various Regulatory Authorities

		Regulatory Authorities			
CAS Number	Chemical	Excluded by EPA	Excluded by California	Excluded by New York	Excluded by New Jersey
506876	Ammonium carbonate	x	x	x	
124389	Carbon dioxide	x	x	x	
630080	Carbon monoxide	x	x	x	
463796	Carbonic acid	x	x	x	
	Certain classes of Perfluorocarbons*	x	x	x	
76131	CFC-113/Freon 113	x	x	x	x
76142	CFC-114	x	x	x	x
76153	CFC-115	x	x	x	x
63938103	Chloro-1,11,2-tetrafluoroethane, 2-	x	x	x	
75683	Chlorodifluoroethane	x	x	x	
75456	Chlorodifluoromethane	x	x	x	x
306832	Dichloro-1,1,1-trifluoroethane, 2,2-	x	x	x	
75718	Dichlorodifluoromethane	x	x	x	x
25167888	Dichlorofluoroethane	x	x	x	
75376	Difluoroethane	x	x	x	
74840	Ethane	x		x	
	Metallic Carbides or Carbonates	x	x	x	
74828	Methane	x	x	x	x
75092	Methylene chloride	x	x	x	
556672	Octamethylcyclotetrasiloxane			x	
354336	Pentafluoroethane	x	x	x	
811972	Tetrafluoroethane, 1,1,1,2-	x	x	x	x
359353	Tetrafluoroethane, 1,1,2,2-	x	x	x	x
71556	Trichloroethane, 1,1,1-	x	x	x	
75694	Trichlorofluoromethane	x	x	x	x
420462	Trifluoroethane, 1,1,1-	x	x	x	
75467	Trifluoromethane	x	x	x	x

* Perfluorocarbons which fall in the following categories:
1. Cyclic, branched, or linear, completely fluorinated alkanes;
2. Cyclic, branched, or linear, completely fluorinated ethers with no unsaturations;
3. Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
4. Sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

Note: CAS Number is the Chemical Abstracts Service Registry Number

Source: EPA-40 CFR 51.100; New Jersey-N.J.A.C. 7:27-23.2, page 27-130; New York-Part 200.1 (Ill); California-Cal. Code of Regs. 17:94508(a)(90)

Table 3-2: Naturally Occurring and Synthetic Volatile Organic Compounds (VOCs) with Highest Concentrations in an Urban Environment, in Decreasing Order

Order	CAS Number	Chemical	Biogenic	Used in Paints or Adhesives*
1	78784	i-pentane		
2	106978	n-butane		x
3	108883	toluene		x
4	99876	p-cymene	x	x
5	109660	n-pentane		
6	71432	benzene		x
7		m- and p-xylene		x
8	107835	2-methyl oentane		
9	110827	cyclohexane		x
10	591764	2-methyl hexane		
11	74840	ethane		
12	112196	undecane		x
13	74986	propane		
14	75285	i-butane		
15	78795	isoprene	x	
16	74862	acetylene		
17	110543	n-hexane		x
18		m- and p-ethyl toluene		
19	94140	3-methyl pentane		
20	74851	ethylene		
21	96377	methyl cyclopentane		x
22	100414	ethylbenzene		x
23	95476	o-xylene		x
24	589344	3-methyl hexane		
25	565593	2,3-dimethyl pentane		
26	105055	1,4-diethyl benzene		
27	23436193	iso-butene		
28	540841	2,2,4-trimethyl pentane		
29	95636	1,2,4-trimethyl pentane		

continued

Table 3-2: Naturally Occurring and Synthetic Volatile Organic Compounds (VOCs) with Highest Concentrations in an Urban Environment, in Decreasing Order (continued)

Order	CAS Number	Chemical	Biogenic	Used in Paints or Adhesives*
30	538932	i-butvl benzene		
31	513359	2-methyl-2-butene		
32	108678	1,3,5-trimethyl benzene		x
33	287923	cyclopentane		
34	115071	propene		
35	98828	i-propyl benzene		

Note: Only two (p-cymene and isoprene) VOCs are of natural origin (biogenic).

Source: Top 35 VOCs Measured at Georgia Tech Campus, Atlanta, GA, 1100-1400 hours, 7/13/81 - 8/03/81, from W. A. Lonneman, S. L. Kopczynski, P. E. Darley, and F. D. Sutterfield, "Hydrocarbon composition of urban air pollution," (Environ. Sci. Technol. 8:229-236, 1974) in National Research Council Committee on Tropospheric Ozone Formation and Measurement, *Rethinking the Ozone Problem in Urban and Regiona/ Air Pollution,* National Academy Press, 1991.

* Sources indicating use in paints or adhesives:
(1) Browning, Ethel, *Toxicity and Metabolism of Industrial Solvents,* Elsevier Publishing Company, 1965.
(2) Marsden, C. and Seymour Mann, *So/vents Guide,* Cleaver-Hume Press Ltd., 1963.
(3) Kirk-Othmer, *Concise Encyclopedia of Chemical* Technology John Wiley & Sons, 1985.
(4) American Institute of Architects, *A1A Environmental Resource Guide Subscription,* January 1993.
(5) Center for Economics Research, *Paint Waste Reduction and Disposal Options, Volume* I, State of Illinois 92/250, February 1993.
(6) 58FR28157, May 12, 1993.
(7) Montgomery, J. and L. Welkom, *Groundwater Chemicals De&Reference,* Lewis Publishers, 1990.
(8) Montgomery, J., *Groundwater Chemicals Desk Reference, Volume* II Lewis Publishers, 1991.
(9) Turner, G.P.A., *Introduction Paint Chemisty and Priniciples of Paint Technology* Third Edition, Chapman & Hall, 1991.

Table 3-3: Hazardous Air Pollutants, as Listed in the Clean Air Act, 1990, that are Used in Paints or Adhesives

CAS Number	Chemical	EPA Carcinogen Classification	TRI Chemical
60355	Acetamide		x
79061	Acrylamide	B2	x
79107	Acrylic acid		x
107131	Acrylonitrile	B1	x
107051	Allyl chloride	C	x
62533	Aniline	B2	x
71432	Benzene	A	x
106990	Butadiene, 1,3-	B2	x
105602	Caprolactam		
120809	Catechol		x
98828	Cumene		x
107062	Dichloroethane, 1,2-	B2	x
111444	Dichloroethyl ether	B2	x
111422	Diethanolamine		x
60117	Dimethyl aminoazobenzene		x
68122	Dimethyl formamide		
131113	Dimethyl phthalate	D	x
106898	Epichlorohydrin	B2	x
140885	Ethyl acrylate	B2	x
100414	Ethylbenzene	D	x
106934	Ethylene dibromide	B2	x
151564	Ethylene imine		x
50000	Formaldehyde	B1	x
118741	Hexachlorobenzene	B2	x
110543	Hexane, N-		
123319	Hydroquinone		x
78591	Isophorone	C	
108316	Maleic anhydride		x
67561	Methanol		x
78933	Methyl ethyl ketone	D	x
108101	Methyl isobutyl ketone		x
75092	Methylene chloride	B2	x
91203	Napthalene	D	x
98953	Nitrobenzene	D	x

continued

Table 3-3: Hazardous Air Pollutants, as Listed in the Clean Air Act, 1990, that are Used in Paints or Adhesives (continued)

CAS Number	Chemical	EPA Carcinogen Classification	TRI Chemical
79469	Nitropropane, 2-	B2	x
87865	Pentachlorophenol	B2	x
108952	Phenol	D	x
75569	Propylene oxide	B2	x
100425	Styrene		x
79345	Tetrachloroethane, 1,1,2,2-	C	x
108883	Toluene	D	x
584849	Toluene diisocyanate, 2,4-		x
71556	Trichloroethane, 1 ,1,1 -	D	x
79016	Trichloroethylene		x
88062	Trichlorophenol, 2,4,6-	B2	x
108054	Vinyl acetate		x
75014	Vinyl chloride	A	x
1330207	Xylenes, mixed	D	x
108383	Xylene, m-		x
95476	Xylene, o-		x
106423	Xylene, p-		x

Notes:
CAS Number is the Chemical Abstracts Service Registry Number.
TRI Chemicals are chemicals for which releases and transfers must be reported to the Toxics Release Inventory.
EPA assigns one of six class designations to toxic chemicals reflecting the weight of evidence indicating that the chemical can cause cancer in humans:
A = Known human carcinogen
B1= Probable human carcinogen, limited human data
B2= Probable human carcinogen, inadequate human data
C = Possible human carcinogen
D = Not classifiable as human carcinogen
E = Evidence that not carcinogenic in humans

* Sources indicating use in paints or adhesives:

(1) Browning, Ethel, *Toxicity and Metabolism of Industrial Solvents,* Elsevier Publishing Company, 1965.
(2) Marsden, C. and Seymour Mann, *Solvents Guide,* Cleaver-Hume Press Ltd., 1963.
(3) Kirk-Othmer, Concise *Encyclopedia of Chemical Technology* John Wiley & Sons, 1985.
(4) American Institute of Architects, *AM Environmental Resource Guide Subscription,* January 1993.
(5) Center for Economics Research, *Paint Waste Reduction and Disposal Options, Volume I,* State of Illinois 92/250, February 1993.
(6) 58FR28157, May 12, 1993.
(7) Montgomery, J. and L. Welkom, *Groundwater Chemicals Desk Reference,* Lewis Publishers, 1990.
(8) Montgomery, J., *Groundwater Chemicals Desk Reference, Volume* II, Lewis Publishers, 1991.
(9) Turner, G P. A., *Introduction to Paint Chemistry and Principles of Paint Technology* Third Edition, Chapman & Hall, 1991.

Table 3-4: Class I Ozone-Depleting Substances, as Listed in the Clean Air Act, 1990

CAS Number	Chemical	Ozone-Depletion Potential
	Group I	
75694	Chlorofluorocarbon-11 (CFC-11)	1.00
75718	Chlorofluorocarbon-12 (CFC-12)	1.00
76131	Chlorofluorocarbon-113 (CFC-113)	1.00
76142	Chlorofluorocarbon-114 (CFC-114)	0.80
76153	Chlorofluorocarbon-115 (CFC-115)	0.60
	Group II	
353593	Halon-1211	3.00
75638	Halon-1301	10.00
25497307	Halon-2402	6.00
	Group III	
75729	Chlorofluorocarbon-13(CFC-13)	1.00
354563	Chlorofluorocarbon-111(CFC-111)	1.00
76120	Chlorofluorocarbon-112(CFC-112)	1.00
	Chlorofluorocarbon-211(CFC-211)	1.00
	Chlorofluorocarbon-212(CFC-212)	1.00
	Chlorofluorocarbon-213(CFC-213)	1.00
	Chlorofluorocarbon-214(CFC-214)	1.00
	Chlorofluorocarbon-215(CFC-215)	1.00
42560985	Chlorofluorocarbon-216(CFC-216)	1.00
	Chlorofluorocarbon-217(CFC-217)	1.00
	Group IV	
56235	Carbon tetrachloride	1.10
	Group V	
71556	Methyl chloroform	0.10

Notes:
(1) Class I substances are CFCs, halons, carbon tetrachloride (phase-out date is the year 2000), and methyl chloroform (phase-out date is the year 2002).
(2) Groups I through V are categorized according to the chemical structure of the substance and an ozone-depletion potential of 0.2 or greater.
(3) Ozone-depletion potential is a factor established to reflect the tendency of a substance to deplete ozone from the stratosphere relative to that of chlorofluorocarbon-11 (CFC-11).
(4) Class II substances, not listed above, are hydrochlorofluorocarbons (HCFCs) which will be phased out by the year 2030.

Table 3-5: Maximum Allowable VOC Content in Architectural Coatings, as Specified in State Regulations (grams of VOC per liter of coating)

Type of Architectural Coating	Arizona(a)	California BAAQMD	California SCAQMD	New Jersey	New York(b)	Texas(c)
Below-ground wood preservatives			350	(d)	(d)	
Bituminous pavement sealer	(e)	(e)	(d)	100	(e)	
Bond breakers			350	600	600	
Concrete curing compounds	350	350	350	350	350	
Dry fog coatings		(d)		400	400	
flats	420		400			
non-flats	400		400			
Enamel undercoaters	350	350	(d)	(d)	(d)	
Epoxy paints		(d)	(d)	(d)	(d)	540
Exterior alkyd paints		(d)	(d)	(d)	(d)	480
Fire retardant coatings						
clear			650	(d)	850	
pigmented			350	(d)	(d)	
opaque			(d)	500	500	
all others			(d)	850	(d)	
Flat architectural coatings	250	(d)		250	(d)	
Form release compounds		(d)	250	(d)	(d)	
Graphic arts (sign) coatings			500	450	450	
Industrial maintenance coatings		(d)		(d)	(d)	
anti-graffiti coatings			550			
high temperature coatings			340	650	650	
Industrial maintenance primers and topcoats			340	450	450	
alkyds	420	420				
catalyzed epoxy	420	420				
bituminous coating materials	420	420				
inorganic polymers	420	420				
vinyl chloride polymers	420	420				
chlorinated rubber	420	420				
acrylic polymers	420	420				
urethane polymers	420	420				
silicones	420	420				
unique vehicles	420	420				
Interior alkyd paints		(d)	(d)	(d)	(d)	420

confined

Table 3-5: Maximum Allowable VOC Content in Architectural Coatings, as Specified in State Regulations (grams of VOC per liter of coating) (continued)

Type of Architectural Coating	Arizona(a)	California		New Jersey	New York(b)	Texas(c)
		BAAQMD	SCAQMD			
Lacquers	680	680	550	680	680	
nitrocellulose-based						670
Magnesite cement coatings		(d)	450	(d)	(d)	
Mastic texture coatings			(d)	200	200	
Metallic pigmented coatings			500	500	500	
Multi-color coatings			420	600	600	
Non-flat and flat latex paints		(d)	(d)	(d)	(d)	260
Non-flat architectural coatings	250	(d)	(d)	380	380	
Primers, sealers, and undercoaters			350	350	350	
general	350	350				
quick dry				500	500	
specialty	350	350				
pretreated wash primers			780			
Quick dry enamels	400	400	(d)	(d)	(d)	
Roof coatings	300	300	300	300	300	
Shellacs						
clear			730	730	730	
pigmented			550	550	550	
Specialty flats	400	400	(d)	(d)	(d)	
Stains						
exterior						720
interior						840
low-solids			120			
opaque	350	350	350	350	350	
semi-transparent	350	350	350	550	550	
Standing sealers (clear wood finishes)		(d)	350	(d)	(d)	
Swimming pool coatings			650	600	600	
Swimming pool repair and maintenance coatings		(d)	650	(d)	(d)	
Tile-like glaze coatings			(d)	550	550	
Traffic coatings(f)	250	250	250	250	250	

continued

Table 3-5: Maximum Allowable VOC Content in Architectural Coatings, as Specified in State Regulations (grams of VOC per liter of coating) (continued)

Type of Architectural Coating	Arizona(a)	California BAAQMD	California SCAQMD	New Jersey	New York(b)	Texas(c)
Urethane coatings		(d)	(d)	(d)	(d)	540
Varnishes	350	350	350	450	450	
alkyd varnishes						540
Waterproof mastic coatings	300	300	300	300	300	
Waterproof sealers	400	400	400	600	600	
Wood preservatives	350	350		550	550	
opaque	350		350			
semi-transparent and clear	350	350	350			

Notes:
BAAQMD: Bay Area Air Quality Management District, which constitutes the greater San Francisco metropolitan area (Alameda, Contra Costa, Marin, Napa, San Francisco, Solano, and the southern part of Sonoma Counties) SCAQMD: South Coast Air Quality Management District
(a) Maricopa County only
(b) New York City metropolitan area only
(c) Beaumont/Port Arthur, Dallas/Fort Worth, El Paso, and Houston/Galveston areas only
(d) Limit of 250 grams of VOC per liter for all architectural coatings not otherwise specified or exempted in the regulations
(e) Must be emulsion-type coating
(f) Applied to streets and highways and other surfaces; black traffic coatings

Sources:
(1) Maricopa County, CA: Air Pollution Control Regs., Reg. Ill, Rule 335, Sec. 300,301-305 (Table1).
(2) Bay Area Air Quality Management District: Reg. 8, Rule 3.
(3) South Coast Air Quality Management District: Rule 1113.
(4) New Jersey: N.J.A.C. Ch. 7:27-23.3 (Table 1).
(5) New York: Title 6, Chapter Ill, Sec. 205.4.
(6) Texas: Air Control Board Reg. V, Subch. E, Section 115.421(11).

Table 3-6: Limits on VOC Content of Various Types of Surface Coatings, as Specified in State Regulations (pounds of VOC per gallon of coating)

Type of Operation	Arizona(a)	Georgia	New Jersey	New York	Texas (b)
Aerospace coating lines					
conformal coating	4.5				
electromagnetic radiation effect coating	5.0				
maskant	3.5			5.1	
phosphate ester-resistant primer	2.9				
primer	2.9			2.9	6.7
rain erosion resistant coating	3.5				
resin surface sealer	5.8				
temporary protective coating	2.1				
topcoat	3.5			5.1	
wing coating	3.5				
Auto and light-duty truck manufacturing					(c)
electrophoretic applied prime operation		1.2	1.2		
spray prime operation		15.1	2.8		
prime coat				1.9	1.2(d)
primer-surfacer				2.8	2.8(d)
topcoat operation		15.1	2.8	2.8	2.8
final repair operation		4.8	4.8	4.8	4.8
custom topcoat			5.0		
refinishing: base coat			6.0		
refinishing: clear coat			4.4		
refinishing: all others			5.0	5.0	
repair/touchups				6.2	
Can coating					
sheet basecoat and overvarnish; 2-piece can exterior	2.8	2.8	2.8	2.8	4.5
2,3-piece can interior body spray; 2-piece can exterior end	4.2	4.2	4.2	4.2	9.8
3-piece side-seam spray	5.5	5.5	5.5	5.5	22.0
end sealing compound	3.7	3.7	3.7	3.7	7.4
Coil coating					2.6
any coat	2.6				
prime and topcoat or single coat		2.6	2.6		4.0
Fabric and vinyl coating					
fabric coating line	2.9	2.9	2.9	2.9	4.8
vinyl coating line	3.8	3.8	3.8	3.8	7.9

continued

Table 3-6: Limits on VOC Content of Various Types of Surface Coatings, as Specified in State Regulations (pounds of VOC per gallon of coating) (continued)

Type of Operation	Arizona(a)	Georgia	New Jersey	New York	Texas (b)
Flat wood paneling					
printed interior panels		6.0 (e)	2.7	2.5	6.0 (e)
natural finish hardwood plywood panels		12.0 (e)	3.3	3.3	12.0 (e)
hardboard panels		10.0 (e)	3.6	3.6	10.0 (e)
Flexible parts and products					
flexible primer	4.1				
color topcoat	3.8				
basecoat/clear coat	4.5				
Glass coating: miscellaneous glass			3.0	3.0	
fluorescent light bulbs				4.1	
Graphic arts systems					
rotogravure and flexographic printing		0.5(f)	2.9		
Large appliance surface coating	2.8	2.8	2.8	2.8	4.5
Leather coating			5.8	5.8	
Major sources		25.0(g)			
Metal furniture coating	3.0	3.0	3.0	3.0	5.1
Miscellaneous metal parts surface coating					
air dried application	3.5	3.5	3.5	3.5	6.7
baked application	3.0				
clear coatings		4.3	4.3	4.3	10.2
extreme performance coatings		3.5	3.5	3.5	6.7
high performance architectural coatings		6.2			
silicone release application	3.5				
all other coatings and applications		3.0	3.0	3.0	5.1
Miscellaneous plastic part coating	3.5				
color topcoat				3.8	
clear coat				4.8	
Paper coating line	2.9	2.9	2.9	2.9	4.8
Tablet coating			5.5	5.5	
Urethane coating			3.8	3.8	
Wire coating		1.7	1.7	1.7	

continued

Table 3-6: Limits on VOC Content of Various Types of Surface Coatings, as Specified in State Regulations (pounds of VOC per gallon of coating) (continued)

Type of Operation	Arizona(a)	Georgia	New Jersey	New York	Texas (b)
Wood furniture surface coating					
clear topcoat			5.6	5.6	
opaque stain			4.7	4.7	
pigmented coat			5.0	5.0	
sealer			5.6	5.6	
semitransparent stain			6.8	6.8	
wash coat			6.1	6.1	

Notes:
(a) Maricopa County only
(b) Beaumont/Port Arthur, Dallas/Fort Worth, El Paso, and Houston/Galveston areas and Gregg, Nueces, and Victoria Counties only
(c) No auto and light-duty truck manufacturing limits in Gregg, Nueces, and Victoria counties
(d) 2.1 pounds per gallon in Dallas and Tarrant counties (in Dallas/Fort Worth area); other auto and truck manufacturing limits based on type of coating in Dallas and Tarrant counties
(e) Pounds per 1000 square feet of finished product
(f) Pounds VOCs per pound of coating solids
(g) Tons per year

Sources:
(1) Maricopa County, CA: Air Pollution Control Regs., Reg. III, Rule 336, Sec. 300, 301 (Table 1).
(2) Georgia: Rules for Air Quality Control, Ch. 391-3-l .02(2)(t) through(aa), (ii), (jj), (mm), and (qq).
(3) New Jersey: N.J.A.C. Ch. 7:27-16.5 (Tables 3A, 3B, 3D, and 3E), pages 27-106.6 and 27-106.10-11.
(4) New York: Title 6, Ch. Ill, Part 228, Sec. 228.7 (Table 1) and 228.8 (Table 2).
(5) Texas: Air Control Board Reg. V, Subch. E, Section 115.421.

Table 3-7: States Adopting the Model CONEG* Regulations Limiting Heavy Metals in Paints, with Dates of Adoption and Implementation

State	Adoption Date	Compliance Date
Connecticut**	June 6,199O	June 6,1992
Florida	May 12,1993	July 1, 1994
Georgia	July 1992	July 1, 1994
Illinois	July 1992	July 1, 1994
Iowa	May 8,199O	July 1, 1992
Maine**	April 4, 1990	April 1, 1992
Maryland	May 1992	July 1, 1993
Massachusetts*'	Pending	
Michigan	Pending	
Minnesota	June 4,1991	August 1,1993
Missouri	July 1, 1993	August 1, 1995
New Hampshire**	April 27, 1990	April 27, 1992
New Jersey'*	January 8,1991	July 1, 1992
New York**	January 1,199O	January I,1992
Pennsylvania**	Pending	
Rhode Island'"	July 5, 1990	July 1, 1992
Vermont**	June 26,199O	July 1,1992
Washington	May 21, 1991	July 1, 1993
Wisconsin	April 27, 1990	June 1,1992

* Under the leadership of the Council of Northeast Governors (CONEG), these states have mandated the removal of heavy metals from paints. The model legislation specifies a limit of 600 parts per million of cadmium, hexavalent chromium, lead, or mercury in paints within two years of the effective date, decreasing to 250 parts per million in the third year and 100 parts per million in the fourth year.

** CONEG member states.

Chapter 4: Methodology of the Study

Case Study Goals

Given the growing awareness in recent years of the health and environmental threats related to products whose manufacture and use involves volatile organic compounds and heavy metals, and the proliferation of regulations to meet those threats, it is crucial to see how companies that make these products are responding. What new and safer products are they developing? What costs are they incurring? What benefits are resulting? Evaluating these innovations must reflect the fact that "success" will depend as much upon their reception by customers as on the evaluations of the products themselves by manufacturers.

Funding for this study allowed INFORM to include no more than nine company case studies. Because two of the companies that agreed to take part eventually proved unable to complete their participation in the study, only seven companies are included in the final report. Such a small number of case studies calls for caution in the interpretation of our findings. Within the seven case study companies INFORM found wide diversity in the environmental innovations taking place. Our broad initial literature search identified many additional paint and adhesives firms involved in environmental innovation.[1] However, a close examination of the experiences of firms outside our case studies could reveal different experiences.

While our case study firms could not be said to provide a statistically representative depiction of the process of environmental innovation in the paints and adhesives industries, they were useful in identifying a range of types of innovations and also the factors that foster or impede environmental innovation in these critical industries. By its nature, every innovation is unique; it is not likely that innovations will lend themselves to ready characterization. By contrast, INFORM found common pressures underlying efforts at innovation and common circumstances helping an innovation to succeed in the marketplace.

Identification of Candidate Companies

An initial list of candidate companies for this study of environmental innovations in paints and adhesives was compiled from various sources. INFORM reviewed the technical, trade and popular press, aided by computer searches on paints and adhesives in bibliographic databases; interviewed organizations and individuals who were familiar with either pollution prevention initiatives, the paints and adhesives industries, or both; collected relevant data gathered in the course of other INFORM research, and reviewed product labels in a variety of local outlets for paints and adhesives. INFORM also contacted both the Adhesive and Sealant Council, Inc., and the National Paint and Coatings Association. While neither trade group was able to provide us with lists of potential companies, each offered its membership for our study. The introduction to the next section presents a sampling of the variety of environmental innovations unearthed in INFORM'S broad research process.

In assembling an initial list of potential case study companies, INFORM had several criteria: First, to include environmental innovations in both paints and adhesives; second, to target paint innovations affecting both organic compounds and inorganics (primarily heavy metals); and third, to cover a range of industrial activities, rather than simply those activities involving the formulation of paints and adhesives. Thus, for paints, changes in pigments, solvents, and resins were all included, and companies included those that were suppliers of paint formulators, as well as the formulators themselves. For adhesives, we contacted not only companies attempting to decrease or eliminate solvents, but also firms involved in complete product substitutions (e.g., replacing solvent-based adhesives with hot-melt adhesives), and developing adhesives to facilitate recycling of the products that incorporated them.

Contact and Selection of Study Companies

The initial list compiled by INFORM of potential study participants included eight companies involved in adhesives, and thirteen involved in paints. The companies chosen for the case studies were those nine that were most willing to participate. This willingness was ascertained by telephoning nine candidate companies, identifying the environmental innovation that had attracted our attention to them, and describing the study to them in general terms. If a company indicated that it was not interested in participation in the study at that point,[2] another company from the list was contacted.

If a company indicated interest in considering participation in the study, INFORM sent a copy of our questionnaire (see Appendix) for informational purposes only. Each questionnaire was clearly marked ("sample only" and "no response requested"). After a company reviewed the questionnaire, we contacted it again by telephone to determine its willingness to participate in the study. The nine companies that agreed to participate were then sent copies of the questionnaire without the disclaimers.

Overall, two companies declined participation following a verbal description of the study and its purposes. Three more companies declined to participate after reviewing the sample questionnaire. One declining company indicated that it was involved in recycling existing paint, rather than changing paint formulations; the others cited lack of available resources to participate.

Hence, one significant distinguishing feature of the case study companies is volunteering to participate, a characteristic clearly not shared by all contacted companies. It is impossible to say whether the participating companies differ from nonparticipants in other ways, as well.

Completion of the Survey

In completing the questionnaire, several case study companies responded in writing (either on paper or by submitting a computer disk). Others provided their answers in telephone interviews. One firm arranged an on-site interview by INFORM staff. Unfortunately, two case study companies, after agreeing to participate, were unable to complete the study. Thus, only seven innovating firms are represented in our results.

The final list of seven case study companies includes two that produce adhesives (one for paper products, one for foam used in furniture manufacture, two producers (formulators) of paint, one supplier of polymer resins to the paint industry, and two companies producing paint additives (one producing colorants, the other corrosion inhibitors and biocides). Such a broad range of activities means that any given company may not reflect other companies in the same area, or even other companies that are introducing environmental innovations in that area. It does, however, provide an indication of the breadth of environmental innovation that is occurring. Table 4-1 summarizes the innovations of the seven case study companies.

Notes

1. A brief description of a variety of these innovations, as reported in the popular, trade, and technical press, is presented at the beginning of the next section.
2. For some firms, it was impossible to make contact with a person who was knowledgeable about the environmental improvement and willing to discuss potential participation in the study.

Table 4-1: Improvements by Case Study Companies

Companv	Improvement(s)	New Chemicals	Chemicals Replaced or Problem Addressed	Risk of Original Product
Ciba-Geigy	Organic corrosion inhibitors as an alternative to chromium salts as active pigments in the protection of steel and aluminum.	Organic (triazine) pigments.	Heavy metal salts, including lead and chromium compounds, used for corrosion protection of aluminum and steel.	Toxicity to humans. Environmental damage
	Organic algicide for use in marine antifouling applications and trade sales paints.	Organic algicide.	Alkyltin compounds. Mercury.	Toxicity to non-target organisms. Human toxicity.
Devoe & Raynolds Co.	Performance of waterborne paints and coatings with low VOC content exceeds that of most water-based products.	Acrylic enamels, epoxy coatings, acrylic dry fog, wood stain.	Solvent-based paints.	Worker safety. Cost of disposal as a hazardous waste.
The Glidden Company (ICI Paints)	Two lines of paints that completely eliminate solvents and VOCs.	New resin formulation.	Latex paints with residual amounts of solvents such as ethylene glycol and glycol ethers.	VOCs form tropospheric ozone. Some are toxic.
Hüls America	Point-of-sale paint colorants completely free of VOCs.	Proprietary information until patents have been filed.	Ethylene glycol. Diethylene glycol.	Ethylene glycol is toxic and a VOC.
Miles	Polyurethane coating system for steel structures that can overcoat lead-based paints.	Polyurethane paint components.	Lead-based paints/ removal of lead paints.	Risks to workers and environment from removal of lead-based paints.
National Starch and Chemical Company	Hot-melt adhesives that are water-dispersible and repulpable. Enables paper products to be effectively recycled.	Different polymers.	Adhesives that do not disperse completely in the repulping process.	Impeded paper recycling.
Swift Adhesives	Waterborne, latex-based, high solids adhesives for flexible foam.	Water-based adhesives.	Methyl chloroform (1,1,1-trichloroethane).	Is a VOC. Methyl chloroform contributes to depletion of stratospheric ozone.

Chapter 5: Study Findings

Environmental Innovations in Paints and Adhesives: An Overview

Over the past few years, the trade and popular press have reported a wide variety of innovations in the paints and adhesives industries, responding to environmental concerns and corresponding regulatory efforts. Some of these innovations have sought to reduce toxic chemicals, VOCs, and ozone-depleting substances in paints and adhesives. Others sought to address environmental concerns associated with related activities, such as the removing and disposing of old paints prior to repainting, or the disposal of waste paint, painting tools, and containers. Table 5-1 presents a list of innovations discovered in our initial search (including those of case-study companies); the list below describes those that are not included in the case studies. It is hardly exhaustive, but it represents some of the major trends that form the context for the innovations of the case study companies.

Removal of Old Paint and Surface Preparation

Removing deteriorated paint from a surface typically involves the use of abrasive tools, heat, or chemicals that soften the existing finish. Processes involving abrasion or heat to remove old finishes can expose workers and the environment to toxic chemicals from these coatings, while the chemicals used to soften paint for removal also pose environmental threats. [1]

Innovations for safe repainting that dispense with most toxic ingredients include new paint remover formulations such as 3M "Safest" stripper, Dumond Chemical Peel Away 6, and Woodfinishers Pride Breath-Easy Formula. They also include paints that can coat over existing finishes, and thus eliminate the need for paint removal. One such example is Porter Paint water-based paints that can be applied directly over oil-based finishes, eliminating the need for strippers with high VOC content (51).

Paints with Decreased Solvents and VOCs

Several paint companies are pursuing new technologies and innovative resins to reduce the VOC content of both solvent-based and waterborne paints. For solvent-based paints, this principally means the production of paints with a higher "solids" content.[2] For waterborne paints, some manufacturers are substituting less toxic solvents for the solvents that remain.[3] For example, Dow is replacing ethylene glyco1 ethers in waterborne paints with less toxic propylene glycol ethers (52).

Environmental concerns also appear to be driving a rebirth of older paint technologies in architectural applications, including "milk" paints based on casein, produced by the Old-Fashioned Milk Paint Company. Another alternative is to use vegetable-based solvents for paints, in place of petroleum-derived solvents.[4] At least three companies, Auro Natural Plant Chemistry, Livos Plant Paints, and Biofa Naturprodukte, produce such paints (21, 53).

In applications involving the manufacture of painted products (original equipment manufacturing, or OEM), particularly in the automotive and aerospace subsectors, there appears to be increasing use of powder coatings (54, 55, 56), as well as of water-curing[5] polymers and radiation-curing polymers (56). Another technology, still in the testing phase, is the use of supercritical[6] CO, in place of solvents as a means to spray-apply paints (56).

Decreases in Toxic Pigments and Additives

Innovations are also directed at replacing heavy metals and other toxic chemicals that are currently used as pigments and additives in paints, or modifying these chemicals to decrease the potential for exposure. Engelhard has developed low-solubility cadmium compounds for pigments, while both Engelhard and Hoechst-Celanese are developing organic replacements for lead and other heavy metals in high-solids and powdered paints/coatings (57).

Other manufacturers, such as Miller Paint Co., Murco Wall Products, and American Formulating Manufacturers (AFM) are developing latex paints with lower levels of biocides than have usually been employed, and that are completely without fungicides (53). ICI is developing new surfactants[7] that would allow paint resins that currently can be used only in solvent-based paints to be used in waterborne paints (58).

In structural steel maintenance, the potential of substituting zinc for lead as a corrosion protection agent is being explored (56). One substitute technology, zinc thermal spraying, has been available since the 192Os, and gives performance that is safe, effective, and economically competitive over its service life. However, its use on existing bridges requires complete removal of existing paint (59). Sherwin-Williams is working on waterborne epoxies for aluminum mastic coatings that permit the application of new paint over existing lead paint (60).

Alternative Perspectives on Paints

Other initiatives have focused on the problem of paint wastes. For example, Kimat is not only producing waterborne paints with very low VOC content (less than 1 gram of VOCs per liter of paint) but also employs a novel delivery and application scheme, involving disposable pads on reusable handles to minimize cleanup, and packaging paint in pouches or reusable squeeze bottles so that there is no wastewater associated with painting operations.[8] Unused paint and containers are collected for recycling by the company and molded into packaging. H20 Green Paint is developing recycled water-based paints for use in traffic markings.

Paints are also being used to conserve energy (and consequently, the environmental problems associated with energy generation). For example, Helios Energy Products produces a paint with insulating properties, sold under the brand name Thermapaint.

Adhesives - Decreased Solvents and VOCs

The adhesives industry is moving toward the reduction of solvents in its products. The trend is reflected in company initiatives to decrease solvents in general, such as the decision by Swift Adhesives in 1991 to decrease solvent content of all its adhesives and increase solids (non-solvent) content from 15-20 percent to 40-50 percent (61), and the 1992 commitment by G.E. Silicones to increase the solids content of its adhesives from 50 percent to 80 percent (39). It is also seen in campaigns to reduce or eliminate specific solvents, such as H.B. Fuller's decision to eliminate use of 1,1,1-trichloroethane by the end of 1992 (39) and National Starch and Chemical's decision to eliminate chlorinated solvents from its packaging adhesives by March of 1991 (62). Many companies, including 3M, Dow, Exxon, H.B. Fuller, National Starch, Shell Elastomers, and Swift Adhesives, are developing 100 percent solid thermoplastic adhesives to replace solvent-based adhesives (17,63).

Low-VOC and even non-VOC adhesives and sealants are already available for architectural applications, including floor-covering adhesives, sealers, and grouts sold by Auro, Envirotec Healthguard, and AFM, and construction adhesive marketed by Franklin International. As in the case of paints, efforts are also being made to control wastes associated with adhesive use. For example, H.B. Fuller has developed a film wrapping for hot-melt[9] adhesives that is incorporated into the adhesive, so that none remains as waste (63).

Innovations of the Case Study Companies

In INFORM'S case study companies we found a range of innovation comparable to that described above. Table 5-2 provides a brief description of each of the innovations introduced by the case study companies, identifying, among other factors, the environmental problem that the innovation was designed to address, the direct and indirect motivations underlying the innovation, its market impact to date, relevant regulatory considerations, and any barriers to the innovation noted by the case study companies. Each innovation is briefly summarized below and presented in greater detail in Section 7.

Ciba Corporation (Ciba) is pursuing two alternative uses of organic (triazine) chemicals as substitutes for metals in paints and coatings. The company is marketing organic corrosion inhibitors (trade name IRGACOR™) as an alternative to zinc and strontium chromate pigments to prevent the corrosion of steel and aluminum. Ciba also has begun the (pesticide) regulatory review process for an organic algicide (IRGAROL™) for use in marine antifouling applications (for example, to inhibit barnacle encrustation of ship hulls) and in trade sales of paints.[10] This algicide replaces tin compounds that have been restricted because of their negative environmental effects, and mercury, which is being restricted as an in-can preservative for emulsion paints.

Devoe & Raynolds Company has introduced a range of waterborne products, including acrylic enamels (high-gloss and semi-gloss), epoxy coatings (gloss and semi-gloss), acrylic dry fog, and wood stain and wood finish. The company claims that the performance of these products exceeds that of most water-based products, and in some cases exceeds the performance of solvent-based products. This gives the user the advantages of waterborne paints, without the sacrifices in performance that have previously been associated with these paints.

The Glidden Company has recently introduced two lines of latex paints, Spred® 2000 (for consumer and contractor markets) and Lifemaster® 2000 (for the contractor market) that completely eliminate solvents and VOCs. Since the introduction of latex paints more than 40 years ago, small amounts" of solvents have been used to aid in application of the paint and in film formation; the new formulation, while completely eliminating the use of solvents,‘* maintains the film-forming and application properties of conventional latex paints. The new product is based on the use of completely new resins, and also eliminates crystalline silica and formaldehyde preservatives.

Hüls America, Inc., has introduced a line of universal[13] colorants for machine tinting of paint that have no volatile organic compounds (VOCs) whatever. These "point of sale"[14] colorants are "plug-in" replacements for Hüls America's existing line of such colorants, with identical application and addressing the same color range.

Miles Corporation has developed a series of polyurethane paint components that can be used to make paints for coating over steel structures that have been painted with lead-based paint, without requiring removal of the lead-based paint. This significantly decreases the risks and expense that would otherwise be associated with removal of lead-based paint from steel structures.

A polyurethane primer containing aluminum or zinc is applied to areas of exposed steel, following spot removal of rust and old paint in areas of corrosion or paint breakdown. This is followed by a polyurethane intermediate coat applied to the entire structure, including areas where old lead-based paints are intact, and finally by a polyurethane topcoat.

National Starch and Chemical Company has introduced a series of hot-melt (thermoplastic) adhesives that are water-dispersible and, consequently, can be recycled along with paper pulp. Previously, paper products made using hot-melt adhesives (such as cardboard boxes) could not be effectively recycled. This family of adhesives can be customized for a variety of applications. While this adhesive technology has been available for approximately 15 years, National Starch has recently begun an intensive effort to introduce it into markets where a product's paper content may be recycled.

These adhesives rely upon completely different polymers, developed by National Starch, from those used in conventional hot-melt paper adhesives. While both the polymers and the polymerization process are different, however, company officials say the adhesives are "drop-in" substitutes for conventional adhesives; they do not require customers (such as box manufacturers) to change their equipment or procedures. The adhesives are currently being reviewed by the Food and Drug Administration for use in food product packages.

Swift Adhesives, Inc., has developed waterborne, latex-based, high-solids adhesives that replace conventional latex adhesives for flexible foam (used, for example, in making furniture). The new adhesives, which required the development of new water-soluble resins, do not employ l,l,l-trichloroethane or similar solvents, as do conventional adhesives for foam. Swift Adhesives is also evaluating hot-melt (100 percent solids) adhesives.

As noted above, with only seven case study companies spanning a wide range of innovations, the findings of this project may not be statistically representative of environmental innovation in the paints and adhesives industries. In addition, these innovations have either not yet been introduced or have been on the market a relatively short time. Thus, it is difficult to judge the extent to which they will ultimately prove successful in the marketplace, or the extent to which apparent barriers will prove to be significant in the long term. Most instructive is the information obtained on the companies' motivations for developing these products, and on their experiences up to the point of commercialization. These responses identify common factors that lead to the introduction, if not the commercialization, of environmental innovations.

The following sections summarize the case study companies' motivation for investing time and money in environmental innovations, identify significant factors in the developmental process, describe the companies' early experiences in attempting to market innovative products, and note the role that regulation has played in fostering or impeding innovation.

Motivations of Companies Making Environmental Improvements

Table 5-3 summarizes some of the factors that motivated case study companies to introduce their environmental innovations. Regulatory constraints, affecting either the companies or their customers, were common to all. The case study companies were roughly evenly divided between those that primarily credited their motivation to corporate initiative and those that stressed market factors. In most cases, corporate environmental concerns and the desire to preserve or expand markets were both noted; the difference was one of emphasis. The separation between environmental and business goals was not always clear-cut. All of the companies saw environmental considerations as likely significant market forces in the future, if not at present. They gave little indication that environmental goals and business objectives were in conflict, except in the very near term.[15]

Environmental Commitments

For those companies that expressed concern over the marketability of environmentally enhanced products (discussed below), the ultimate judgment was that the environmental considerations were paramount. The companies repeatedly cited the Chemical Manufacturers' Association's "Responsible Care" initiative in product stewardship; six of the seven companies are CMA members.[16] Four of the seven are also participants in EPA's voluntary 33/50 initiative to reduce releases of 17 toxic chemicals.

Commercial Expectations

Not surprisingly, all of the companies anticipated eventually reaping a significant commercial benefit from their environmental innovations. (Indeed, if this were not the case, it is hard to imagine that any rational business manager would support the innovation.) Expectations varied widely, however, as to the timing of commercial success. Companies such as Swift Adhesives expected an immediate market, given apparently pressing needs on their customers' part. Others anticipated an extended process of market entry, reflecting extensive barriers to new products in their market, as in the case of bridge paints, where an extensive review process precedes acceptance by state authorities. As noted below, short-term expectations of significant market advantage from these innovations seem to have been tempered by various forms of customer reluctance, although none of the companies expressed lack of faith in the ultimate commercial success of its innovation.

Regulatory Imperatives

All seven companies noted regulatory constraints serving to motivate their innovations, either directly or indirectly. In the case of Ciba, Devoe & Raynolds, Miles, and Swift Adhesives, new products were being introduced to address current regulatory concerns, such as limitations on the VOC content of paint. However, Glidden and Hüls America introduced products that went substantially beyond the requirements of current regulations, while National Starch addressed an environmental problem not yet covered by regulations. As officials at Hüls America noted, they had no desire to be faced with continual tightening of regulatory requirements, and so acted to eliminate rather than simply reduce the amounts of the regulated substances from their products.

Another striking feature of the regulatory impetus to environmental innovation is that the regulations that were effective in stimulating environmental innovation were frequently not those that affected the innovating companies, but rather those that affected their customers, or even their customers' customers. Regulations on bridge repainting, for example, affect state highway departments and their painting contractors, not resin producers such as Miles or the paint companies they supply. Similarly, Ciba is creating organic compounds to replace regulated compounds containing toxic inorganics. Thus, it may be very misleading to consider only regulated industries when attempting to judge the impact of regulation. Creative responses, with positive economic results, may come from the suppliers of goods or services to the regulated industry.

While some innovations responded to regulations already in place or being instituted in accordance with known schedules, other innovations reflected a company's anticipation of regulations to come. Indeed, National Starch noted that the future regulations mandating recycling would improve the market for its innovative products.

The Process of Developing Environmentally Improved Products

The management policies and structure of the case study companies, as well as external factors such as regulation and market demand, significantly affected the process of innovation. Table 5-4 presents some of the management characteristics noted for case study companies.

Prominent among management features described by the case study companies were 1) frequent expression of explicit corporate environmental goals, 2) the reported absence of internal hierarchy that would pose a barrier to innovative product development, 3) collaborative efforts between marketing and research and development groups in product development, 4) relative autonomy in committing resources to development efforts, and 5) Total Quality Management or similar approaches, involving employees directly in the process of innovation, both environmental and commercial. It would be instructive to ascertain whether these are general features of current American business practice, or more likely to be associated with innovative companies.

The prevalence of explicit corporate environmental policies in the case study companies is a factor that was also noted to be important in previous INFORM studies of companies that had taken action to reduce hazardous and toxic wastes in their production facilities. In contrast to companies that were active in reducing production wastes, however, only one of INFORM'S case study companies employed full cost accounting, while two others did incorporate some allocation of environmental costs to specific products. It might be useful to study whether corporate policies and management programs favoring environmental efficiency in plant operations differ from those leading to introduction of environmentally improved products.

Notably, none of the case study companies reported their innovations to be the result of formal analysis of the overall environmental impact of the product, such as life cycle assessment (LCA). Rather, each of the environmental innovations was addressed to a known environmental problem, regulation, or market opportunity. Few case study companies were able to provide extensive information on the chemical life cycles in which their operations played a part. To the extent that life cycle considerations were addressed by respondents, those downstream (i.e., effects of the actions taken by their customers and customers' customers) were better characterized than those of their suppliers-not surprising, in view of the market-driven nature of many of these innovations.

Factors that Favor the Introduction of Environmental Innovation

Table 5-5 presents some factors - environmental/ regulatory considerations and product performance - that appear to favor the innovations introduced by the case study companies.

Market Issues

An expectation of commercial success is basic to the introduction of any commercial product. Among the case study companies, however, only Devoe & Raynolds reported major market success to date. Miles noted that a significant number of bridge-painting projects would employ its products in 1994; the other firms either noted a relatively slow growth of demand for the improved products, or indicated that the products had not been on the market long enough to gauge their success. The absence of immediate major market results has produced a range of reactions on the part of the companies; officials at some indicated disappointment, while others indicated that they had not expected rapid success. All companies continued to anticipate future success for their innovations.

When asked about the markets in which their products were sold, company officials identified several features of the markets in which they operate that appeared to influence the potential success of their innovations. These are discussed below.

Market Specialization

Three of the innovations developed by the case study companies were focused on markets that are highly specialized - "niche" markets. These are the antifouling compounds developed by Ciba, the bridge overcoating system developed by Miles, and the foam adhesives developed by Swift Adhesives. The remaining innovations address more general markets, such as architectural coatings and paper packaging. The innovations for these specialized markets have not reflected noticeably more or less success than those directed at more general markets.

Geography

All of the companies have markets that are national or international, rather than local and regional. Several companies noted that innovations were being made in part to comply with local regulations, so that these local requirements (e.g., California VOC limits for paints) were having a national effect.[17]

For those companies selling in international markets, actual or potential sales were judged to be significantly better than sales in the United States. Company officials suggested that the need to compete in these more environmentally conscious markets was a spur to US innovation. They anticipated that this need would give them a head start on competitors. However, Ciba, in particular, noted some difficulty in adapting to the US market innovations developed in Europe.

Pace of Innovation

Almost all respondents indicated that their markets were relatively mature, characterized by continual minor improvements rather than major or rapid technological change. In contrast, both Ciba's antifouling compounds and Miles' bridge overcoating system addressed markets in which a dominant technology had been substantially eliminated (in both cases by regulatory constraints, either direct or indirect). This appears to be a factor favoring the success of these innovations, as competing systems either have much reduced performance (e.g., copper-based antifouling compounds), entail great cost (e.g., total lead removal from bridges), or are equally innovative.

Market Share Distribution

There was wide variation among the case study companies in the size distribution of customers in their market and in the share of the market they controlled. Few reported having market dominance, although many were among the larger competitors in the market. None saw its size as an advantage in achieving acceptance of its innovations.

The size of customer companies appeared to be a better predictor of the success of innovations. Those firms that served a mix of large and small firms noted that the larger firms tended to be more receptive to innovative products and to environmental concerns in general. Companies that sold to small customers noted a significant general resistance to innovation.

Regulatory Issues

Most (but not all) case study companies, as noted above, were not reacting directly to regulations that affected their operations or their products. All of the innovations under study, however, represented responses to regulations that affected their customers.

If the experience of INFORM'S case study companies is representative, industrial innovation appears to be able to keep abreast of regulation, if not well ahead. For example, with no change in capital equipment by foam manufacturers, 1,1,l-trichloroethane could be eliminated in foam assembly today, rather than at the end of 1995, as required under the Bush Administration's 1992 decision to accelerate the elimination of ozone depleting substances covered by the Montreal Protocol (64). Similarly, architectural paints that are completely free of VOCs are available now, with a full range of colors for point-of-sale tinting. Frequently, even the innovators' own expectations have been exceeded.

As also mentioned above, local regulations can have national and even international effects on innovation, if a product's market is national in scope. Suppliers may either forfeit the strict local market, or bring all of their products into compliance with that market's regulatory constraints; the case study companies seem to have followed the latter course. Similarly, foreign regulations can have significant impact on the US market. Thus, European regulations on recycling are beginning to affect even US operations of multinational firms (65).

Varied Effects

None of the case study companies reported any effect on its own regulatory environment (as opposed to that of its customers) as a consequence of its innovation, and many said they anticipate no long-range effects, as their operations were diversified and the innovation did not eliminate a chemical from all of their product lines. Those firms with a corporate commitment to replace entirely certain chemicals (such as Glidden and Swift Adhesives) reported that they expect a corresponding eventual diminution of their regulatory burden. Some respondents indicated that they expect an increase in their regulatory burdens, because in the course of commercializing the innovation they expected to produce types of chemicals that they previously had obtained from others.

Impediments to Environmental Innovation

Despite the environmental and health benefits offered by their new products, officials at three companies (Ciba, Miles, and National Starch) noted specific regulatory obstacles to introducing their innovations. All of the companies identified market factors that, under current conditions, served as barriers to the success of their innovations, and some cited technical obstacles. Some of these factors are noted in Table 5-6.

Market Obstacles

Competitive Products

In all cases except that of Ciba's antifouling compounds, competing products with similar performance (from a non-environmental perspective) and similar price appeared to be available, either from competitors or from the case study companies themselves. Price differentials, even if small, were specifically noted as a barrier to market acceptance of their innovation by Glidden, Hüls and National Starch, while performance concerns confronted Ciba's anticorrosion pigments and Devoe & Raynolds and Swift adhesives. The case studies suggest that as long as a conventional alternative is available, many customers remain reluctant to pay more solely for enhanced environmental performance.

One might expect that such price concerns would be most important when the price of the innovative product represented a significant fraction of the total cost of the operations in which it is used, but this does not appear to be the case. For example, colorants constitute a very small part of the cost of a gallon of paint, and an even smaller fraction of the cost of painting a room, when labor, preparation, and other materials are considered, yet Hüls America has experienced resistance to a 20 percent price increase for colorants. Similarly, according to National Starch, although the total cost of adhesive in a cardboard box may be less than $0.01, few customers were willing to pay twice the price for a repulpable adhesive. Glidden found consumer reluctance to a paint price increase of $1 or $2 per gallon.

Inertia

Even when their innovations promised net savings, as in the case of the antifouling compounds developed by Ciba,[18] or the waterborne adhesives developed by Swift Adhesives, the companies faced reluctance to accept the new products. A major factor leading smaller customers to reject environmental innovations, noted by both Devoe & Raynolds and Swift Adhesives, was reluctance to change existing work patterns, whether these reflected long-standing traditional practices or were merely small procedural adjustments. Ciba also noted that traditional test methods (reflecting industrial consensus) could work against innovations. As procedural rigidity is a criticism often leveled at regulation, it is interesting to note that it is not absent in business practices.

Regulatory Issues

Differential Scrutiny

While regulation generally motivated company innovations, two firms (Ciba and National Starch) also pointed to regulatory scrutiny of their new products as a significant barrier to their introduction, even though the new products addressed an identified environmental problem. A third firm (Miles) noted that increasingly strict occupational regulations will affect its innovative products to the same extent as older products, despite a significant difference in their risks.

Pre-market review of new chemicals is a common feature of several US laws. The most important are the Toxic Substances Control Act (TSCA), which requires Premanufacture Notification (PMN) of, and review by, the EPA prior to a chemical's introduction into commerce; the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), which requires submission of health and safety and efficacy data; and the Federal Food, Drug, and Cosmetic Act (FFDCA), which evaluates both food additives and drugs. While reviews under these laws serve the important goal of preventing undue risks from new chemicals, review procedures are predicated on the often debatable assumption that existing materials have been reasonably well characterized.

One of the case study companies' products is being reviewed under FIFRA (Ciba's biocide for paints), and one as an indirect food additive under FFDCA (National Starch's adhesive to be used on paper food containers). In each case, the developing company indicated that the expense and uncertainty attached to the evaluation effort were a substantial barrier to product introduction, and that the new product received more thorough review than that faced by existing products, either when they were introduced to market, or during subsequent reevaluations.

Excessive Uniformity

Officials at Miles noted that the recent lead exposure control regulations for the construction industry, promulgated by OSHA in June 1993, would impose the same control requirements on hand-tool removal of lead paint from bridges as on abrasive blasting operations. They expressed concern that this would diminish the price advantage of overcoating technologies, relative to those that depend on complete removal of lead paint from bridges, despite the fact that occupational exposures would be reduced in the case of hand-tool removal.

Lack of Clarity

Regulations were also cited as posing a barrier when their criteria are unclear or imprecise. Both Hüls America and Devoe & Raynolds noted that the EPA-specified test method could yield very variable results,[19] and Devoe & Raynolds described the test method as biased toward overestimating VOC content.

Notes

1. For example, paint strippers may contain considerable amounts of VOCs, as well as toxic compounds such as the carcinogen methylene chloride.
2. Paints in which the ratio of solvents to paint components that will remain after drying (solids) is decreased.
3. Small amounts of solvent are used in most waterborne paints to help the resins disperse in the water; this eases application and promotes more consistent paint film on drying.
4. Such paints mostly use limonene as a solvent, a citrus-based terpene that can be derived from lemon, bergamot, caraway, and other vegetables, and is used as a flavoring in foods. The International Agency for Research on Cancer has recently characterized this solvent as a possible human carcinogen (53), although there is some dispute regarding the meaning of animal data.
5. These are resins in which the polymerization reaction involves the absorption of water, rather than the evaporation of solvent.
6. A supercritical fluid is a dense gas that is maintained at high pressure at a temperature above that at which it can be liquefied by pressure (the critical temperature). Such a gas behaves like an extremely non-viscous liquid.
7. This is a chemical (surface active agent) that allows non-water soluble organic compounds to be dissipated in water. For example, oil and water will not mix by themselves, but with the addition of detergent (a surfactant), they can be mixed.
8. Clearly, this approach may involve some (small) increase in the generation of solid wastes associated with the painting process (if one assumes that conventional applicators and containers such as brushes, rollers, and cans have a longer service life). This needs to be contrasted with the decrease in water pollution.
9. These adhesives melt when heated, then set to form a firm bond when they cool. They can either be thermoplastic (i.e., they will melt whenever heated) or thermosetting (the change in the cooling process is irreversible).
10. This is already marketed outside of the United States.
11. Between 2 and 6 fluid ounces per gallon (between 1.6 and 4.7 percent by volume).
12. The principle solvents eliminated are ethylene gyco1 and glycol ethers,

13. A “universal” colorant can be mixed with either water-based or solvent-based paints.
14. This denotes a colorant that is used to produce a custom tint for a customer, for example at a paint store, as opposed to a stock colorant added to the paint at the factory.
15. One company, Hüls America, noted that it specifically sought business opportunities in situations where a regulated industry believed it lacked the technology to respond to an environmental concern; by providing innovative technology to resolve the dilemma, the company could enhance its market position while competitors were engaged in arguing against the regulation.
16. Devoe & Raynolds, a paint formulator that is not a subsidiary of a chemical company, is the sole exception.
17. Even Devoe & Raynolds, which noted that a sister company covers the most highly regulated (California) market, acknowledged the influence of California regulations on its products.
18. Labor savings from less-frequent application, or alternatively, fuel savings from reduced fouling, would more than offset the price of the product.
19. Scientific Certification Systems also noted that the EPA test was unreliable at low VOC concentrations.

Table 51: Brief Survey of Recent Environmental Innovation in Paints and Adhesives

P A I N T S

Innovation	Company	Importance
. REMOVAL OF OLD PAINT AND SURFACE PREPARATION		
"Safer" stripper (paint and varnish remover)	3M	Very few known toxic ingredients used
Peel Away 6 (paint and varnish remover)	Dumond Chemical	Very few known toxic ingredients used
Breath-Easy Formula (paint and varnish remover)	Woodfinishers Pride	Very few known toxic ingredients used
Polyurethane paint components that permit overcoating of steel structures previously painted with lead-based paint	Miles	Does not require the removal of existing paint and therefore reduces lead contamination to the surrounding environment
Waterborne epoxies for aluminum mastic coatings that enable the application of new paint over existing lead paint	Sherwin-Williams	Does not require the removal of existing paint and therefore reduces lead contamination to the surrounding environment
Water-based paints that can be applied directly over oil-based finishes	Porter Paints	Eliminates the need for strippers with high VOC content
. PAINTS WITH DECREASED SOLVENTS AND VOLATILE ORGANIC COMPOUNDS (VOCS)		
Vegetable-based solvents for paints	Auro Natural Plant Chemistrv	Replaces petroleum-derived solvents
Vegetable-based solvents for paints	Biofa Naturorodukte	Replaces petroleum-derived solvents
Vegetable-based solvents for paints	Livos Plant Paints	Replaces petroleum-derived solvents
"Milk" paints based on casein	Old Fashioned Milk Paint Company	No solvents or heavy metals used
Waterborne acrylic enamels, epoxy coatings, and acrylic dry fog	Devoe & Raynolds Co.	These products exceed the performance of most water-based products, and in some cases that of solvent-based products
Replacing ethylene glycol ethers in waterborne paints with propylene glycol ethers	Dow	Substituting less toxic solvents
Spred® 2000 and Lifemaster® 2000 (latex paints)	The Glidden Company	Completely eliminates the use of solvents and VOCs
Universal colorants for machine tinting	Hüls America	Completely eliminates the use of VOCs
. DECREASES IN TOXIC ADDITIVES		
Developing latex paints with lower levels of biocides and completely without fungicides	American Formulating Manufacturers	Little or no exposure to heavy metals
Developing latex paints with lower levels of biocides and completelv without fungicides	Miller Paint Co.	Little or no exposure to heavy metals
Developing latex paints with lower levels of biocides and completely without fungicides	Murco Wall Products	Little or no exposure to heavy metals
Developing new surfactants that would allow paint resins that currently can only be used in solvent-based systems to be used in waterborne paints	ICI	Eliminates use of solvents

continued

Table 51: Brief Survey of Recent Environmental Innovation in Paints and Adhesives (continued)

PAINTS

Innovation	Company	Importance
• DECREASES IN TOXIC PIGMENTS		
Developing organic replacements for lead and other heavy metals in paints/coatings	Ciba-Geigy	Little or no exposure to heavy metals
Developing organic replacements for lead and other heavy metals in high-solids and powdered paints/coatings	Engelhard	Little or no exposure to heavy metals
Developing organic replacements for lead and other heavy metals in high-solids and powdered paints/coatings	Hoechst-Celanese	Little or no exposure to heavy metals
Low-solubility cadmium compounds for pigments	Engelhard	Decreases the potential for exposure
• ALTERNATIVE PERSPECTIVE ON PAINTS		
Developing recycled water-based paints for use in traffic markings	H20 Green Paint	Fewer solvents and heavy metals used
Thermapaint with insulating properties	Helios Energy Products	Addresses environmental problems associated with energy use
Waterborne paints with very low VOC content and novel delivery and application scheme	Kimat Paints	Reduces waste because non-used paint and containers are collected for recycling and no wastewater is produced because paint isapplied directly from reusable squeeze bottles or pouches

continued

Table 5-1: Brief Survey of Recent Environmental Innovation in Paints and Adhesives (continued)

A D H E S I V E S

Innovation	Company	Importance
▪ DECREASED SOLVENTS AND VOLATILE ORGANIC COMPOUNDS		
Developing 100% solid thermoplastic adhesives	3M	Replaces solvent-based adhesives
Developing 100% solid thermoplastic adhesives	Dow	Replaces solvent-based adhesives
Developing 100% solid thermoplastic adhesives	Exxon	Replaces solvent-based adhesives
Developing 100% solid thermoplastic adhesives	H.B. Fuller	Replaces solvent-based adhesives
Developing 100% solid thermoplastic adhesives	National Starch and Chemical	Replaces solvent-based adhesives
Developing 100% solid thermoplastic adhesives	Shell Elastomers	Replaces solvent-based adhesives
Increase the solids content of its adhesives	G.E. Silicones	Reduces solvents in adhesives
Low-VOC and non-VOC adhesives and sealants for architectural applications	American Formulating Manufacturers	Reduces VOCs
Low-VOC and non-VOC adhesives and sealants for architectural applications	Auro Natural Plant Chemistry	Reduces VOCs
Low-VOC and non-VOC adhesives and sealants for architectural applications	Envirotec Healthguard	Reduces VOCs
Low-VOC and non-VOC construction adhesives	Franklin International	Reduces VOCs
▪ OZONE-DEPLETING SUBSTANCE		
Eliminate use of 1,1,1-trichloroethane	H.B. Fuller	Reduces or eliminates solvents
Eliminate use of 1,1,1-trichloroethane	Swift Adhesives	Reduces or eliminates solvents
▪ TOXIC SOLVENTS		
Eliminate chlorinated solvents from its packaging adhesives	National Starch and Chemical	Reduces or eliminates toxic solvents
▪ SOLID WASTE REDUCTION		
Film wrapping for hot-melt adhesives that is incorporated into the adhesive	H.B. Fuller	Reduces wastes associated with adhesive use

Table 5-2: Summaries of Case Study Companies

Company	Improvement(s)	New Chemicals	Chemicals Replaced or Problem Addressed	Risk of Original Product
Ciba-Geigy	Organic corrosion inhibitors as an alternative to chromium salts as active pigments in the protection of steel and aluminum.	Organic (triazine) pigments.	Heavy metal salts, including lead and chromium compounds, used for corrosion protection of aluminum and steel.	Toxicity to humans. Environmental damage.
	Organic algicide for use in marine antifouling applications and trade sales paints.	Organic algicide.	Alkyltin compounds. Mercury.	Toxicity to non-target organisms. Human toxicity.
Devoe & Raynolds Co.	Performance of waterborne paints and coatings with low VOC content exceeds that of most water-based products.	Acrylic enamels, epoxy coatings, acrylic dry fog, wood stain.	Solvent-based paints.	Worker safety. Cost of disposal as a hazardous waste.
The Glidden Company (ICI paints)	Two lines of paints that completely eliminate solvents and VOCs.	New resin formulation.	Latex paints with residual amounts of solvents such as ethylene glycol and glycol ethers.	VOCs form tropospheric ozone. Some are toxic.
Hüls America	Point-of-sale paint colorants completely free of VOCs.	Proprietary information until patents have been filed.	Ethylene glycol. Diethylene glycol.	Ethylene glycol is toxic and a VOC.
Miles	Polyurethane coating system for steel structures that can overcoat lead-based paints.	Polyurethane paint components.	Lead-based paints/removal of lead paints.	Risks to workers and environment from removal of lead-based paints.
National Starch and Chemical Company	Hot-melt adhesives that are water-dispersible and repulpable. Enables paper products to be effectively recycled.	Different polymers.	Adhesives that do not disperse completely in the repulping process.	Impeded paper recycling.
Swift Adhesives	Waterborne, latex-based, high solids adhesives for flexible foam.	Water-based adhesives.	Methyl chloroform. (1,1,1-trichloroethane).	Is a VOC. Methyl chloroform contributes to depletion of stratospheric ozone.

Disadvantages of New Product	Status of New Products	Motivation: Direct(D) Indirect (I)	Regulatory Environment	Barriers to Development of Improved Products
Does not show comparable performance to chromate-based paints in standard test systems.	Currently marketing organic corrosion inhibitors.	D: Customers demanding industrial coatings that are lead- and chromate- free. I: Regulatory pressures to control heavy metals.	Regulatory concern over heavy metals favors introduction of this product.	Accelerated salt spray test is not reflective of the organic corrosion inhibitors' performance. Reliance on this test method is retarding introduction of safer alternative and access to larger markets.
	Begun pesticide review process. Not yet available in US. Available elsewhere.	D: Improved service life relative to available alternatives. I: Avoids tin-induced damage to aquatic ecosystems."	Safety testing required to support cost-benefit analyses under FIFRA which counter-balances pressure favoring new products in the form of restrictions on old.	Registration costs with EPA as a pesticide represent a significant expense relative to the value of the total markets.
Products still contain VOCs (less than 200g/l total) and some hazardous chemicals.	On market for approximately two years.	D: Unacceptable performance of existing waterborne paints. I: Existence of regulatory constraints on VOC content of paints. Worker safety concerns.	Range of state restrictions on VOC content in paint. Waterborne paints meet all VOC requirements.	Skepticism among paint contractors regarding the performance potential of waterborne products.
Color range of paints is limited at first. Per-gallon cost of paint is higher than that of conventional latex paints.	Have been on the market a short time.	D: Glidden goal of removing all solvents from its decorative products by the year 2000. I: Regulatory pressures under the CAA amendments."	VOCs in paints are regulated in areas of some states. Federal regulation of VOC content in paint is under development."	Customer reluctance to pay increased price for environmentally improved product.
New formulations cost approximately 20% more than the products they replace.	Have been on the market a short time.	D: To avoid the need for warning labels for ethylene glycol. I: Customers requesting low-VOC and non-VOC paints."	Requirements of the OSHA on Material Safety Data Sheets (MSDSs). Clean Air Act amendments of 1990 introduced pressure to eliminate VOCs from several paints and coatings."	Customer reluctance to pay increased price for environmentally improved product. Limitations of VOC measurement methods.
If 30% of structure has paint failure, lead paint removal still necessary.	Recently applied to second bridge. Ten additional bridges scheduled for near future.	D: Overcoating is safer and cheaper than complete removal of lead I: Several states require complete containment during removal of lead-based paints."	Waste disposal restrictions on removed paint imposed by RCRA. OSHA regulations on paint removal.	New chemical review process at EPA is slow. New OSHA regulations do not distinguish between spot and complete removal of lead-based paint. Specifications for bridge paints often require environmental tests for up to three years.
Polymer constituents of adhesives are synthesized from toxic monomers, just as are those replaced.	Developed 15 years ago; commercially available for 2-3 years.	D: National Starch's belief that in the future environmental concerns will be market drivers. I: Future program to recycle paper products.	Will need monitors and control equipment to produce polymers. Regulation by FDA if adhesives are used in food packaging.	Twice as expensive as the conventional products that they replace. Customers for adhesives are rarely directly involved in recycling; they have little incentive to pay a higher price for a new adhesive.
Does not bond styrene foams well.	In process of introducing waterborne adhesives into foam fabrication industry.	D: Corporate goal to eliminate solvents from adhesives. I: Regulatory pressure under Montreal Protocol.	Methyl chloroform is taxed; has to be eliminated by 1995.	Customer reluctance to change procedures.

Table 5-3: Motivations of the Case Study Companies for Introducing Clean Products

Company	Market	Regulatory	Corporate
Ciba-Geigy	Coating formulators' customers were demanding industrial coatings that were lead- and chromate-free.	Mercury is coming under increased regulatory controls in paints and other applications. Tin-based antifouling paints were restricted by regulations on maximum tin release rates. Ongoing regulatory efforts to control heavy metals exist in both worker safety and environmental contexts. New initiatives in emissions reporting and source reduction under SARA 313 are seen as an increasing issue for coatings manufacturers.	Waste disposal costs can be decreased significantly by the elimination of toxic metals.
Devoe & Raynolds Co.	Worker safety concerns important to Devoe & Raynolds s contractor customers. Customer demands for low-VOC paints.	Regulatory constraints of VOC emissions in some jurisdictions. All products contain less than 200g/l total VOCs, and thus comply with all US and state regulations.	Allows expansion of Devoe & Raynolds s market.
The Glidden Company (ICI Paints)	Anticipates growth in customer demand from increased awareness of ozone-formation and toxicity problems.	Regulatory pressure for ozone nonattainment areas will grow under the 1990 CAA amendments. VOC content in paints is regulated in specific areas.These paints meet all VOC requirements.	Environmental goal of removing all solvents from its decorative products by the year 2000.
Hüls America	Paint companies (customers) began to request colorants that have little or no VOC content.	To avoid new OSHA requirement for warning on product labels, it became important to remove ethylene glycol from the product. CAA amendments of 1990 introduced pressure to reduce or eliminate VOCs.	Commitment to environmental and employee protection.
Miles	Use of lead paint for repainting is no longer an option. Total removal of lead paint involves significant cost disadvantage.	Several states have mandated total enclosure methods for the removal of lead-based paints. Regulation of paints used for structural rehabilitation and repainting; lead no longer useable. Waste disposal restrictions imposed by RCRA. Worker exposures to lead during removal must be controlled.	
National Starch and Chemical Company	Belief that in the future, environmental concerns will be important market drivers.	Future "recycled content" laws.	Internal company initiative to remove toxic chemicals from its products.
Swift Adhesives	Future market as a result of customers' becoming informed about environmental costs associated with conventional adhesives.	Methyl chloroform subject to taxation at present, must be eliminated entirely from use by 1995. Labeling for ozone-depleting substances and regulation as a RCRA hazardous waste.	Eliminate solvents from all of its adhesives.

Table 5-4: Management Features of Companies Introducing Clean Products

Company	Formal Corporate Environmental Policy	Participation in Multi-firm Environmental Initiative		Full Cost Accounting	Managerial Independence vs. Layering of Authority	Total Quality Management or Other Employee Involvement Program	Employee Environmental Incentives
		33/50	CMA				
Ciba-Geigy	X	X[1]	X			X	
Devoe & Raynolds	X		n/a	+/-	X	X	
Glidden	X	X[2]	X		X	X	X
Hüls America	X		X	+/-	X	X	X
Miles	X	X[1]	X			X	X
National Starch	X	X[3]	X		X	X	X
Swift Adhesives	X		X	X	X	X	

(1) Committed to 50% reduction of all seventeen 33/50 chemicals by 1995
(2) Committed to 33/50 Program, but no percentages given.
(3) Commitment through parent company only.

Definitions:
Formal Corporate Environmental Policy: explicit written environmental policy.
Full Cost Accounting: Allocation of the environmental costs incurred by a plant (e.g., waste disposal costs) to the specific products and processes that cause those costs to be incurred.
Employee Environmental Incentives: Explicit system of giving financial or other awards to employees who suggest ways to improve environmental performance.
Managerial Independence vs. Layering of Authority: Ability of plant or business unit managers to undertake environmental or other initiatives without the need for extensive review by higher management.
33150: EPA's 33/50 Program for voluntary industry reductions of emissions of 17 chemicals by 50% by 1995.
CMA: Chemical Manufacturers Association's Responsible Care Program represents the commitment of the chemical industry to:(i) improve performance, safety, and health of the public, workers, and the environment and (2) to listen and respond to the public.
+/-: Some but not all environmental costs are allocated to specific products.
n/a: not applicable, unlike the other firms, this is a paint formulator not affiliated with a chemical company.

Table 5-5: Factors Favoring Innovation of Clean Products

Company	Improvement(s)	Market	Regulatory	Technical
Ciba-Geigy	Organic algicide for use in marine antifouling applications and trade sales paints.	Substitutes have comparable anti-corrosion performance with less human and environmental toxicity. Extended service life; ability to repaint less frequently than with tin formulations; therefore, a cost advantage. Little competition in these niche markets.	Replacement of tin in antifouling applications makes company in compliance with regulations. Worker safety, health, and waste disposal regulations favor use of less toxic alternatives. Replacement of mercury, which is restricted as an in-can preservative for emulsion paints. Worker safety, health, and waste disposal regulations favor use of less toxic alternatives.	
	Organic corrosion inhibitors as an alternative to chromium salts as active pigments in the protection of steel and aluminum.	Little competition in these niche markets. Substitutes have comparable anti-corrosion performance with less human and environmental toxicity.		
Devoe & Raynolds Co.	Performance of waterborne paints and coatings with low VOC content exceeds that of most water-based products.	Opportunity to increase market share by improved performance of products.	Now comply with all US and state regulations on the level of VOCs in paints: products have less than 200 g/l as specified. New product doesn't require disposal as a hazardous waste and improves worker safety.	
The Glidden Company (ICI Paints)	Two lines of paints that completely eliminate solvents and VOCs.	Performance equals or exceeds that of similar paints formulated with solvents.	Zero-VOC paints have put them in compliance with EPA and all states.	
Hüls America	Point-of-sale paint colorants completely free of VOCs.	Can be applied in identical manner and can address same color range. Improved performance; less drying time and no streaking.	Low VOC regulations led to no-VOC colorants. Product does not require labeling regarding ethylene glycol.	New colorants are drop-in substitutes and do not require a change in equipment or procedures.
Miles	Polyurethane coating system for steel structures that can overcoat lead-based paints.	Rapid drying and ability to be applied in high humidity.	Lead-based paint removal regulations for bridges will be met with this product. Decrease in health and environmental risks and costs for painting contractor.	Allows repainting without complete removal of old paint.
National Starch and Chemical Company	Hot-melt adhesives that are water-dispersible and repulpable. Enables paper products to be effectively recycled.	Better adhesion than conventional hot-melt adhesives for paper. Repulpability of adhesives increases the recyclability of paper products to which they are applied.		New adhesives are drop-in substitutes and do not require a change in equipment or procedures.
Swift Adhesives	Waterborne, latex-based, high solids adhesives for flexible foam.	Cost savings in taxes, emission controls, and waste disposal.	Fewer regulatory requirements apply Existing solvent will be banned.	

Table 5-6: Barriers to Introduction of Clean Products

Company	Market	Regulatory	Technical
Ciba-Geigy	Key problem of commercialization of organic inhibitors has been the entrenched use of a single, poorly predictive test (accelerated salt spray) as a standard of performance.	Algicide currently undergoing regulatory review for use in the US, with safety testing to support cost-benefit analysis under FIFRA.	The anti-corrosion pigment was determined to have undesirable reactions with a number of components in paints in the US market. This problem was overcome by significant reformulation.
Devoe & Raynolds Co.	Painting contractors (customers) tend to be conservative and skeptical regarding product performance of waterborne paints.		Difficulty of the chemistry involved to achieve appropriate paint characteristics.
The Glidden Company (ICI Paints)	Currently costs are higher than those of conventional latex paints. Customers uncertain about the extent of the problem represented by solvents in paint.		Color range of paints was limited, and point-of-sale tinting was not yet available until recently.
Hüls America	The greater expense of the colorants has induced some reluctance to switching on the part of paint manufacturers.		CONVON colorants introduced earlier, suitable only for water-based paints, could not be used in "point of sale" applications, have reduced shelf- life, and have lesser color range. Measurement of VOC content was not always straightforward.
Miles	Where permitted, it is cheaper to continue using lead paint. Specifications for bridge paints often require actual environmental tests for periods of up to three years.	Paint formulators (customers) are faced with regulations regarding resins, particularly for the two-part paints. New chemical review process at EPA is slow. OSHA lead-based paint removal regulations pertaining to worker precautions may treat spot removal as equivalent to complete removal.	
National Starch and Chemical Company	Increased price represents a significant barrier to commercial introduction of these adhesives. The customer may have no direct link to paper recycling, thus diminishing demand for repulpable adhesives.	Regulated by FDA since adhesives are used in packaging for foods. Expense and uncertainty of testing effort.	
Swift Adhesives	Customer reluctance to change their patterns of adhesive use, even for minor adjustments to spraying and foam assembly techniques.		Does not bond styrene foams well.

Chapter 6: Implications for Corporate and Government Policy

Several of the findings discussed in the previous section suggest strategies that merit government and environmental community consideration as ways to encourage product improvements to enhance the environment and public health. Several have implications for companies that wish to compete successfully in the face of mounting environmental pressures in both the US and global markets.

Demand Side: Government and Public Pressure

Two key findings of these case studies involve the role of regulation in environmental improvement and business performance. First, a universal finding in INFORM'S case study companies was that regulatory requirements, either national or international, played a key role in stimulating innovation, although the nature and locus of the regulation varied among companies. Most obvious is the restriction on the VOC content of paints, both under federal and state laws and regulations. Second, reporting and labeling laws for toxic product constituents were also seen as key motivators for innovation, as were taxes (and a forthcoming ban) on ozone-depleting substances. While most firms indicated that an internal environmental commitment was important, the existence of a regulation provided a purely commercial motivation for environmental innovation.

Regulation and the Drive to Innovate

The companies developing innovative products, as noted earlier, were not always those subject to regulation. For both adhesives manufacturers and suppliers of paint additives, the relevant regulations primarily affected their customers, rather than their own operations. In this context, meeting regulatory requirements is simply a way of meeting customer requirements. INFORM'S research found that, in some cases, while suppliers who were not facing direct regulatory constraints invested in innovations to meet the needs of customers who were faced with such constraints, many of the companies directly affected by the regulations appear to have taken a less active role. For example, even though Swift Adhesives has developed a replacement that would allow its customers to avoid paying a tax on a regulated solvent and to dispense with expensive pollution control equipment, with no need for any capital investment, many customers were reported reluctant to change the product they use.

This behavioral pattern has at least two implications for determining the potential consequences of regulatory action. First, analysis of the regulated entities themselves is insufficient to define an industry’s potential to respond to a regulatory requirement. Regulated industries may honestly doubt whether they can technically meet regulatory requirements; however, they may simply be underestimating the innovative capabilities of their suppliers (or of companies that would like to become their suppliers). Second, coupled with the repeated observation that innovating companies had difficulty gaining acceptance of their new products by industrial customers, even when the innovation offered economic, as well as environmental, enhancements, regulators must recognize resistance to regulation as, in some cases, simply a more general resistance to change. Both factors deserve consideration when evaluating the cost and feasibility of planned regulations; regulators should seek to evaluate the potential contributions of firms at many stages in a product's life cycle.

As INFORM found regulatory negotiations at risk of excluding innovative companies, policymakers should consider whether regulatory negotiations may underestimate the true innovative capabilities of US industry. Hüls America noted that a key value of observing such negotiations was to learn the technical limitations of its customers and competitors; it expressed confidence in achieving better performance than that agreed to in such negotiations. Glidden has already introduced a paint that is free of VOCs, and is therefore in a position to reduce VOCs in all of its architectural coatings in advance of the schedule developed by the EPA-sponsored regulatory negotiations.

Labeling and Reporting: The Value of Information

INFORM found that regulatory attention to public disclosure and labeling requirements also proved valuable in stimulating innovation. Two case study companies assigned great importance to regulations requiring the dissemination of environmental information as motivators for the introduction of their innovative products. Moreover, the Toxics Release Inventory, similar state reporting requirements, and labeling requirements for products containing toxic constituents were noted by all respondents as features of the regulatory environment that would motivate product change.

The response of Hüls America to the change in labeling that would be required when glycol ethers were found to have teratogenic potential suggests how labeling requirements may motivate change. By reformulating the product, it could avoid labeling it as containing a chemical associated with birth defects. None of the case study firms, incidentally, expressed the opinion that these information disclosure requirements were inappropriate, despite the fact that they were having a significant impact on their activities.

The Uneven Playing Field

Three of the case study companies noted that regulatory review and testing requirements for new products could impede, as well as stimulate, the introduction of the products. Ciba's organic biocide for antifouling paints must be reviewed as a pesticide, while the repulpable adhesive developed by National Starch must be reviewed as an "indirect food additive" if it is to be used on packaging for food. Neither company objected to such regulatory review per se, but each expressed a view that new products faced a disproportionate burden under, respectively, FIFRA and FFDCA. Miles noted that newly issued (June 1993) OSHA regulations on lead exposure in the construction industry appeared to require comparable controls, whether the anticipated exposure was large (as in abrasive blasting) or small (as in hand scraping).

Under both FIFRA and FFDCA, the fundamental principle is that all products used as pesticides or food additives should be reviewed for safety (and also for efficacy, under FIFRA). The problem arises because older products generally underwent review at a time when the sophistication of toxicological investigations was limited, by current standards. New products, in contrast, are subject to extensive (and expensive) evaluation. For a new product to be successful, not only must sales be adequate to cover the costs of testing as well as of development, but the market must also be able to accommodate the delays involved in testing. Established products may have been "grandfathered" onto the market with little or no testing, as is the case for many substances classified as "GRAS" (generally regarded as safe) under FFDCA.

The FDA, EPA, and Congress have all attempted to respond to this regulatory discrepancy in varying degrees, but with limited success. Efforts to review existing food additives are based upon the reporting of adverse effects and monitoring of the scientific literature for toxicity information, rather than an explicit reevaluation process. While the EPA's goal is to reevaluate all pesticides, using current standards, on the average of once in 12 years, such reevaluations are not far advanced. EPA has fallen significantly behind the ambitious schedule established by Congress when it reauthorized and amended FIFRA in 1988. As long as these regulatory imbalances remain, they will tend to inhibit innovation for those products that still face premarket "licensing" requirements.

Cost Accounting Disincentives

One current view of environmental regulation is that it should ensure that the marketplace reflects the true costs of goods and services, including costs of damage to public health and the environment. When such costs (or benefits) are not incorporated into the market for a substance, they are referred to as "externalities." In many of the businesses covered by this report, markets do reflect environmental costs, at least in terms of mandated control technology. Thus, Swift Adhesives can explicitly inform its customers of the savings to be gained by using an adhesive without 1,1,1-trichloroethane - savings that result from dispensing with emissions control equipment that would otherwise be required, as well as from the 13 percent tax on products containing this chemical.

In other markets, a continuing ability to externalize environmental costs becomes a disincentive to environmental innovation. This can be due to fragmentation of a product's life cycle into relatively independent markets, as in the case of paper packaging and the repulpable adhesives introduced by National Starch. The environmental costs of not recycling such products are borne by the entire society. However, the costs imposed by nonrecyclable adhesives are borne by the recycling industry, while those of improved repulpable adhesives would be borne by the packaging industry. The lack of a mechanism for communicating costs between these industries acts as an impediment to marketing such products in the United States. In Europe, the imposition of strict responsibility for product packaging (as in Germany's Packaging Ordinance) has served to enforce such a link.

Evolving Customer Expectations

All of the case study companies indicated that the expectation of commercial success for their innovations was as much a factor in their decision-making as were environmental considerations. While some firms noted strong commitments to environmental quality, others, which had been just as active in pursuing environmental innovations, stressed their competitive position in the market, rather than environmental benefits, as the key stimulus. Still, for government, this suggests that regulations or taxes that create environmental demands are likely to be an effective spur to innovation, regardless of the degree of environmental commitment of US industry.

For individual consumers and the public sector, this finding suggests that a concerted effort to note and to publicize the environmental implications of purchases will elicit an effective response from business. Only two of the case study products (the paints sold by Glidden and Devoe & Raynolds) are sold on the retail market; the rest are sold to other manufacturers or to service industries. Only Glidden's paint is strongly marketed from an environmental viewpoint. It may be promising to revisit this case study in a few years, to assess the extent of the "green market" at the consumer level.

In contrast to marked response to mandated labeling that describes potential risks, direct efforts at explicit environmental messages and marketing on the part of the case study companies were limited, perhaps reflecting the fact that many of the products were aimed at industrial or commercial customers rather than retail sale to the public. Both of the respondents marketing directly to the public were considering an explicit environmental claim, and Devoe & Raynolds had an "ECO Friendly" label on one of its products, but neither reported using the services of a "green labeling" organization (nor did any of the other companies). For the companies with industrial clients, claims were based on specific changes in composition (e.g., no VOCs), with no more specific claim regarding actual or potential environmental impact. Two of the firms reported concern over potential legal liability if environmental claims (other than documented product contents) were made.

Supply Side: Successful Environmental Innovation

None of the innovations introduced by the case study companies has a significant marketing history as yet. This limits our ability to analyze factors that contribute to the success or failure of environmental innovations in the marketplace. The case studies do, however, provide information on factors that determine whether an environmental innovation reaches the market.

Cost, Performance, and the Environment

On the basis of pre-introduction discussions of the case study companies with their customers, as well as initial customer reactions, two responses were universal. First, no innovation that involves decreased performance, relative to the product for which it is a substitute, is likely to make much progress in the marketplace. Second, tolerance for cost increases, even when accompanied by environmental and other product enhancements, appears to be quite limited in the current economy.

The case study companies have attempted to combine environmental enhancements with equivalent or improved product performance, with the trade-off being some increase in cost. Even when these cost increases have been a small fraction of the total cost to their customers, or have even been offset by a real decrease in overall costs (as when pollution control costs are reduced or eliminated), there has been reluctance to accept cost increases associated with the innovative product. The alternative strategy of maintaining price but sacrificing conventional performance was viewed by the case study companies as unlikely to be successful.

Resistance to Change

As noted above, both Devoe & Raynolds and Swift Adhesives encountered customer reluctance to accept innovations, even if they were associated with performance enhancements or significant cost advantages. In the case of painting contractors, there was an assumed performance loss for waterborne paints that had to be countered, while the foam furniture fabricators were reluctant to re-train staff and change operations.

These observations bring home the point that businesses, like any human organization, entail dynamics other than economic considerations. Even innovative products with enhanced performance may have difficulty gaining acceptance. Companies that have made an environmental commitment will have to educate their consumers, as well as introduce product innovation. Those that pursue environmental innovation from a strictly commercial perspective will either have to pursue similar educational exercises, or limit themselves to markets where strong external pressures (such as regulation) will overcome resistance to change.

As Ciba officials noted, industry standard test methods can be just as large a barrier as regulatory constraints to the introduction of a new technology. Keeping such standards abreast of developing technology requires a continuing effort, and likely a significant dedication of resources to participation in standard-setting organizations (such as the American Society for Testing and Materials).

Timing is Critical

Many of the case study firms introduced innovative products in advance of significant customer demand. In some cases, such as adhesives free of l,1,1,1-trichloroethane, one can be reasonably confident that demand will arise, given the legal constraints on the use of this solvent. In other cases, such as paints (and paint additives) that have low or no VOCs, it is less clear that the national market in the United States for these products will ever require reductions as significant as those that have been achieved. In still other cases, such as organic corrosion inhibitors and coatings for bridges, the technology surpasses current industrial standards.

Some of these innovators may find themselves well positioned in the near future; for others, their new products may languish for an extended period. It may prove informative to re-visit these innovations in two years.

The Global Village

At present, the European market is significantly more sensitive than the domestic market to environmental aspects of products, particularly with regard to materials used in packaging. It may be, then, that for companies with multinational sales, reluctance in the US market is less important than customer demand abroad. Pursuing environmental innovation may be critical to a global competitive posture.

Looking at the Life Cycle

Life cycle assessment is an area of analytical thinking aimed at evaluating the cradle-to-grave environmental burdens associated with a product, process, or activity. It is striking, in the context of this interest, that none of the case study companies engaged in any significant life-cycle analysis of an innovation covered by this report. As many of the case study companies also claim to employ Total Quality Management approaches to management, focusing on continuous improvement and on analysis of systems for areas where the greatest improvement is possible, the absence of efforts to conduct life cycle assessments is noteworthy.

Coupled with the increasing European interest in such comprehensive "ecobalances," this observation suggests a possible competitive disadvantage for US firms in the international market. While the case study companies, and others, have produced dramatic product improvements in specific product characteristics in very limited time, few seemed prepared to provide comprehensive assessments of the environmental burdens associated with their products. This may prove to be an area of vulnerability in global competition.

Chapter 7: The Case Studies

Ciba-Geigy Corporation (Ciba)

Additives Division
CRP Department
7 Skyline Drive
Hawthorne. NY 10532-2188

The Company

Ciba-Geigy Corporation (Ciba) is the US subsidiary of a large, multinational chemical company (Ciba Ltd.) that produces pharmaceuticals, agricultural chemicals, dyes, plastics, and specialty chemicals, including paint additives. It has a US work force of more than 16,000 and reported sales of $4.3 billion in 1991.

The Improvement: Organic Paint Additives that Rep/ace Toxic Metals

Ciba is pursuing two alternative uses of organic (triazine) chemicals as substitutes for metals in paints and coatings. It is currently marketing organic corrosion inhibitors (trade name IRGACOR™) as an alternative to chromium salts (specifically, zinc and strontium chromate) used as active pigments in the protection of steel and aluminum. It has also begun the regulatory review process, specified under FIFRA for proposed new pesticides, for an organic algicide (IRGAROL™) to be used in marine antifouling applications - controlling slime and other growths on boat hulls and other underwater surfaces - and as a preservative in trade sales paints. IRGAROL™, already marketed outside of the United States, replaces tin compounds that have been restricted in marine antifouling applications because of their environmental impact, and mercury, which is being restricted as an in-can preservative for emulsion paints.

Environmental Advantages

Heavy metal salts, including both lead and chromium compounds, have dominated the market for corrosion protection of steel and aluminum. Both the lead and the hexavalent chromium compounds used for corrosion inhibition, however, pose risks of toxicity to human beings and environmental damage. The organic substitutes combine comparable anti-corrosion performance with lesser human and environmental toxicity.

Alkyltin[1] compounds, while markedly effective in antifouling paints for marine applications, have been found to be unacceptably harmful to the environment, primarily in their toxicity to non-target aquatic organisms, owing to their persistence and bioaccumulation on release from the antifouling paint. Mercury, while an effective biocide in trade-sales paints, also raises concern for its human toxicity (primarily in causing nervous system and developmental damage), and is coming under increasing regulatory control in paints and other applications. The replacement algicide offers comparable performance with reduced toxicity to humans and non-target species.

Other Advantages

Restrictions on alkyltin antifouling compounds have led to their replacement with older formulations, including traditional copper-based antifouling paints, as well as with tin-containing formulations designed to release less tin into the water; neither has been adequate. In the former case, the degree of antifouling protection provided is reduced, while in the latter, the service life between reapplications is significantly shortened.

The organic algicide developed by Ciba, in combination with cuprous oxide, lasts longer and works almost as well as restricted tin compounds, particularly in controlling slime. As the labor costs of reapplying marine antifouling applications are far higher than the costs of the paints, this represents a significant cost advantage for coatings using these organic-based antifouling compounds.

Disadvantages

Although the original form of anti-corrosion pigment proved successful when used in an alkyd paint formulation common in Europe, it was found to interact harmfully with components in various paints in the US market. Overcoming these undesired reactions required significant reformulation, with technical service to customers by Ciba. The company has since produced a modified form of the pigment that reduces or eliminates these undesired reactions.

As will be discussed further (see "Barriers to Development"), some coatings using the organic corrosion inhibitor do not perform as well as chromate-based paints in tests using accelerated salt spray to measure corrosion resistance.

Because it is still undergoing regulatory review, the algicide is not yet available in the United States. It has performed well in worldwide testing.

Direct Motivating Factors

In each case, Ciba's decision to proceed with product development was based on an analysis of an identified, quantifiable niche market, although potential applications were identified in other markets.

In the case of corrosion inhibitors, interviews with coating formulators indicated the formulators' customers were demanding industrial coatings that were lead and chromate free (with no loss of performance). This suggested a market for organic corrosion inhibitors, particularly as metal primers, that Ciba had originally been investigating in the context of water treatment.

The algicide was originally developed as an enhancement for tin-containing antifouling paints. However, when these were restricted by regulations on maximum tin release rates, their antifouling performance was compromised (primarily by a significant decrease in service life). Ciba determined that if it could provide an organic substitute for the restricted tin-based formulations, it should be able to capture a significant fraction of the market for antifouling compounds.

Indirect Motivating Factors

For each product, regulatory pressures fostered market opportunities. For example, regulatory efforts to control heavy metals (including hexavalent chromium compounds) are continuing, for both worker safety and environmental protection, and regulatory pressures on these chemicals increased in the 1980s. In automotive refinishing, steel structure, and aerospace applications, there has been concern over worker exposures. Further, applications in these areas can generate significant quantities of waste, and disposal costs can be substantially reduced if the waste does not contain materials that cause it to be legally designated as hazardous. There are also waste disposal costs associated with the ultimate need to remove these coatings, which again can be decreased significantly by the elimination of toxic metals. New laws and regulations requiring reporting of emissions and source reduction for chemicals listed on EPA's Toxics Release Inventory are also a growing issue for coatings manufacturers.

The discovery that alkyltin antifouling compounds were damaging aquatic environments, as the released tin persisted and bioaccumulated, led to regulatory controls. Only those formulations releasing less tin remained on the market. As noted above, neither these antifouling formulations, nor the older copper-based formulations that had been supplanted by tin formulations, performed as well as the tin formulations removed from the market.

Development Process

The corrosion inhibitors and the algicides resulted from continuing research and development, which was then directed at specific market niches where Ciba had identified an opportunity to introduce products based on chemistries it had studied. Each is an example of cross-fertilization between Ciba's coatings activities and its work in agricultural chemicals and water treatment.

Organic corrosion inhibitors were being studied by Ciba's water treatment business center in the United Kingdom; when Ciba saw the opportunity to replace chromium-based corrosion inhibitors in industrial coatings, it screened promising compounds for coatings use in Switzerland. The growing regulatory pressure on chromates and other heavy metals in the 1980s spurred this effort.

The initial market focus for this effort was industrial primers, where Ciba sought a share of the market for replacements for chromates. Testing originally focused on a typical European paint formulation; as noted above, the transition to the US coatings market required more work. Subsequently, researchers identified a potential use to improve adhesion of urethanes to metal, as an in-can corrosion control agent, and in the packaging of corrosives.

The algicide was originated as an additive to improve the performance of tin-based antifouling formulations. When subsequent regulatory action led to the substitution of less effective formulations, Ciba explored the use of this organic compound, in combination with cuprous oxide, to regain the performance characteristics that had been lost from reformulated tin-based antifoulants. Worldwide testing in both static aging and actual hull tests demonstrated the formulation's effectiveness, and it is currently undergoing regulatory review for use in the United States. With the product established in the (non-US) marine antifouling market, Ciba is examining other applications, such as use as an in-can algicide to replace mercury.

Market Status

Ciba reported that it has taken longer than anticipated to establish both products in the market. For the corrosion inhibitors, problems included incompatibility with the wide range of coatings formulations used in the United States, the need to educate and provide technical support for paint formulators, and eventually the development of a modified product. The algicide is still under regulatory review in the United States, but has proven successful in marine antifouling applications in other markets worldwide.

Corporate Environment

The new products represent cross-fertilization between different business units at Ciba, a biologically-oriented company manufacturing pharmaceutical and agricultural products. It is typical for the company that its coatings division would consider pesticidal additives, and that both water treatment and coatings business centers would be concerned with corrosion control.

Ciba accepts that high-risk/high-reward research and development projects take time. As a company official noted, "The harder it is to get where you want to be, the greater the comparative security once you get there."

Regulatory Environment

Regulatory environments differ for the corrosion inhibitor and the algicide. For the inhibitor, regulatory pressures favor introduction. Federal worker safety and health regulations, waste disposal regulations, and right-to-know requirements all favor the use of less toxic alternatives. Ciba reports, however, that the coatings industry perceives an adversarial relationship with regulators, particularly at the local level, which may hamper product introductions.

The algicide requires safety testing to support cost-benefit analyses under FIFRA, tending to offset the pressure favoring new products by restricting the old. Thus, while restrictions on tin-based antifouling coatings favor introduction of an organic substitute with comparable performance, the prolonged approval process, with its attendant uncertainty, discourages the introduction of new products.

Market Environment

Industrial coatings is a small niche market. As noted below, the entrenched nature of techniques for evaluating corrosion resistance has hampered product innovation.

To Ciba, the niche character of the industrial coatings market, and the fact that new biologically active compounds are rarely introduced, suggested that an effective non-metal algicide could have a long product life with little competition. Also, the marine antifouling market is driven by costs that are much greater than those of the antifouling agents themselves - as is generally true of industrial coating work. Ciba cites an estimate that 85 percent of the cost of industrial coatings involves factors other than materials, including labor, surface preparation, and waste disposal. In the marine context, costs for vessel down time and drydock fees, as well as the impact of fouling on fuel consumption, further offset the costs of coatings.

Barriers to Development of Improved Products

Ciba reports that a key problem in the commercialization of organic corrosion inhibitors has been the entrenched use of a single, poorly predictive test (accelerated salt spray) as a standard of performance by industry. The company believes chromate-based corrosion inhibitors enjoy an advantage in this test that does not reflect their actual performance. Accordingly, continued reliance on this test method is seen by Ciba as retarding the introduction of safer alternatives.

Industrial innovation, such as the replacement of traditional tests with more appropriate tests and specifications, requires both changes in attitude and significant expense. Innovation has been found by Ciba to be accelerated by regulatory review of hazardous materials and by escalating disposal costs (which may themselves be viewed as a result of regulatory pressures, among others). To facilitate innovations that reduce environmental risks, Ciba wants regulators and industry to compare overall risks of alternatives, so that restrictions are applied to the more hazardous materials. Without regulatory pressure on hazardous materials, companies will be less willing to assume the financial risk of developing environmentally improved materials.

Ciba's corrosion inhibitors also encountered a technical barrier, the occurrence of undesirable chemical interactions between its corrosion inhibitor and some paint components in the US market. This problem required a substantial investment in customer education and technical assistance, and eventually the development of an improved product.

An algicide must be registered with EPA as a pesticide under FIFRA. In a niche market such as algicides for paints, registration costs represent a significant expense relative to the value of the total market. Further, this expense tends to be unpredictable for innovative technologies. In the case of Ciba's algicide, this uncertainty almost led to cancellation of the project. Only the fact that the product was successfully marketed outside North America, in a different regulatory context, kept the project on track. Once a company has entered a market, however, these same barriers offer some protection from competitors.

Life Cycle Consequences

The identified life cycle problems addressed by these chemical replacements primarily concern their ultimate disposition, although other issues arise from their use. No environmental issues associated with raw materials or production were addressed in Ciba's comments, although the need for "cradle to grave" economic assessment was noted.

For corrosion inhibitors, the problems addressed are the risks associated with application (risks to workers and application waste) and ultimate removal and disposal. For marine antifouling applications, algicides are "self-removing" and necessarily enter the aquatic environment. The critical problem is that toxic metal-based compounds remain and accumulate in this environment.

/Votes

1. Chemical compounds that combine hydrocarbon groups with tin, increasing the tendency of the toxic tin to be absorbed by living organisms.

Devoe & Raynolds Co.

4000 DuPont Circle
Louisville, KY 40207

The Company

Devoe & Raynolds is a manufacturer of paints, varnishes, and allied products. A subsidiary of Grow Group, Inc., it has approximately 1,200 employees. Sales for the fiscal year that ended June 30, 1993, were estimated at $145 million. Devoe & Raynolds operates three plants (in Florida, Kentucky, and Texas), with sales primarily east of the Rocky Mountains. Another Grow Group company, Ameritone, serves the market west of the Rockies.

The Improvement: Waterborne Paints and Coatings with Low VOC Content and Enhanced Performance

Devoe & Raynolds has introduced a range of waterborne, low-VOC products, including acrylic enamels (high-gloss and semi-gloss), 2-part polyamide epoxy coatings (gloss and semi-gloss), acrylic dry fog,' and wood stain & wood finishes. The performance of these products exceeds that of most water-based products, and in some cases that of solvent-based products, allowing the user to obtain the advantages of waterborne paints, without the sacrifices in performance that have previously been associated with these paints.

Environmental Advantages

All products contain less than 250 grams per liter (g/l) total Volatile Organic Compounds (VOCs), as measured by EPA-specified methods.[2] In contrast, a typical gloss enamel might have as much as 411 g/l VOCs. They thus comply with all US and state regulations, and their use is not restricted. For example, the products conform with the California South Coast Air Quality Management District Rule 1113.

As in the case of many waterborne coatings, these products do not entirely eliminate VOCs, and for certain products, some hazardous chemicals remain." The key feature of this innovation is not simply the development of a low VOC paint, but the development of low VOC paints that perform at least as well as solvent-based formulations.

The use of waterborne formulations not only reduces air pollution but improves worker safety and facilitates disposal. For example, all of these products are nonflammable (no flash-point), with the exception of the epoxy, which has a flash point of greater than 200° Centigrade. Solvent-based paint wastes, such as unusable leftover paint, generally require disposal as hazardous waste, but wastes from waterborne formulations do not.

Other Advantages

Like most waterborne formulations, these new paints have less odor and can be cleaned up with soap and water rather than solvents.[4] The key enhancements emphasized by Devoe & Raynolds are:

Coverage: The area covered per gallon of dry fog is up to twice that of solvent-based products.

Adhesion/Surface Compatibility: The dry fog adheres and resists rust better than competing waterborne fogs; it will adhere to multiple materials. The epoxy can be applied over oil-based, alkyd, or latex paints, unlike solvent-based epoxies that lift and wrinkle alkyd enamels if used to overcoat them. The enamel adheres to aged alkyd or oil-based paints faster than alkyd enamels. Unlike most latex enamels, which develop adhesion slowly and poorly, this enamel will bond to glossy surfaces without sanding.

Flow/Leveling: The flow and leveling characteristics of the enamel approach those of alkyd enamels; the product also atomizes better for spraying than other latex enamels.

Drying: The enamel dries rapidly to a hard surface and may be re-coated in two hours - faster than typical latex gloss enamels or alkyd enamels. Paint stickiness is reduced, and the product yields hardness equivalent to an alkyd, but faster.

Durability: The enamel develops a sufficiently hard film to be effective for shelving or handrails; the epoxy is suitable for painting concrete floors.

Gloss: Unlike most water-based enamels, the high-gloss acrylic enamel achieves gloss comparable to solvent-based enamels.

Color Retention: The waterborne enamel does not yellow as do alkyd or oil-based enamels.

Disadvantages

These paints cost about 10 percent more, but the company says the difference does not appear to be a significant impediment to acceptance. Rather, it is their innovative nature that seems to be a market hindrance, because customers (painting contractors) tend to be conservative. The company is mounting an active effort to demonstrate the paints' performance to these contractors, to overcome the perceived disadvantage of any waterborne formulation.

Direct Motivating Factors

State regulations limiting VOC emissions were the prime motivation for investing in formulations that would overcome the deficiencies of waterborne products in these paint categories. These regulations affected parts of Arizona, California, Georgia, New Jersey, and New York, and meant that some Devoe & Raynolds' solvent-based formulations could not be marketed in these areas. While the company may not accept the underlying rationale for these regulations, it accepts them as a condition of the market in which it operates.

Indirect Motivating Factors

Worker safety concerns are important to Devoe & Raynolds' contractor customers; the low flammability of these waterborne formulations is an added advantage in this market. In addition, some of the customers of the painting contractors (who are, in turn, Devoe & Raynolds' customers) are attempting to limit total VOC emissions and are specifying low-VOC paints for their facilities. While explicit environmental marketing is not a significant part of Devoe & Raynolds' strategy, the water-based wood stain and wood finish labels do include an "eco friendly" logo.

Development Process

The lack of adequate water-based paint formulations for high-gloss, high-durability applications represented an obvious market opportunity for Devoe & Raynolds, given the regulatory strictures being applied to VOCs. Devoe & Raynolds' marketing department, through field sales groups, advises management and the research and development department on customer needs. Once management decided to explore performance enhancements of waterborne enamels and epoxies, responsibility passed from marketing to the research and development group. After Devoe & Raynolds was satisfied with its product formulation, products were supplied to selected contractors to confirm their acceptability before general production began.

The development process for the waterborne enamels required about two years, which represents an increase of 25-30 percent over the time normally required for a new product. This added time reflects the difficulty of the chemistry involved in achieving appropriate paint characteristics.

Market Status

These paints are intended not to replace existing solvent-based products but to expand the market for circumstances in which solvent-based paints may be inappropriate, or where existing water-based paints perform inadequately. Although the new paints are proving successful in the market, displacement of solvent-based products has been even less than anticipated. Still, in the two years that the products have been on the market, overall market share has increased by 2 percent-the fastest growth for any new product that Devoe & Raynolds has introduced in the past 10 years. Devoe & Raynolds has also already licensed this technology to another company.

Devoe & Raynolds believes that because of the enhanced performance of these products (particularly the enamels and epoxies), opportunities may exist for expansion beyond the architectural market, into product finishing by original equipment manufacturers.

Corporate Environment

Decisions on product innovations at Devoe & Raynolds are generally made in group meetings involving field representatives, marketing, and research and development personnel. The absence of layers of review allows for rapid decisions. These products did not result from a particular "clean products" effort, but rather from normal, market-driven research and development. They represent an expected evolution of the product line in the face of market limitations imposed by VOC regulations.

Grow Group, Inc., has developed a series of general environmental policy goals and statements that are designed to assist its companies in complying with all environmental regulations. The statements are not specific for any product or product lines; instead, they cover each major law and the appropriate health, safety, and environmental regulations. The local facility and division management teams are responsible for compliance at each location.

Devoe & Raynolds has representatives serving on two of the National Paint & Coating Association's (NPCA) committees: the Air Quality Committee and the Water Quality and Waste Management Committee. The former is currently involved in negotiations on regulations affecting VOC content in products, in response to the Clean Air Act Amendments of 1990. The latter committee is involved in the NPCA's Paint Pollution Prevention Program; a similar program will be incorporated within Devoe & Raynolds in the next year. The Grow Group has an active waste management effort for its companies, focusing on the pollution prevention hierarchy (reduce, reuse, recycle, recover).

Safety, liability, waste disposal, and other environmental costs are not accounted to individual production processes, but the costs of lost materials are.

Regulatory Environment

As noted in Chapter 3, there is a range of state restrictions on VOC content in paint, generally applying to areas within each state that are not in compliance with ozone standards established under the Clean Air Act. Those of the California South Coast Air Quality Management District are particularly strict, reflecting the severe smog problems of the region. In addition, national regulations are expected under the 1990 Clean Air Act Amendments. These waterborne paints meet all VOC requirements of federal and state regulatory authorities in the United States, so they may be used in any jurisdiction.

Market Environment

Devoe & Raynolds' primary customer is the professional paint contractor dealing in architectural coatings for the commercial and industrial sector. Performance, rather than environmental characteristics, is what counts for this market. However, some of these contractors' client companies are concerned about their total VOC emissions, and would seek low-VOC paints for this reason. Military bases are prominent among these. Paint contractors appear reluctant to accept product changes, unless forced to by external factors; thus, performance enhancements have to be firmly proven to these customers to gain market acceptance.

Customers served by painting contractors using Devoe & Raynolds paints range from large institutional clients (the Houston Astrodome, automobile companies) to individual residential clients. The size of the paint contracting companies varies accordingly. The market is nationwide, although west of the Rocky Mountains, the market is served by Ameritone, a sister company that produces slightly different product formulations tailored to meet regional customer needs.

In general, this is a mature and relatively stable market. While general recessions will tend to decrease new construction work for the painting contractors who are Devoe & Raynolds' customers, the shortfall may be offset by an increase in maintenance and renovation work. Innovation in the field occurs primarily in response to such external influences as regulatory changes.

Barriers to Development of Improved Products

The most significant barrier to innovation encountered by Devoe and Raynolds has been the attitude of professional painting contractors toward new paint products. Especially where older customers are involved, prejudices about the performance of waterborne products impede acceptance of such products for applications where solvent-based products have in the past performed well. Only external pressures will motivate these customers to change from their currently preferred products.

Life Cycle Consequences

From an environmental perspective, the principal effect of these new paint formulations is to reduce emissions of VOCs in the paint application and drying process. No explicit life-cycle study has been performed by Devoe & Raynolds, although the company noted that waste water-based paints are subject to fewer legal restrictions than solvent-based wastes.

Raw materials acquisition differs from that of solvent-based paints, as solvent requirements are less for this product. However, these paints are displacing solvent-based paints in only a few parts of the market. No major changes in equipment or process chemistry were required, as Devoe & Raynolds has been producing waterborne paints for years. The change is a new application of waterborne paint technology. Energy requirements are essentially the same.

Notes

1. A rapidly drying architectural coating that adheres to a wide variety of surfaces. Used, for example, to coat ceilings in new construction.
2. Calculated VOC contents, according to EPA methods, and expressed as the weight of VOCs (in grams) per liter of paint, vary among the products: 46 g/l (dry fog), 142 g/l (wood stain), 143 g/l (wood finish), 181 g/l (gloss epoxy), 191 g/l (semi-gloss epoxy), 192 g/l (semi-gloss enamel), 225 g/l (high gloss enamel). Devoe & Raynolds believes that EPA methods overestimate VOCs for waterborne paints, relative to solvent-based paints with equivalent solids content. Thus, a calculation of 225 g/l VOCs was made for high-gloss enamel using EPA methods, while the actual content was 112 g/l.
3. Ethylene glycol monobutyl ether, diethylene glycol monobutyl ether, and butyl carbitol, used in the enamel to coalesce the resin.
4. This is not represented as an environmental enhancement, but a convenience factor, in light of the water pollution issues raised by all waterborne paints.

The Glidden Company (ICI Paints)

925 Euclid Avenue
Cleveland, OH 44115

The Company

The Glidden Company, with headquarters in Cleveland, Ohio, is a manufacturer of paints and coatings for the consumer and industrial markets. It is a subsidiary of ICI American Holdings, Inc., the US arm of the British-based multinational, Imperial Chemical Industries. The Glidden Company operates ten plants in six states. Of these, eight produce paints and coatings; the remaining two produce adhesives and caulks for Glidden's Macco Division. Glidden has 4,600 employees, with reported sales of $900 million for 1991.

The Improvement: Waterborne Architectural Paints with No Organic Solvents

Glidden has recently introduced two lines of latex paints, Spred® 2000 (for consumer and contractor markets) and Lifemaster® 2000 (for the contractor market) with no added solvents and zero V0Cs.[1] Since the introduction of latex paints more than 40 years ago, small amounts[2] of solvents have been used to aid in application of the paint and in film formation; this new formulation completely eliminates the use of added solvents[3] while maintaining the film-forming and application properties of conventional latex paints. The product also eliminates crystalline silica and formaldehyde preservatives.

Environmental Advantages

The elimination of solvents from these paints eliminates any contribution of such VOCs to the formation of ground level ozone, via reaction with oxides of nitrogen. Moreover, workers formulating the paint, and people applying the paint or inhabiting freshly-painted areas, are spared any risks of toxic solvents.

Other Advantages

The paint's performance equals or exceeds that of waterborne paints that contain solvents, in terms of coverage, application, and other properties. It dries faster than conventional latex paints and has virtually no odor. (The "paint smell" from conventional formulations can last for several days.)

Disadvantages

At present, the color range of both Spred® 2000 and Lifemaster® 2000 is more limited than that of similar paints containing solvents, and point-of-sale tinting is not yet available. Glidden anticipates that a tint base that will allow the production of several hundred colors in both lines will be available by the end of 1993.

The Lifemaster® 2000 formulation is currently available only in an eggshell (satin) sheen finish, while the Spred® 2000 is formulated in both flat and semigloss finishes.

Currently, the per-gallon cost of this paint is higher than that of conventional latex paints for similar applications, reflecting increased costs to Glidden for the improved resins.

Direct Motivating Factors

Glidden has set a corporate environmental goal of removing all solvents from its decorative products by the year 2000.

Indirect Motivating Factors

Current customer demand in this area is not high, but Glidden anticipates that it will grow as the public becomes more aware of the ozone and toxicity problems associated with solvents in paints. Regulatory pressure, particularly for ozone nonattainment areas, will also grow under the 1990 Clean Air Act Amendments.

Development Process

Glidden has been involved in the development of low-solvent (waterborne) paints for many years, and market research had indicated high interest in "solvent-less" paints.[4] However, the genesis of this line of completely solvent-free paints was in the research and development department, which brought the possibility to the attention of marketing. The marketing department, which has final decision-making authority, approved the project.

Glidden developed the product over five years, with collaboration and additional research by Rohm & Haas, one of its resin suppliers. Besides Glidden's research on paint formulation, resin development work was needed. Following completion of the paint formulation research, nearly two years was required for product introduction, including extensive market research into product features and market positioning. That research accounted, in part, for the considerably longer time required to commercialize this product than most of Glidden's new products require.

Throughout the project, Glidden kept ICI apprised of developments. This served the dual goals of enabling technical cooperation with other ICI subsidiaries that might have developed relevant technologies and of ensuring that ICI companies operating in other markets would be able to evaluate the new product's potential for those markets.

Market Status

As these products have been on the market a relatively short time, it is difficult to forecast their ultimate effect on Glidden's market share and overall sales. Although Glidden says that customers express general interest in environmentally enhanced products, some customers are reluctant on the basis of additional cost, and some are skeptical of the need for the improvement. The reduced color range currently available may also be a barrier to market penetration.

Glidden intends to pursue its goal of removing all solvents from its decorative products by the end of the decade. As noted above, it expects to expand the color range by the end of 1993. It also believes that as consumers learn more about solvents in paints, demand should increase. As the use of the technology represented by these products expands, the price differential should decrease. Growing regulation of VOCs in paint will also make the price disadvantage less of a factor.

At present, these products are formulated for interior applications in the architectural market. Glidden foresees potential for use in exterior paints, both consumer and commercial. In the long term, they may also be applicable to the industrial maintenance market.

Corporate Environment

Glidden has a corporate policy of environmental stewardship and believes it has responsibilities to its customers, workers, and the communities in which its facilities are located. It wants to be viewed as credible and caring.

Glidden has written plans to reduce - or eliminate if possible - solvents from its products. Now that the technical and commercial feasibility of a solvent-free product has been demonstrated, Glidden's goal is to expand this non-VOC technology as quickly as possible.

Waste disposal, lost materials, safety, liability, and other environmental management costs are not routinely allocated to specific products or product lines, but are considered in assessing the costs of Glidden operations.

Glidden (and ICI) has a technical merit award plan to recognize employee contributions to all types of product development, administered at Glidden by a committee headed by the vice president of research. While not a specifically environmental program, it includes environmental, as well as other, innovations. Two marketing managers and three research and development technicians received awards for the Spred® 2000 and Lifemaster® 2000 project.

Through its parent company, ICI American Holdings, Glidden is also a participant in EPA's voluntary 33/50 Program aimed at reducing emissions of 17 toxic chemicals. However, this participation does not affect the Spred®/Lifemaster® 2000 project.

Regulatory Environment

No specific regulatory requirements have been identified that apply to these products that would not apply to any latex paint. Because such paints (unlike some alkyd formulations) are not regulated as hazardous wastes, there is no impact on waste disposal. Pending a complete transition to solvent-free formulations, there has been no change in Glidden's regulatory environment. However, when completed, the changeover to non-solvent paints may reduce Glidden's reporting requirements.

Market Environment

Within the architectural paints market, particularly the consumer sub-market, large suppliers tend to dominate. For the most part, market changes reflect a series of minor enhancements to existing product lines, with occasional innovation leading to introductions of new product lines.

Both the new product lines, and the conventional formulations they resemble, are marketed nationwide in the United States, as well as in Canada and in Europe.[5]

Barriers to Development of Improved Products

Because the development of this product reflects a general corporate commitment, there was little internal reluctance to pursue the project. Company officials were concerned about customer willingness to pay more for an environmentally improved product. This concern, as noted, was apparently well-founded; Glidden intends to address it by consumer education.

Glidden held two considerations uppermost for the successful introduction of an environmentally-enhanced product. The first was the need to maintain or exceed performance levels of existing products; the second was to ensure that customers understood and accepted the reason for the change.

Life Cycle Consequences

No formal life cycle analysis appears to underlie the introduction of these paints. While the focus of this innovation is on reducing the release of VOCs during the paint application process, the fact that solvents are eliminated from these paints also has implications for releases at other life cycle stages: There would be no release, for example, during paint formulation. The displacement of other paints from the market by such solvent-free paints could lead to decreases in the production of solvents such as ethylene glycol.

Notes

Certified as less than 1 gram per liter by Scientific Certification Systems.

Between 2 and 6 fluid ounces per gallon (between 1.6 and 4.7 percent by volume).

The principle solvents eliminated are ethylene gly-co1 and glycol ethers. Also, the paints use ingredients that do not require the use of unreacted solvents in their formulation. It is possible that the paints could contain small amounts of free monomer from the latex polymerization, or contaminants in raw materials, that could be detected by sensitive analytical methods, but even these are certified as being less than 1 gram per liter.

This appears to reflect a desire to avoid paint odors, as much as or more than environmental concerns. In Glidden's view, the public appears to be uncertain regarding the extent of the environmental problem posed by paint solvents.

Specific paint formulations may vary from country to country, although all formulations meet the same "solvent-free" criteria.

Hüls America, Inc.

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Piscataway, NJ 08855-6800

The Company

Hüls America Inc. (Hüls), with 12 plants across eight states and two plants in Canada, is the US subsidiary of Hüls AG, a chemical company headquartered in Marl, Germany. Hüls AG is itself a subsidiary of VEBA AG, one of Germany's largest holding companies. Hüls produces plastics, adhesives, specialty chemicals, and products for the coatings industry. Hüls has approximately 1,500 employees, and reported sales of $200 million in 1991.

The Improvement: Paint Colorants Completely Free of VOCs

In the autumn of 1993, Hüls introduced to the market a line of universal] colorants for machine tinting of paint that have no Volatile Organic Compounds (VOCs). These "point of sale"[2] colorants are "drop-in" replacements for Hüls's existing line of such colorants, with identical application and addressing the same color range.

Environmental Advantages

The colorants for which the new products are a substitute contain 25-30 percent ethylene glycol or diethylene glycol. Ethylene glycol is both toxic and a VOC subject to regulation to prevent air quality degradation. Unlike propylene glycol, a substitute for ethylene glycol that is less toxic but still a VOC, the substitute chemicals in these colorants address both toxicity and volatility concerns. These chemicals are not regulated as hazardous, and are used in the pharmaceutical industry. The only chemical that vaporizes from the colorant is water.

Hüls estimates that complete substitution of its current line of colorants with these new non-VOC formulations will lead to a decrease of 6 million to 7 million pounds of ethylene glycol emissions in the United States, and 2 million pounds in Europe.

Other Advantages

The new colorants were explicitly designed to be drop-in substitutes for existing colorants, but turned out to improve performance. The ethylene glycol in existing formulations can retard paint drying and, with high humidity, lead to streaking in the paint finish. Ethylene glycol also adversely decreases paint viscosity. All of these disadvantages are eliminated in the new colorant formulation.

Disadvantages

Ethylene glycol and glycol ethers are inexpensive commodity chemicals, while the substitutes involved in these new colorants are not. The replacement colorants cost approximately 20 percent more than the products they replace. While a relatively small element in the total cost of the paint (particularly if application costs are considered), it appears to be enough to make some paint manufacturers reluctant to switch. Hüls customers indicate that a price differential of 10 percent, rather than 20 percent, might yield wider acceptance. Hüls expects that as market and regulatory pressures on VOCs increase, the price disadvantage will diminish.

Direct Motivating Factors

The key motivating event occurred when scientific evidence indicated that ethylene glycol was potentially teratogenic. This finding required a modification of the chemical's Material Safety Data Sheet (MSDS),[3] and triggered safety notification requirements for products that contain it. To avoid the need for warnings on product labels, the company decided to remove ethylene glycol from the product.

Propylene glycol was considered as one alternative to ethylene glycol, as its toxicity is much lower. However, shortly after Hüls became concerned over the toxicity of ethylene glycol, customers (paint companies) began to request colorants that had little or no VOC content. Substitution of propylene glyco1 for ethylene glycol would actually have increased the VOC content of the colorant, in order to achieve the same degree of freezing point depression (an important colorant characteristic) achieved with ethylene glycol.

Faced with these two environmental goals for their colorant products, Hüls initiated a research program focused on the creation of low-VOC or no-VOC substitutes that completely eliminated ethylene glycol. While a low-VOC substitute was deemed acceptable (a goal of 100 grams/liter),[4] Hüls aimed at lowering VOC content well below foreseeable regulatory limits, in order to avoid the expenditure of continually reformulating the colorants to lower VOC content.

In 1990, Hüls launched a five year research effort to develop a substitute universal colorant. While research on a universal colorant was proceeding, Hüls introduced COVON™ colorants, which are VOC free but suitable only for water-based paints and cannot be used in point of sale applications; they also have a shorter shelf-life and lesser color range than Hüls universal colorants, and have had a relatively small impact in the market.

Indirect Motivating Factors

Each aspect of the environmental improvement in Hüls colorants reflects the activities of regulatory agencies. With regard to the elimination of ethylene glycol, the requirements of OSHA on MSDSs made Hüls aware of ethylene glycol toxicity. Labeling requirements meant that in addition to internal concerns, continuing to include ethylene glycol in their colorants could lead to loss of customers.

VOC regulation also played a role. Not only have several states (Arizona, California, Georgia, New Jersey, New York, and Texas) begun to regulate the total VOC content of paints, either in certain areas or statewide, but the US Environmental Protection Agency (EPA) is developing national regulations under the Clean Air Act Amendments of 1990.

Hüls indicates that as a company that invests substantially in research and development, it also had a particular interest in cases where the majority of the industry deemed a regulatory goal unattainable. Hüls viewed these as market opportunities for technological innovation. The new colorants were an example. Hüls views continuous innovation as necessary to maintain leadership in the market.

Development Process

The marketing department requested that research and development create, within five years, drop-in substitute colorants with less than 100 grams per liter total VOCs. Although skeptical, research and development initiated a research program. To support it, marketing diverted resources normally allocated to routine work on gradual product enhancement.

As it turned out, research and development was able to eliminate VOCs completely. As it became clearer that non-VOC drop-in substitute colorants were feasible, Hüls accelerated the allocation of resources to this research effort. Although a five-year development schedule had been considered optimistic, it took only three years to develop these colorants. As soon as the alternative chemistry was demonstrated to be technically feasible, development proceeded rapidly.

Toward the end of the development process, Hüls supplied some of its major customers with test samples of these colorants. They quickly met with technical, if not economic, acceptance.

Market Status

Two of Hül's customers have low-VOC paint product lines and are committed to promoting these colorants for those lines. Although the new colorants represent a drop-in substitute for existing products, requiring no capital investment by customers, and although they combine several technical advantages along with environmental improvement, Hüls anticipates that they will only gradually come to replace those existing products. Customers indicated that the additional cost outweighs the advantages under current conditions. This may reflect the fact that for many paints, the VOC content contributed by colorants is a small fraction of the total content.[5] Accordingly, the reduction in VOCs offered by the colorants will be significant only for those paint manufacturers who have reduced, or will be reducing, the other sources of VOCs in their paints.

Although this product is ultimately used by retail paint consumers and painting contractors, Hüls customers are the paint companies. Consumer preferences are not yet having a significant impact on this product. If strong consumer preference develops for VOC-free paint formulations with a wide color range, the price objections of paint companies might be offset by the ability to pass such costs on.

Corporate Environment

Worldwide, Hüls has a corporate commitment to environmental and employee protection. It seeks to ensure that all of its plants comply fully with all health, safety, and environmental quality regulations. The company engages in constant monitoring and research aimed at reducing emissions from manufacturing, and it endorses the Chemical Manufacturers Association's "Responsible Care" program. The introduction of these colorants reflects this commitment.

Environmental decision-making and the development of new products are both strongly influenced by Hüls Total Quality Management (TQM). TQM work groups meet at least monthly to address quality issues, newsletters distribute information on TQM activities, and bonuses (in the form of bonds) are awarded. "Corrective Action Teams" cross corporate divisions to address TQM issues. In concert with the TQM principle, Hüls provides its divisions with considerable operational authority and dispenses with multiple layers of management review and approval. The colorants project was initiated and brought to completion under the authority of US management.

Regulatory compliance, liability, and waste disposal costs are not routinely charged back to individual product lines at Hüls. However, Hüls employs materials tracking[6] for process streams that includes wastes and off-grade materials. This system could be used to allocate wastes to process streams if doing so were determined to be desirable.

The research and development department is chartered to anticipate customer needs, to enable the firm to maintain its leadership position in the market. Research and development is advised by marketing, which relies on informal consultations with customers rather than formal market research. The colorants project is an example of such a response to, and attempt to anticipate, market conditions, rather than an internal pollution control or prevention decision.

Regulatory Environment

As noted above, a key motivation for developing these new colorants was the requirement that product labels for the existing formulation warn of the toxicity of ethylene glycol. This requirement does not apply to the new formulation, as ethylene glyco1 has been eliminated.

The eliminated chemicals are subject to federal reporting to the Toxics Release Inventory (TRI); in addition, New Jersey, in which Hüls headquarters and one of its three US colorant plants are located, has notably stringent environmental reporting regulations for any substance with an MSDS, such as these. Even complete substitution of current colorants with the new formulation, however, would not relieve Hüls of these reporting responsibilities, as there are other uses of these chemicals at Hüls plants. In general, this change in product composition will not affect the overall regulatory environment in which Hüls operates, but will change the specifics of product labeling and reporting to regulatory authorities.

Market Environment

Hüls America supplies point-of-sale colorants to paint manufacturers, who in turn provide these colorants to paint users via retail paint outlets. In this market, Hüls is the major supplier. The bulk of Hüls's market is represented by large paint companies. Some of these emphasize innovation in environmental matters, while others concentrate on regulatory compliance. A number of smaller paint firms generally follow the example set by the larger companies.

The market for point-of-sale colorants is generally considered a "mature" one, in which small incremental product enhancements, rather than dramatic changes, represent the technical basis of competition. Hüls' colorants market covers the entire United States, with some sales in Europe. In general, market pressures for low-VOC or non-VOC colorants have been stronger in Europe than in the United States. This may reflect the fact that most US paints contain relatively high VOC concentrations, as noted above. As pressure grows for low-VOC or non-VOC paints, Hüls anticipates that its market for the new non-VOC colorants could expand beyond point-of-sale into both in-plant paint colorants and artists' supply paints.

Hüls has not used the services of any "eco-labeling" organization in marketing these colorants, nor has it made any environmental claims for them, other than the factual claim that these colorants contain no VOCs. It should be kept in mind that while these colorants are used at retail paint stores, Hüls customers are paint companies, rather than retail purchasers of paints.

Barriers to Development of Improved Products

As noted above, increased costs may present some barrier to market penetration. Hüls officials, however, believe the prime barriers to the innovation itself were technical. For example, various mixtures of non-volatile ingredients resulted in a mixture with measurable VOC content. Moreover, they noted that the measurement of VOC content was not always straightforward, given the inherent variability of the process.[7] Measured in this way, and given some inherent inaccuracy in any measurement, total VOC content ranges from slightly above zero to slightly negative.*

Life Cycle Consequences

No explicit analysis of the colorant or paint life cycle was conducted in deciding to pursue this product improvement. Rather, the innovation represents a response to customer concerns and regulatory (labeling) requirements. However, Hüls officials noted the following consequences of the substitution over the life cycle of the product:

If the new colorants totally replace the current product, suppliers of ethylene glycol (commodity chemical companies) will have lost this fraction of the market (6-7 million pounds/year of ethylene glycol). This is worth approximately $1.2 million at current prices. It is not known whether other uses of ethylene glycol would expand to use this production capacity, but commodity chemical companies are developing ethylene glycol substitutes (primarily propylene glycols) for many applications. A corresponding increase in purchases of the (proprietary) substitute chemicals by Hüls would be expected.

The prime impact within Hüls facilities involves worker safety. Chemical mixing tanks are heated (but have exhaust hoods). A complete product changeover would eliminate the possibility of ethylene glycol exposure.

Hüls worked to maintain compatibility with capital equipment and with customer paint formulations in developing the substitute colorants as drop-in replacements; this is likely to minimize downstream effects of the substitution. Little impact is likely in the immediate future for any ethylene glycol or diethylene glycol release reporting by customers, because the colorant is generally less than 2 percent of paint. However, the prime use of these colorants is likely to be in combination with reduction of other sources of VOCs. It should be remembered that the hazardous chemicals being replaced evaporate completely during paint use. Accordingly, there is an ultimate potential reduction in annual environmental (atmospheric) releases of 6-7 million pounds.

Colorant packaging represents a continuing disposal cost for retail outlets; these materials are either returned to the paint company or, probably more frequently, disposed of as municipal solid waste. Hüls believes that the bright colors of the colorants may draw attention to this discarded material. This could mean that a warning label required for a product with ethylene glycol would be more likely to be noticed than for other products, and might lead to difficulties in disposing of packaging.

Notes

1. A "universal" colorant can be mixed with either water-based or solvent-based paints.
2. This denotes a colorant that is used to produce a custom tint for a customer, for example at a paint store, as opposed to a stock colorant added to the paint at the factory.
3. Under the Occupational Safety and Health Act, suppliers of a chemical must provide an MSDS, listing hazards known to be associated with a chemical or mixture. The Occupational Safety and Health Administration (OSHA) requires that this information be communicated to workers, and the Consumer Product Safety Commission requires appropriate warning language on product labels.
4. 100 grams of solvent in each liter of colorant.
5. The colorant represents a small fraction (approximately 2 percent) of the total paint mixture. Thus, if the colorant were the only source of VOCs in the paint, and had 100 g/l of VOCs, the paint would have only 2 g/l of VOCs. In reality, even "low-VOC" paints have up to 200 g/l of VOCs, and it would not be unusual for a normal waterborne paint to have 400 g/l of VOCs.
6. This means that detailed records are kept of physical quantities of raw materials, wastes, etc., and can be traced to specific product lines. The distinction from full-cost accounting is that this is not allocated on the basis of economic effects.
7. EPA specifies the procedures for measuring VOC content, which involves measuring total volatiles and volatility attributable to water, with VOC content calculated as the difference between the two measurements.
8. In reality, of course, "content" cannot be negative, but must be zero or greater. The finding of a negative value merely indicates the imprecise nature of the process.

Miles, Inc.

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The Company

The Industrial Chemicals Division of Miles, Inc., produces raw materials for the paint and coatings industry at plants in New Martinsville, West Virginia and Baytown, Texas. Miles is a research-based company with major businesses in chemicals, health care, and imaging technologies. The company's 1992 sales were about $6.5 billion. Miles employs some 26,000 people and has 57 locations throughout North America.

The Improvement: Polyurethane Coating System for Steel Structures to Overcoat Lead-Containing Paints

Miles has developed a series of polyurethane paint components that permit overcoating of steel structures without complete removal of old lead-based paint, significantly decreasing the risks and expense of removing the lead-based paint.

A moisture-curing polyurethane primer containing micaceous iron oxide or aluminum is applied to areas of exposed steel after spot removal of rust and old paint in areas of corrosion or paint breakdown. A polyurethane intermediate coat is then applied to the entire structure, including areas where previously applied lead-based paints are intact, followed by a polyurethane topcoat.

Environmental Advantages

The problems posed by the use of lead-based paints to protect steel structures such as bridges have been extensively discussed in the popular, trade, and scientific press. To repair corrosion and repaint these structures to prevent further corrosion, it has generally been necessary either to continue to use lead-based paints,' or to remove the existing lead-based paint entirely. The alternative of continuing to use lead-based paints entails significant risks and has been substantially eliminated by the waste-disposal restrictions imposed by the Resource Conservation and Recovery Act (RCRA), as well as by explicit regulation of paints used for structural rehabilitation and repainting, primarily by state governments.

Traditional methods of paint removal from steel structures - generally open-air abrasive blasting - contaminate the environment near the structure and generate large quantities of hazardous waste that are difficult and expensive to dispose of. Recently, most states have mandated total enclosure methods for the removal of lead-based paint, to minimize general environmental contamination during and after paint removal. While effective in reducing general environmental contamination, however, containment systems risk increased occupational exposures for workers removing the paint. This dilemma has led to significant delays in the maintenance and repainting of these structures, as effective containment systems compatible with Occupational Safety and Health Administration (OSHA) regulations on worker exposure could not be developed at reasonable cost.

Overcoating with paint systems incorporating Miles resins provides an alternative to complete removal of lead-based paints from the structure, because the overcoating paint will adhere to a minimally prepared surface, including one that is lead-based. Removal is necessary only for those areas in which paint failure (chipping, flaking) or corrosion has occurred.

These paints also comply with current regulations on VOCs for paints used on steel structures. None exceeds 3.5 pounds of VOCs per gallon of paint (420 grams of VOCs per liter); the primer, intermediate, and topcoat contains 2.8 pounds per gallon (336 g/l) VOCs.

Other Advantages

This approach to structural maintenance not only reduces the generation of hazardous waste and the risks of occupational exposure to lead or environmental contamination, but may also save money because less surface preparation is required. Miles estimates the cost to be approximately one-half that for repainting that requires full removal without containment, and one-quarter of the cost with containment.

The new paints offer advantages even if the condition of the old paint requires full removal. The moisture-curing properties of the polyurethane mean that painting can continue in conditions of high humidity - up to 99 percent - and while the paints must be applied above freezing, they will cure at below-freezing temperatures.

The primer also dries to the touch rapidly-within 15-30 minutes - allowing priming and repainting to occur in relatively close proximity. Recoating times of two to four hours for the primer and two to four hours for the intermediate and topcoat allow rapid completion of a given area, which may be important when operating in a containment structure that must be moved, or when painting operations interfere with other activities such as traffic.

Disadvantages

The coating system is not applicable to overcoating if more than 30 percent of the structure has paint failure or corrosion, unless total removal of earlier paint is required.

Direct Motivating Factors

The concept of overcoating lead-based paints with less hazardous alternatives has been around for a long time, according to Miles. Its overcoat approach was used on one bridge project as far back as 1978. Cost was the key issue at that time; however, as long as lead paint could be used for spot maintenance, both overcoating and complete removal of lead paint were at a competitive disadvantage. Increased concern over the harmful effects of lead to the environment and to workers, coupled with new requirements for enclosures when removing lead-based paint, have made the economics of overcoating far more attractive.

Indirect Motivating Factors

Given the high concentrations of lead in paint removed from steel structures, removed paint often qualifies as a hazardous waste under RCRA. Moreover, traditional removal methods can result in the dispersal of lead over a significant area. The Transportation Research Board of the National Research Council reported a survey of bridge painting contractors in 1992 indicating that 70 percent of the bridges painted required some kind of containment. The combined need to prevent general environmental contamination from paint removal, while ensuring adequate safety for paint removal workers, represents a nearly insoluble engineering problem; at best, it can make complete lead removal very expensive. Thus, a strong economic incentive exists for a bridge maintenance system that neither continues to use lead-based paint, nor requires complete removal of old lead-based paint.

Development Process

A paint system based on Miles's polymer chemistry was applied in a bridge overcoating project in 1978. The paint has performed well in intervening years; as of 1992, less than 5 percent of the bridge showed signs of corrosion, and gloss retention was still good. This bridge, located in an industrial area in Pennsylvania with heavy commercial traffic, is exposed to a variety of air contaminants. A moisture-curing spot primer containing aluminum based on Miles' Desmodur E-series aromatic polyisocyanate, an intermediate coat based on the same compound, and a two-component polyesteraliphatic polyurethane topcoat based on Desmophen polyester polyol and Desmodur N aliphatic polyisocyanate was used.

Over the years, Miles has further developed the polyurethane-based system.[2] The resulting coatings have performed well in three-year weathering tests in Florida and have been applied to steel structures in widely varying climates. A system using these coatings (with a zinc-based, rather than aluminum, primer) was used in a project that involved complete removal of lead-based paint, in total containment, in 1992- 1993.

Market Status

As noted above, recent changes in the economics of bridge and other steel structure maintenance have had a significant impact on the costs of overcoating, relative to other maintenance approaches. Paints based on Miles's polymer technology were used on two bridge painting projects in the Pittsburgh area in 1993, and were to be applied to two bridges in Kentucky in 1994. Miles is promoting the technology in other states, 16 of which currently use or are evaluating the overcoat technology.

Corporate Environment

Miles is a Chemcial Manufacturers Associaton member subscribing to the "Responsible Care" principles, and a participant in EPA's 33/50 Program to voluntarily reduce emissions of 17 chemicals 50 percent by 1995. In addition, Miles's internal Waste Reduction and Management (WRAM) program proposed to reduce all wastes (air emissions, water emissions, and solid waste) 50 percent by the end of 1993, relative to 1987 levels. At the end of 1992, Miles had achieved reductions of 44 percent.

Miles also employs a "Total Quality Management" approach to its general operations that assists the company's WRAM efforts.

Regulatory Environment

Three phases of regulation affect this painting system. First, Miles is regulated as a commodity chemical company, dealing with the toxic risks posed by the isocyanates[3] on which these resins are based. Second, the paint formulators who are Miles's customers face similar concerns regarding the resins, particularly for the two-part paints (each paint component being reactive). Finally, there are concerns for workers who apply the paint.

With respect to the first two stages, Miles is governed by Toxic Substances Control Act (TSCA) requirements on the evaluation of new chemicals, OSHA standards for its production facilities, emissions regulations under the Clean Air Act and Clean Water Act, RCRA waste regulations, and release reporting to the Toxics Release Inventory.

In the paint application process, regulations cover VOC releases, as well as the removal of existing lead paint. As noted above, Miles states that the paints can be formulated to comply with all current relevant VOC requirements. Because removal of intact lead paint is not required, regulatory requirements will be less burdensome when this system is applied than when an alternative system requiring paint removal is specified. Less lead-containing paint waste will be generated, and spot removal of deteriorated paint does not require large-scale abrasive blasting, as is generally needed for complete paint removal. The reduced lead paint removal also facilitates compliance with OSHA requirements regarding worker exposures.

Market Environment

State transportation or highway departments comprise a major fraction of the ultimate market for these paints. It is unusual for state transportation departments to use any paint manufacturer's "off the shelf' product. Rather, they take one of three approaches to specifying the paint to be used when they issue a contract for bridge maintenance: some states have a list of qualified products; others, such as Texas, provide a paint formulation specification; still others issue a performance specification. Actual specifications are subject to constant change.

Miles's approach to marketing, therefore, is to ensure that state agencies are aware of Miles's technology, so that it can be incorporated into their paint specifications. In effect, although Miles's customers are paint formulators, for this market Miles must devote significant marketing effort to the end-use consumers of the paint, its customers' customers. For other uses, such as heavy-duty industrial maintenance, marketing is more straightforward, as the painting contractor would negotiate paint specifications with the owner of the facilities.

Barriers to Development of Improved Products

Miles officials note that the Premanufacture Notice program administered by EPA under TSCA appears to have slowed down in recent years. While it was formerly possible to bring a chemical to market in a few months, it now can take between one and two years to complete review of a new chemical. They also noted that the recent OSHA standards for lead exposure in the construction industry may tend to lessen the advantage of overcoating systems, relative to complete removal of lead paint. Although exposures from hand-tool cleaning used in spot removals are generally far lower than those associated with complete removal, they may still exceed the permissible exposure levels and are likely to require air monitoring and medical surveillance of workers, at least until it is demonstrated that unacceptable exposures do not occur. These monitoring and surveillance costs represent a significant fraction of the current cost differential between spot removal and total removal.

Miles officials also note that state specifications for paint performance are tightening, with increasing likelihood of requiring actual environmental testing, rather than dependence on accelerated laboratory testing. Obviously, a three-year delay for a paint durability test significantly slows the introduction of new paint products.

Life Cycle Consequences

Miles officials note that the overcoating method does not completely solve the environmental problems posed by earlier use of lead paint on bridges and other steel structures. Rather, it allows maintenance to proceed without unacceptable harm to workers or the environment. Eventually, however, all of the lead-based paint on bridges will have to be dealt with, even if it can be deferred until bridge demolition.

Notes

1. Most other paints suitable for steel structures do not adhere satisfactorily to lead paints that have been in place for some years.
2. An alternative, lower viscosity aromatic polyisocyanate has been developed for the spot primer. An alternative intermediate coat is a two-component system, based on Desmophen acrylic polyols and a Desmodur N aliphatic polyisocyanate. For the topcoat, Desmophen acrylic polyols can be used in place of the earlier polyester polyol with Desmodur N aliphatic polyisocyanates.
3. A compound containing the isocyanate radical - NCO. Monoisocyanates are in use, but the term isocyanate usually refers to a diisocyanate.

National Starch and Chemical Company

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The Company

National Starch and Chemical Company manufactures adhesives, sealants, and synthetic resins, as well as specialty starch products derived from wet-corn milling. It is a subsidiary of Unilever United States, Inc., which is itself a subsidiary of the multinational Unilever, based in the United Kingdom and the Netherlands. National Starch has approximately 7,600 employees, with reported sales of $1.8 billion in 1992. It operates 26 plants in 17 states.

The Improvement: Hot-Melt Adhesives that are Repulpable

National Starch has introduced a series of hot-melt (thermoplastic) adhesives that disperse in water, enabling paper products that have been made using hot-melt adhesives to be reduced again to paper pulp and effectively recycled. The adhesives can be customized for a variety of applications. While the adhesive technology involved has been available for some years, National Starch has recently begun an intensive effort to introduce it into markets where the paper content of the product may be recycled.

These adhesives rely upon completely different polymers, developed by National Starch, from those used in conventional hot-melt adhesives. While both the polymers and the polymerization process are different, however, the adhesives are “drop-in” substitutes for conventional adhesives, and do not require customers to change either their equipment or their procedures.

Environmental Advantages

Hot-melt adhesives are widely used in paper products ranging from books to corrugated cardboard cartons. While they may represent a small fraction of the total mass or volume of such products, they have proven to be a significant barrier to paper recycling. Most paper recycling involves repulping, in which the paper product is broken down back into fibrous pulp, usually in a process involving hot water and mechanical shear. Because the hot-melt adhesives in general use are not water-soluble or water-dispersible, they remain in solid form during this process. As a result, when the pulp is formed into new sheets of paper, these remaining bits of solid adhesive may cause malfunctions in the paper-forming machinery, necessitating shutdown and repair. In severe cases, the machinery may be damaged. Moreover, pieces of the adhesive may become embedded in the recycled paper, rendering it unfit for many uses. For example, most adhesives will not absorb ink, as paper does, leading to problems in printing on the recycled paper. They may also cause the layers of a roll of paper to stick together, ruining the entire roll.

The adhesives developed by National Starch, in contrast, disperse completely in the hot, agitated water used in the repulping process.[1] Because the adhesives are then uniformly dispersed throughout the recycled pulp in concentrations too low to affect its properties, rather than remaining as a collection of solid particles, the problems of machine damage and lowered paper quality are eliminated. Similarly, the paper produced will not be rendered unusable by the inclusion of adhesive particles.

Other Advantages

The new adhesives provide better adhesion to some paper types than do conventional hot-melt adhesives. There are also applications other than recycling in which water-sensitivity is a useful property for an adhesive.

Disadvantages

Repulpable hot-melt adhesives are approximately twice as expensive as the conventional products that they replace. While the price of the adhesive may represent an extremely small fraction of the overall price of an item (such as a cardboard box),[2] customer reluctance to pay this increased price represents a significant barrier to commercial introduction of these adhesives.

Direct Motivating Factors

The drive to introduce these products into the hot-melt adhesives market reflects an overall commitment by National Starch to environmental stewardship,[3] as well as the belief that in the future environmental concerns will be important market drivers, although they are not as yet. Informal market research indicated that the market for such a product would expand. National Starch's goal is both to replace the conventional (non-repulpable) hot-melt adhesives it currently sells, and to increase its share of the market for hot-melt adhesives.

Indirect Motivating Factors

National Starch believes recycling of paper products will be an increasingly important concern in the future, as environmental issues related to waste disposal and raw materials acquisition become more widely appreciated. This may be reflected in regulations (such as recycled-content laws) and other actions that influence the market for paper products, and correspondingly, for adhesives used with paper products.

Development Process

The polymer chemistry that underlies these products was developed by National Starch in the late 1970s in response to a perceived need in the book-binding market. However, these products were not then commercialized. In response to environmental concerns, efforts to introduce them into the market were initiated in 1990, and these adhesives have been commercially available since 1991.

In the course of commercializing these products, National Starch has relied both upon in-house research and development and, particularly with respect to some formulating additives, collaborative work with its suppliers.

National Starch has invested significant capital to develop these products. Production of these adhesives will also involve the production of the component polymers; accordingly, production facilities and equipment for these polymers must be underwritten.

Market Status

The current market is considerably smaller than the eventual market envisioned by National Starch. In part this reflects the price differential noted above. The company is involved in educational efforts (technical seminars, journal publication) aimed at increasing knowledge about these products and their environmental utility, as well as customer education by its sales force. Reasons underlying customers' unwillingness to accept the price differential on these products are discussed below.

Corporate Environment

National Starch has an explicit, written, corporate environmental commitment and participates in the Chemical Manufacturers Association's "Responsible Care" program. The company does not participate in EPA's voluntary 33/50 Program for reduction of the emissions of 17 chemicals, because it considers its releases of these chemicals to be minor.

New product developments at National Starch generally involve cooperation across different functional divisions. Staff involved in developing these adhesives indicate that there are few internal barriers to new ideas, and that the company has an active Total Quality Management program with rewards for employee initiatives.

The program to introduce repulpable adhesives into the market has been supported by upper management at National Starch, because it is consistent with the corporation's environmental commitment, rather than in response to an existing market demand.

Regulatory Environment

Within National Starch, the major regulatory issues arise from the decision to produce not only the adhesives but also their polymer constituents. Because all polymers are synthesized from monomers that are inherently reactive,[4] appropriate controls are needed to prevent excessive occupational exposures. In the new polymer production facilities, National Starch will need monitors and control equipment similar to that used in its other polymer production lines. This differs from the situation for comparable adhesives where production is not vertically integrated within National Starch.

Because one of the intended uses of these adhesives is in packaging for foods, they are also subject to regulation by FDA as "indirect food additives." This involves evaluation both of the likelihood that the adhesives (or their chemical constituents) will migrate out of the packaging and into the food, and of the potential for such chemicals in the food to pose a hazard to consumers.

Market Environment

The market for hot-melt adhesives for paper products spans a wide range of customers, from industrial giants manufacturing thousands of products per day (e.g., a cereal manufacturer using cardboard boxes), down to very small firms (a manufacturer of air fresheners in a local market). National Starch has several thousand customers spanning this market range. Most are direct customers, while the smallest are serviced by distributors. In the markets they serve, National Starch has one major competitor, and six to ten smaller ones.

In general, this is a mature market, in which continual minor improvements are made to existing products and dramatic innovations are rare.

A key factor affecting the market for repulpable adhesives is that the customer for the adhesives sold by National Starch (or its competitors) may itself have no direct link to paper recycling. While some firms attempt to collect their paper packaging for recycling, much of the paper recycling market involves firms that contract with retail outlets to obtain their high-grade paper products, or municipal programs run in conjunction with other solid-waste management programs. This dissociation between the market for paper to be recycled, where repulpable adhesives are important, and the market in which paper adhesives are sold, where recycling does not affect marketability, tends to diminish demand for repulpable adhesives.

The infrastructure for paper recycling is not well developed. The few cases in which there is "closed-loop" recycling represent the best current market for recyclable paper adhesives. National Starch believes that as a more general recycling infrastructure develops, requirements for feedstocks (used paper products) are likely to become standardized, as they are in much of industry. Such industry consensus standards are likely to stimulate the market for repulpable adhesives.

A variety of initiatives, such as Germany's Dual System packaging program,' or recycled content regulations on paper products that require the inclusion of post-consumer waste, will tend to increase the linkage between the primary consumer of adhesives for paper and the market for paper recycling. Because the market for these adhesives is international, recycling regulations abroad may drive the market at least as much as those issued in the United States.

Barriers to Development of Improved Products

National Starch has identified two primary barriers to effective marketing of these improved adhesives. The first involves the economic disconnection between producers of paper products who purchase adhesives and the recycling industry for which non-repulpable adhesives represent a problem. Because the customers for adhesives are rarely themselves involved in recycling, they have little incentive to pay the increased price for the repulpable adhesive, even if the cost of adhesive is a tiny fraction of their overall costs. This problem may be temporary, as recycled-content regulations and similar initiatives place on producers the responsibility for the ultimate fate of paper products.

National Starch also expressed the view that the regulatory approach employed by FDA for indirect food additives required new products to undergo a more stringent review than had been used for products already in commerce. Moreover, the company is uncertain what kind of information will be required to obtain FDA approval.

Life Cycle Consequences

The new adhesives involve polymers and polymerization processes that differ completely from the adhesives they are designed to replace. National Starch will produce these new polymers in its own facilities, rather than purchasing them from outside suppliers. Because of the different chemistries involved, National Starch will also be using different suppliers from those who support its comparable conventional adhesives (30 percent of suppliers are new; 70 percent are current suppliers).

The life-cycle questions concerning these improved adhesives have to do with disposition after their useful life, and that of products that incorporate them, is over. The design objective is to enable paper products that are not currently recyclable to be recycled, and thus diverted from disposal. Questions remain about the ultimate fate of these products after repeated recycling - e.g., do adhesives tend eventually to build up to concentrations that degrade the paper's quality?

Notes

1. The sensitivity to water involved in the design of such adhesives is not all-or-none, but rather reflects the specific conditions used in repulping paper. It is thus possible to design an adhesive that will disperse under the conditions of the repulping process, but will not be excessively sensitive to water if the conditions of high temperature and high shear forces are not present.
2. National Starch estimated that the adhesive in a typical cardboard cereal box, for example, would cost one-tenth of one cent.
3. National Starch mentioned its participation in CMA's "Responsible Care" program, as well as an internal company initiative to remove toxic chemicals from its products.
4. It is quite common in industrial chemistry that extremely toxic compounds (monomers) can form polymers that have little or no toxic hazard. Two familiar examples are polyvinyl chloride (PVC), which is made from vinyl chloride, a known human carcinogen, and polystyrene foam (e.g., Styrofoam), made from the neurotoxicant styrene.
5. Under German law, firms are responsible for reclaiming the packaging used for their products from consumers. Alternatively, they have the option of participating in an organization that collects and markets recyclable packaging materials, and certifies that a particular package is covered by the program (indicated by a green dot).

Swift Adhesives

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The Company

Swift Adhesives manufactures industrial and household adhesives, sealants, and related products at 13 locations in the United States and Canada, as well as one in Mexico. The company is a subsidiary of Reichhold Chemicals, Inc., of Research Triangle Park, North Carolina. Reichhold, in turn, is a subsidiary of the Japanese-based multinational Dainippon Ink and Chemicals, Incorporated. Swift Adhesives reported sales of $609 million in 1991.

The Improvement: Solvent-Free Adhesive for Foam Fabrication

These waterborne, latex-based, high solids adhesives replace conventional latex adhesives for flexible foam, such as is used in furniture. The new adhesives, called the 49200 series, which required the development of new water-soluble resins, do not employ 1,l,1-trichloroethane or similar non-flammable solvents, as do conventional adhesives for foam. Swift Adhesives is also testing hot-melt adhesives for complementary uses.

Environmental Advantages

The complete elimination of solvents (1,1,1-trichloroethane in the case of the specific adhesives being replaced by Swift Adhesives) eliminates a number of potential health and environmental problems and frees both Swift Adhesives and its customers from regulatory requirements designed to address those problems. Swift Adhesives estimates that the foam fabricating industry releases as much as 3 million gallons of solvent VOCs per year. While the conventional adhesive replaced by the new product contains approximately 200 grams of Volatile Organic Compounds (VOCs) per liter of adhesive, 49200 series adhesives contain no VOCs.

Methyl chloroform (1,1,1-trichloroethane) has been determined to be one of the chemicals that contributes to the depletion of stratospheric ozone. As such, it is subject to taxation at present (which increases the cost to users of adhesives that contain it), and will have to be eliminated entirely from use by 1995. In addition, concerns about its toxicity require controls to prevent overexposure to workers.

Among the requirements that affect conventional formulations based on 1,1,1-trichloroethane, but do not apply to the new water-based adhesive, are emission control systems; employee monitoring under requirements of the Occupational Safety and Health Administration (OSHA); reporting under Sections 311, 312, and 313 of the Super-fund Amendments and Reauthorization Act (SARA), as well as comparable state reporting requirements; labeling for ozone depleting substances; and regulation as a hazardous waste under the Resource Conservation and Recovery Act (RCRA). For the new adhesive, no hazardous ingredients or SARA Title III reportable substances are listed on the Material Safety Data Sheet (MSDS). Within Swift Adhesives' plants, there has been a steady decrease in the amount of hazardous waste generated since the introduction of the water-based adhesive.

Other Advantages

The change in the environmental characteristics of the product can result in significant cost savings in terms of emission controls and waste disposal.

While solvent-borne adhesives generally require that foam-to-foam bonding take place within 20 to 25 minutes of adhesive application, bonding with this water-based formulation can take place any time between 20 minutes and one week following adhesive application. However, as noted below, the requirement for a minimum delay of 20 minutes between adhesive application and foam assembly (vs. immediate assembly for solvent-based adhesives) does impose some changes on users.

Because of the high solids content (60 percent vs. 18 percent for a typical solvent-borne adhesive), a given quantity of adhesive will coat a significantly greater area of foam. In other respects, performance is similar to conventional products, with improved resistance to degradation by high heat or ultraviolet light.

Disadvantages

The new adhesive, while bonding almost all soft foams (urethane, ethylene, or natural latex), does not bond styrene foams well.

Of greater consequence to most users is the need for minor adjustments to spraying and foam assembly techniques. While the new adhesives can be used on existing production lines without equipment changes, procedural changes are required to accommodate the slightly different properties of the waterborne adhesives; for example, the different resins and higher solids content may require some retraining of spray equipment operators. Also, greater force must be applied to form the foam-to-foam bond.

In addition, the longer evaporation time of water, as compared to conventional non-flammable solvents, calls for some reordering of foam assembly operations. For example, to accommodate the rapid drying time and short assembly window of solvent-borne adhesives, typical procedure would be to spray adhesive on a few pieces, assemble them, and then spray the next set. With the water-based adhesives, one would instead spray a larger number of pieces, prior to switching to assembly. Swift Adhesives notes that the slight increase in the minimum time between adhesive application and foam assembly is offset by the greatly extended time available for foam assembly after spraying.

Direct Motivating Factors

The development of these adhesives represents the implementation of Swift Adhesives' general policy of eliminating solvents from all of its adhesives, as part of a corporate goal of environmentally friendly products. Swift Adhesives believes these products will come to be preferred as customers become informed about the environmental costs associated with conventional adhesive formulations.

Indirect Motivating Factors

The adhesives market for flexible foam applications is primarily based on the use of non-flammable solvents, such as 1,1,1-trichloroethane. However, emissions concerns and product safety issues are helping to drive this market towards the use of aqueous formulations. For example, 1,1,1-trichloroethane is being taxed and, under EPA regulations, will have to be eliminated by 1995. Customers will soon need environmentally improved adhesives, although demand is not yet strong.

Development Process

The marketing group communicated to the research and development staff the need for an alternative adhesive for foam fabrication. The basic specification was the need to eliminate the solvents that presented environmental problems, while retaining the performance characteristics of the solvent-borne adhesive. The development process involved not only research and development staff, but continuing interaction with marketing and production personnel, with an advisory role played by the regulatory group. This involved extensive inter-departmental cooperation, and the support of upper management.

While work on the development of these adhesives was primarily internal, some collaborative work on resin chemistry was done with the suppliers of the new raw materials involved, and with customers, who evaluated the characteristics of the new adhesives. Development of these adhesives has been substantially independent from other environmental improvement efforts at Reichhold.

The development time was approximately six months, which is longer than that for most adhesive formulation projects carried out by Swift. The decision to proceed with commercialization, following the development of an appropriate formulation, was made by the marketing department.

Market Status

Swift Adhesives is still in the process of introducing these waterborne adhesives into the foam fabrication industry; reaction has thus far been mixed. While the new adhesives were awarded one of seven Challenger awards by the International Woodworking Fair (the first time such an award has been made to an adhesive company), and customers have expressed interest in the technology, a number of customers have been reluctant to change from solvent-borne adhesive formulations. The prime reason for such customer reluctance appears to be the need to change the timing of foam assembly operations, as noted above.

Consequently, the time for commercializing these new adhesives has been significantly extended relative to that for most formulation changes introduced by Swift Adhesives, which have generally been instituted to satisfy immediate customer demand. The water-borne adhesive is only slowly beginning to displace sales of solvent-borne adhesives. Introducing this product has not yet increased Swift Adhesives' market share, but the company believes it will.

Corporate Environment

Swift Adhesives has an explicit corporate policy to provide environmentally friendly adhesives and an ongoing program to replace current products that are not consistent with this policy. This includes the replacement of solvent-borne adhesives with waterborne formulations. As part of its overall corporate environmental commitment, it participates in the Chemical Manufacturers Association's "Responsible Care" initiative.

Swift Adhesives' parent company, Reichhold Chemicals, is a participant in EPA's voluntary 33/50 Program to reduce emissions of 17 toxic or environmentally harmful chemicals, including 1,1,1-trichloroethane. The decrease in use of 1,1,1-trichloroethane in Swift's adhesives has helped Reichhold to meet its 33/50 goals, although company officials were not in a position to state the fraction of Reichhold's reductions that was represented by these efforts on the part of Swift Adhesives. While Swift Adhesives works closely with the parent company, the new adhesives represent an independent development effort by Swift. The information gained in the course of developing the 49200 adhesives for foam has helped Swift Adhesives to eliminate 1,1,1-trichloroethane from other adhesives as well, particularly from packaging adhesives.

Swift Adhesives' commitment to environmental improvement is balanced by an explicit commitment not to change product formulations without advance notice to customers. Accordingly, some customers were involved in this product development, while the solvent-borne formulation it is intended to replace is still supplied to other customers. In the case of the new foam adhesives, the corporate policy favoring environmental improvements supported the innovation, even though immediate customer demand was limited.

Swift Adhesives' accounting system incorporates some elements of "full-cost accounting." For example, waste disposal and product waste costs are accounted to specific products. Other environmental efforts, however, such as quality and safety bonus programs, are accounted to general administration. These latter efforts represent one aspect of a Total Quality Management program at Swift Adhesives. Both the research and development and marketing staffs are continually trained in the need for involvement in the move to clean products, and the elimination or reduction of hazardous materials is always a topic at research and development meetings.

Regulatory Environment

Foam fabricating adhesives generally employ nonflammable solvents. As noted above, these are subject to taxation and regulations of increasing stringency, because of their contribution to stratospheric ozone depletion. In contrast, the waterborne formulation has less of a regulatory burden. Swift Adhesives and its customers will be subject to fewer regulatory requirements when the waterborne adhesives have completely displaced conventional solvent-borne equivalents.

Market Environment

Although international in scope, the foam fabricating market has little interplay with other adhesives markets. Foam fabricating adhesives are specialty products, with little or no direct utility in other applications. There is a wide range of sizes of both customers (foam fabricators) and adhesives suppliers in this market. In general, the market has been relatively stable, characterized more by minor functional improvements of existing product lines than by major innovations.

Barriers to Development of Improved Products

The only barrier that Swift Adhesives has encountered in introducing this series of adhesives is customer reluctance to change patterns of adhesive use (principally the timing of adhesive application and foam assembly). Swift Adhesives is actively working on increasing customer awareness of environmental and regulatory issues and expresses confidence that the new adhesives will succeed. Regulatory constraints on 1,1,1-trichloroethane will likely play a major role in encouraging the use of the new adhesives.

Life-Cycle Consequences

Swift Adhesives has acquired new suppliers for the new raw materials needed for the waterborne adhesives. To formulate these adhesives, high-speed batch reactors have been required. However, Swift Adhesives officials report no discernable changes in energy requirements. No releases of 1,1,1-trichloroethane will occur from producing this adhesive, and Swift Adhesives notes that the quantity of hazardous waste produced at its facility has decreased.

Appendix: Questionnaire

CLEAN PRODUCTS (PAINTS AND ADHESIVES)

Goal of the Clean Products Study

The fundamental goal of the EPA program that supports this study is to facilitate the development of products that have a reduced potential to cause adverse environmental impacts, while maintaining desirable product characteristics and economics.

In order to achieve this goal, EPA, the public, and product manufacturers need to have information on those factors that encourage or hinder the development of such "clean" or "environmentally friendly" products. As an initial focus, **INFORM** is looking at the paints and coatings and the adhesives industries, where there has been considerable emphasis on the development and marketing of "clean products" in recent years.

In order to identify the factors that help and hinder the development of "clean products," **INFORM** is developing interview-based case studies of companies that have pioneered the development of such products. Within a very limited sample size, we are trying to obtain information on "clean products" that incorporate a range of changes, serve a variety of purposes, and reflect several different market sectors. We hope that the experiences of firms that have already developed such products can provide valuable information that will assist additional firms in reducing the adverse environmental impacts associated with important commercial goods. We seek no confidential information of any kind and anticipate that participation in this study will help a company in its efforts to market improved products.

Your firm is one of nine companies that have developed a "clean product" and have agreed to participate as a case study company for this effort. We thank you for your time and effort and hope that the interview based on this questionnaire will not prove too onerous. Please note, we are seeking only information that you are willing to divulge publicly. The following pages outline the five major categories of information we wish to discuss:

- The nature of the product improvement - key feature(s) and impacts,
- The history of its conception and development,
- Distinguishing features of the product's market,
- Barriers to developing and marketing the product, and
- Other perspectives.

NATURE OF THE PRODUCT IMPROVEMENT NARRATIVE

Please provide a description of the unique characteristics of the new product, or include copies of any descriptive materials that you have developed.

CHEMICAL / PERFORMANCE CHANGES

Chemical Composition Changes

What toxic or otherwise hazardous chemical(s)' were reduced or eliminated from the product?

What role did the chemical(s) play in the original product?

- Solvent
- Resin/Binder
- Colorant
- Additive (e.g., biocide, plasticizer)
- Other

Was another chemical or set of chemicals substituted in the same role? If so, which?

Did the change require the addition of other chemicals to the product? If so, which? What role(s) do they play?

Production Process Changes

Did the change require any other chemicals to be used in the production process? If so, which? What role(s) do they play?

Did the product change lead to changes in energy use for the production process? If so, can you provide a quantitative estimate of the change per unit of production, per year, or as a percentage?

Did the change require changes in process equipment or personnel? If so, please describe.

What changes were imposed on your suppliers by this product change?

Product Performance Changes

Disregarding the improved environmental performance of the new product, is it equivalent to, better than, or not as good as the product it replaces?

- What specific performance enhancements are embodied in the product?
- What disadvantages, if any, are associated with the product?

ENVIRONMENTAL / REGULATORY IMPACTS OF THE PRODUCT CHANGE

User/Customer Health and Safety Impacts of the Product Change:

How has the product change affected user/customer health and safety?

- Is exposure to, or release of, toxic or hazardous chemicals during application reduced? If so, can you provide a quantitative estimate of the change (e.g., milligrams emitted per square foot of coated area)?
- Is off-gassing of chemicals reduced? Can you estimate the extent of the reduction?
- Are quantities or toxicity of waste associated with the product reduced? If so, can you provide an estimate for typical conditions?
- Are risks from ancillary processes (e.g., stripping off existing coatings) reduced? Please describe.

Please describe any health/safety improvements not listed above.

Worker Health and Safety Impacts of the Product Change:

How has the product change affected worker health and safety at your plant(s) (e.g., levels, nature, and duration of exposure to potentially toxic or hazardous chemicals)? Please describe.

General Environmental Improvement - Reductions of Emissions

Are releases and transfers of the reduced or eliminated chemical(s) required to be reported to the Toxics Release Inventory?

- If so, what are the reported releases and transfers to each environmental medium (air, water, land, off-site) for the years before and after the product change? (Please provide reported quantities and, if possible, changes in pounds of releases and transfers per unit of production.)

Are releases and transfers of the substituted chemical(s) required to be reported to the Toxics Release Inventory?

- If so, what are the reported releases and transfers to each environmental medium of the substitute chemical(s) for the years before and after the product change? (Please provide quantities and, if possible, changes in pounds of releases and transfers per unit of production.)

What other measures are made of production waste stream quantity or composition (e.g., RCRA hazardous waste generator reports, NPDES wastewater discharge monitoring reports, etc.)?

- How have these changed for the years before and after the product change (please provide quantities and, if possible, pounds of waste generated per unit of production)?

If your customers are commercial or industrial, do you know whether the product change reduces emissions of these chemicals from their facilities? If possible, please provide us with estimates of these changes.

Regulatory Impacts of the Product Change:

Do State, Federal, Foreign, or International Controls apply to the new product? If so, which laws? Please describe the nature of the controls that apply.

- Did these same laws apply to the original product?

Did other laws apply to the original product that do not apply to the new product? If so, which laws?

Has the product change affected the regulatory environment faced by your customers? If so, please describe.

ECONOMIC IMPACTS OF THE PRODUCT CHANGE

Competitiveness/Production

Do the changes in environmental risks associated with the new product contribute to its economic viability? Please explain.

- Has the product change affected the cost of production?
- Has the product change diminished concerns over liability?
- Has the product change decreased waste disposal costs?

Do other performance changes associated with the new product contribute to its economic viability? How?

Is the new product more, or less, competitive than the original product? Please explain.

- In terms of direct costs to the user (e.g., labor needs, application frequency, disposal costs)?
- In terms of indirect costs (e.g., more reflective - allows consumer to spend less on lighting)?

What changes, if any, are imposed on your customers by switching to the new product (e.g., changes in application equipment or procedures, etc.)?

Does the change in the product have any effect on transportation costs associated with its use and distribution? Please describe.

Cost Accounting

In calculating costs associated with a product, what external costs does your firm routinely consider:

- Worker safety / compensation costs
- Potential product liability / toxics torts
- Waste disposal costs
- Lost materials costs
- Other environmental management costs

If so, how are these costs accounted for?

What have these external costs been for the product for the years before and after the change (if possible, on a dollars per unit of production basis)?

CONCEPTUALIZATION AND DEVELOPMENT OF THE CLEAN PRODUCT

Primary Motivating Factors

Please describe any that apply, adding items that are not included on the following list.

"Cleaner" Product per se

- As part of an overall corporate environmental strategy
- To meet customer demand
- To respond to regulations
- To improve worker safety
- To reduce liability concerns
- To improve public relations

Improved performance in other respects

- Please describe (e.g., reduced application labor, enhanced durability).

Source(s) of the Idea for the Product

Please provide a description for each that applies.

Customer(s)

- Customer request (specific or general)
- Market research (explicit or informal)
- Public attitudes (how determined)

Internal

- R & D staff
- Production staff
- Ongoing product improvement program (e.g., TQM)
- Specific corporate initiative on environmental concerns[2]

Government

- Regulatory mandate
- Incentive (e.g., tax incentive)
- Technology transfer
- Other voluntary program

The Development Process

Was the process developed independently or in collaboration with other institutions (including collaboration with customers/suppliers). Please describe.

What was the time required for research and development?

What was the time required for implementation?

How do these times compare to R&D and implementation times for new products in general at your company (e.g., longer, shorter, or average time)?

Please describe the internal communications paths:

- Who did the originator of the idea communicate it to?
- Who else was informed of the idea?
- Who approved the development; were multiple departments involved, who had final approval authority?
- What criteria were used to make the final decision?

Policies and Programs Governing Product Changes

What written policies governing product changes were in place prior to the product change?

Have any policies been put in place since the product change? If so, were they a result of this product change?

How are employees, at all levels, trained, encouraged, and rewarded for initiating ideas for new "clean products" at your company?

- Is there a formal "employee involvement" program? If so, please describe it in terms of three possible components:
  - "Clean product" education and training.
  - Active employee participation in generating ideas for clean products.
  - Employee recognition/reward programs.

Other Salient Features of the Development Process. Please Describe.

MARKET FACTORS - COMMERCIALIZATION

Defining the Market for this Product (e.g., Consumer, OEM, Industrial, Government)?

Within the market sector, does this product address the general market or an identified niche market?

Please describe the relationships between customers and suppliers in this market, for example:

- A few large suppliers sell to many small customers
- Many small suppliers sell to a few large customers
- A single customer sets specifications for competition
- A mix of sizes among either suppliers or customers

In general, what is the role of innovation and R&D activities in this market?

- Relatively stable market, with little product change (like commodity foods)
- Continual minor enhancements to a basic product line
- Innovation-driven, with rapid product obsolescence (like microprocessors)

Is the market for this new product local, regional, nationwide and/or international? What was it for the original product?

New and Pre-Existing Markets

Is the original product for which this substitutes still marketed?

- Is there a significant difference in performance or price? Please describe, and if possible, quantify.
- Is the new product displacing the old, expanding the market, or both?

Has introducing this product had a significant impact on your market share? If so, what is the estimated change?

Does the product have potential for use in other market sectors? If so, which?

- What further changes are needed?

Role of Customer Demand for “Clean Products” in this Market

Do customers have a general interest in this type of product?

Have customers made a specific request for developing this product, or for this type of product?

Has expressed customer reluctance inhibited the development of products like this?

Is the product explicitly marketed as being an environmental improvement through such terms as “Clean, “(Green,” “Environmentally Friendly,” etc.?

- What was the role (if any) of “eco-1abelling” organizations?

Unusual Aspects of the Commercialization Process for this Product

Has the time to commercialize this product been unusually short or long, relative to normal experience?

Has your advertising strategy differed significantly for this product? Please consider not only the green component discussed above, but also any discussion of regulatory relief of performance advantages.

Other Key Factors That Affected the Marketing of this Product

Please describe.

BARRIERS THAT HAD TO BE OVERCOME

Internal Reluctance within Your Company

Please provide a description for each of the following categories, or other categories that apply:

- On the part of upper management?
- On the part of marketing?
- On the part of finance?
- On the part of production/engineering?

Problems of Market Penetration?

Have customers been unwilling to accept changed formulation?

- Increased price as a problem
- Customer uncertainty regarding product performance
- Product requires unacceptable changes to a customer’s processes

Have customers expressed criticism/skepticism regarding environmental, health and safety improvements?

- Customers view as unnecessary
- Customers do not accept claims of improvement

Regulatory Obstacles

Have any federal regulations impeded the development or marketing of this product?

- Need for revised air/water discharge permits
- Review of “new” chemicals under TSCA
- Worker safety issues

State Regulations?

- CA/NJ VOC Regulations
- Proposition 65

Regulations in Other Countries?

Other Obstacles You Have Encountered

Please describe.

PERSPECTIVES

On the basis of your experience to date, has this innovation been a success?

What advice would you offer to other firms seeking to develop “Cleaner Products?”

Notes

1. For the purpose of this study, INFORM uses the terms “toxic” or “hazardous” to include substances appearing on lists in several federal and state environmental laws, such as the Clean Air Act (hazardous air emissions), Federal Water Pollution Control Act (priority pollutants), Resource Conservation and Recovery Act (RCRA) (hazardous constituents, hazardous wastes, acute hazardous wastes), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (hazardous substances), Emergency Planning and Community Right-to-Know Act (toxic chemicals, extremely hazardous substances), and many others.

   We also include any other of the more than 70,000 chemicals in commercial use that may not be regulated but may nonetheless be potentially subject to regulation on the basis of toxicity. For example, various chemicals that are listed as known or probable human carcinogens by the US Department of Health and Human Services or the International Agency for Research on Cancer are not covered by Toxics Release Inventory reporting requirements, but would be of interest in this study. Alternately, any chemical that you consider to be toxic or pose other hazards merits inclusion.
2. If so, are there other product improvements that you would like to describe to us?

Glossary

Accelerated salt spray test: Salt-spray tests involve the exposure of a material to be evaluated for corrosion resistance to a continuous fog of salt dissolved in water. Intended to reproduce the corrosion that occurs in atmospheres containing salt spray or splash. ASTM indicates, however, that the system is better suited to examining the relative resistance of a specific type of material or coating than to evaluating different materials. In addition to the standard test, copper and acetic acid may be added to accelerate the process of corrosion.

Acrylic: Refers to a family of polymers made from esters of the unsaturated acids: acrylic acid and methacrylic acid. One example is polymethyl methacrylate ("plexiglass").

Adhesion: The state in which two surfaces are held together by interfacial forces, which may consist of valence forces or interlocking action, or both. Enables dry paint to attach to and remain fixed on the surface.

Algicide: Chemical agent that destroys algae.

Aliphatic: One of the major groups of organic compounds, characterized by straight- or branched-chain arrangement of the constituent carbon atoms. (Compare with Aromatic.)

Alkyd (paint): Denoting a combination of alcohol and acid, refers primarily to synthetic resins that came to substitute for natural oils (e.g., linseed oil) in the 1930s and 1940s.

Alkyltin: Chemical compounds that combine hydrocarbon groups with tin, increasing the tendency of the toxic tin to be absorbed by living organisms. Previously added to paints as antifouling agents.

Amine: A class of organic compounds of nitrogen that may be considered as derived from ammonia by replacing one or more of the hydrogen atoms with alkyl groups. The amine is primary, secondary, or tertiary depending on whether one, two, or three of the hydrogen atoms are replaced. All amines are basic in nature and usually combine readily with hydrochloric or other strong acids to form salts.

Antifouling paint (see Fouling): A coating formulated especially for use on the hulls and bottoms of ships, boats, buoys, pilings, and the like to protect them from attack by barnacles, shipworms, and other marine organisms.

Aromatic: A major group of unsaturated cyclic hydrocarbons containing one or more rings. Typified by benzene, which has a six-carbon ring containing three double bonds. (Compare with Aliphatic.)

Binder: Film-former in which the pigment particles are dispersed and which binds the pigment to the painted surface; the part of a coating that remains on the surface after drying. Consists of resins (e.g., oils, alkyd, latex). Determines many of the paint's performance characteristics, such as washability, toughness, and color retention.

Bioaccumulation: A chemical bioaccumulates if the concentration in organisms increases with increasing trophic level in the food chain (food web). Also called biomagnification. (A trophic level is one of the hierarchical strata of food webs characterized by organisms that are the same number of steps removed from the primary producers.)

Bioconcentration: A chemical bioconcentrates if concentrations in organisms tend to significantly exceed concentrations in environmental media (e.g., concentrations in fish are much higher than those in the water in which the fish swim).

Blocking: Undesirable cohesion of films or layers in paint, e.g., sticking that makes windows hard to open.

Block polymer: A combination long-chain macromolecule comprised of any given polymer and either another polymer or a non-polymer linking chemical (coupling group) of relatively low molecular weight.

Chemical: A substance produced by or used in a chemical reaction.

Commodity: A chemical used in a wide variety of industrial applications and generally sold in bulk, e.g., formaldehyde.

Specialty: A chemical with a limited range of applications, used and sold in smaller quantities, e.g., some alkyltin compounds used as plasticizers.

Closed-loop recycling: A system in which wastes are generated, reclaimed, and reused within a single industrial process. For example, the use of paper trimmings to make new paper at the same plant.

Cohesion: Bonding of a single substance to itself.

Colorant: Material (usually a combination of pigments, solvents, and additives) that can be added to paint after manufacture to achieve desired tint.

Universal colorant: Colorant that can be used in both solvent-based and water-based paints.

Corrosion: The electrochemical degradation of metals or alloys due to reaction with their environment, which is accelerated by the presence of acids or bases. Corrosion products often take the form of metallic oxides.

CPSC (Consumer Product Safety Commission): An independent regulatory commission that is charged with (1) maintaining an Injury Information Clearinghouse to collect, investigate, analyze, and disseminate injury data and information relating to the causes and prevention of death, injury, and illness associated with consumer products; (2) conducting continuing studies and investigation of deaths, injuries, diseases, other health impairment, and economic losses resulting from accidents involving consumer products; (3) assisting in the development of safety standards addressing the risk of injury; and (4) assisting administratively and technically in the development of product safety standards and test methods.

Crosslinking: Attachment of two chains of polymer molecules by bridges composed of another chemical compound that joins certain carbon atoms of the chains by primary chemical bonds.

Curing: The conversion of applied paint or adhesive material, by means of a chemical reaction, into a continuous solid film with desired characteristics. A wide variety of mechanisms may be involved in the curing of paints or adhesives, including oxidation, polymerization, or photochemically mediated reactions.

Moisture-curing: Curing that occurs as a consequence of absorption of moisture into the resin.

Dispersible: Ability of finely divided solid, liquid, or gaseous particles to distribute in a liquid, solid, or gaseous medium.

Dispersion: A two-phase system in which finely divided particles are distributed throughout a bulk substance, the particles being the disperse or internal phase and the bulk substance the continuous or external phase. Under natural conditions, the distribution is seldom uniform, but under controlled conditions, uniformity can be increased by the addition of wetting or dispersing agents (surfactants), such as a fatty acid.

"Drop-in": Substitutable for an existing product with absolutely no modification of equipment or procedures. Functionally identical.

Dry fog: A rapidly drying architectural coating that adheres to a wide variety of surfaces. Used, for example, to coat ceilings in new construction.

Eco-labeling: The use of environmentally relevant information in product labels, to identify the environmental advantages of one's product, relative to those of competitors, or to establish that the product meets a given standard. Currently, two alternative approaches are most widely used: documenting specific claims or documenting compliance with a standard published by an independent organization.

Eggshell finish: A finish with a very slight gloss, rather than completely flat.

Emulsion: A stable mixture of two or more immiscible liquids, often of oil or fat particles in water, held in suspension by small percentages of substances called emulsifiers. These are of two types: (1) polymers that act by coating the surfaces of the dispersed particles, thus preventing them from coalescing (protective colloids) and (2) alcohols and fatty acids that reduce the surface tension at the interface of the suspended particles (detergents).

Emulsion paint: See Latex paint.

Enamel paint: Coating that is characterized by its ability to form a smooth surface. Originally associated with a high gloss, but may include lower degrees of gloss, *i.e.,* flat enamels.

Epoxy: A thermosetting resin based on the reactivity of the epoxide group. An epoxide group consists of the union of an oxygen atom with two other atoms (usually carbon). Such resins have a broad spectrum of uses, among the more important of which are as strong-bonding adhesives, effective with metal/ceramic composites, as well as with wood. Epoxy coatings have high resistance to attack by chemicals, corrosion, weathering, and electricity.

Ethylene (see Polyethylene): A compound consisting of two carbon compounds joined by a double bond, with two hydrogen atoms filling the remaining two bonds of each carbon atom. Although flammable, ethylene is essentially nontoxic.

Feedstock: Raw materials used in a chemical process. Generally refers to commodity chemicals or mixtures rather than specialty chemicals. Also used to refer to chemical mixtures derived by thermal or catalytic cracking of petroleum.

FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act): As amended, directs EPA to regulate the manufacture, distribution, and use of pesticides and conduct research into their health and environmental effects.

Film-former: See Binder.

Flammable material: Any solid, liquid, vapor, or gas that will ignite easily and burn rapidly.

Flash point: The temperature at which a liquid or volatile solid gives off vapor sufficient to form an ignitable mixture with the air near the surface of the material or within the test vessel.

Flash-rust resistance: Flash rust is rust that occurs on metal within minutes after exposure to moisture, which can adversely affect the appearance and/or adhesion of water-based coatings applied to metal.

Formulator: A manufacturer that combines chemical compounds into mixtures, rather than reacting them to produce new compounds. The manufacture of gunpowder, and of most paints, involves formulating mixtures rather than synthesizing new chemicals.

Fouling (see Antifouling): The undesired growth of aquatic organisms (e.g., barnacles, zebra mussels) on a surface in contact with water. It is of greatest consequence where it obstructs the flow of water or the movement of a surface (such as a boat hull) through water.

Freezing point depression: Modification of a substance in such a way that it does not freeze at the temperature at which it normally would freeze. For example, if alcohol is added to water, the mixture has a lower freezing point than water alone.

Gloss: The degree of coherence with which light is reflected from a surface. In paints, gloss ranges from the minimal gloss seen with flat paints to the nearly mirrored finish of clear coat enamels used on automobiles.

Glycol ether: A compound that combines an alcohol (a hydrocarbon in which one hydrogen is replaced with a hydroxyl [-OH] group) and an ether (in which an oxygen atom is interposed between two carbon atoms).

Green Dot: An industry-run program in Germany, operated by Duales System Deutschland, to assure recycling of packaging materials. Producers of goods may either take back their packaging materials from consumers or participate in this organization that ensures collection and recycling of packaging materials. Packages that are eligible to be collected through this recycling program are marked with a green dot.

Hardener: A chemical that, when added to a resin, either participates in, or acts as a catalyst for, a polymerization ("curing") reaction.

Hazardous: Having the inherent ability to cause harm, which may or may not result in actual harm. For example, a chemical may be toxic or explosive (and thus present a hazard), but if no exposure or ignition occurs, there will be no adverse effect. Although toxicity is a critical potential hazard, it is not the only hazard posed by the commercial use of chemicals.

Heavy metal: While most metals are, technically speaking, heavy metals, the term is most commonly used to refer to highly toxic metals such as antimony, arsenic, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, silver, and tin.

Hexavalent chromium: Chromium in the environment generally exists in one of two valence states. The hexavalent (+6) form is far more toxic than the trivalent (+3) and is carcinogenic.

Hot-melt: A solid, thermoplastic material which melts upon heating and then sets to a firm bond on cooling. Hot-melt adhesives offer the possibility of almost instantaneous bonding, making them well suited to automated operation. In general, they are low-cost, low-strength products, but are entirely adequate for bonding cellulosic materials (paper and wood).

Inorganic chemical: In general, a chemical that does not contain the element carbon. (The exceptions include certain simple carbon-containing compounds such as oxides [carbon monoxide, carbon dioxide], carbonates and bicarbonates [baking soda, baking powder, and chalk], cyanides and cyanates, and carbon disulfide.)

Intermediate coat: A layer of paint between that which is in contact with the painted surface (the primer and sealer) and that which is in contact with the external environment (the topcoat).

Isocyanate: A compound containing the isocyanate radical -NCO. Monoisocyanates are in use, but the term isocyanate usually refers to a diisocyanate.

Latex paint (or emulsion paint): A paint composed of two dispersions: (1) dry powders (colorants, fillers, extenders) and (2) resin. The two dispersions are blended to produce an emulsion paint. Surfactants and protective colloids are necessary to stabilize the product. In emulsion paints, the binder is in a water-dispersed form, whereas in solvent paints, it is in soluble form.

LCA (Life Cycle Analysis or Assessment): An objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those uses and releases on the environment, and to evaluate and identify opportunities to effect environmental improvements. The analysis includes the entire life cycle of the product, process, or activity, encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use/re-use/maintenance, recycling, and final disposal. (While the term Life Cycle Assessment has been used interchangeably, Analysis is now preferred, as embodying fewer assumptions about the exhaustiveness of the evaluation.)

Leveling: A term used in the paint industry to describe the application properties of a paint, *i.e.*, its ability to cover a dry surface easily, fill in surface irregularities, and hold its level without sagging or running.

Machine tinting: The automated addition of a colorant to a paint to achieve a desired shade.

Mastic coatings: Coatings that are formulated to cover holes, fill minor cracks, and conceal surface irregularities and that are applied in thicknesses of at least 10 mils (dry, single coat).

Mature market: A market characterized by a relatively slow rate of change in demand and supply, with incremental technical improvements and expansion of applications, rather than dramatic economic growth or rapid technological change.

Melamine: A type of amino resin. The first step in resin formation is the production of trimethylol melamine, the molecules of which contain a ring with three carbon and three nitrogen atoms.

Metal drier: A metal such as cobalt or manganese that catalyzes the uptake of oxygen into a paint film and the decomposition of peroxide in the film to free radicals. These chemical reactions are part of the curing process of some paints, so the catalysts speed the curing of the paint.

Monomer: A simple compound of low molecular weight capable of undergoing a chemical reaction in which it bonds with other such molecules to form very large compounds of very high molecular weight (polymers). Examples of common monomers are styrene, ethylene, acrylonitrile, vinyl chloride, and propylene.

MSDS (Material Safety Data Sheet): Part of the Hazard Communication Standards (HCS) set up by the US Occupational Safety and Health Administration (OSHA) to protect workers from chemical hazards. An MSDS provides the chemical composition of the substance being used, its trade name and name of the manufacturer, known hazards associated with the substance, and precautions that workers should take to avoid such hazards.

Niche market: A market defined by a very narrow and specialized range of product applications and generally by a limited number of suppliers. For example, biocidal marine paints.

Oil paint: Paints may employ resins derived from natural oils that polymerize in the presence of air to form stable films. Linseed oil and tung oil are typical examples. True oil paints have been substantially displaced by synthetic or semisynthetic alkyds.

Open-loop recycling: The use of a waste material from one process as a raw material in a separate process. For example, the use of empty milk bottles to produce plastic “lumber.”

Organic chemical: A chemical compound containing carbon, except for certain simple ones. (See inorganic chemical.)

OSHA (Occupational Safety and Health Administration): That part of the Department of Labor charged with the promulgation and enforcement of standards for occupational safety and health.

Overcoating: Application of a paint over another paint or other finish, without removal of the old finish.

Ozone: An unstable, highly reactive molecule consisting of three oxygen atoms. Ozone is very irritating to the respiratory system. In the stratosphere, ozone serves to absorb much ultraviolet radiation.

> **Ozone precursor:** A chemical, such as one of the VOCs, that reacts under atmospheric conditions so as to yield ozone.

Paint market sectors: The market for paints can be classified in a variety of ways. Frequently used major categories include (1) architectural paints, (2) OEM [original equipment manufacturer] coatings, (3) industrial maintenance coatings, and (4) specialty coatings.

> **Architectural:** Interior and exterior building paints of various types, as well as paints for furniture and home repairs.

> **OEM (original equipment manufacturer):** Includes products such as household appliances and automobiles, as well as many smaller, more specialized uses.

> **Specialty:** Used for marking traffic lanes on roadways, refinishing automobiles or other equipment, and protecting steel structures such as highway bridges, among other uses.

> **Trade sales - consumer:** direct sales to homeowner (final consumer).

PEL (Permissible Exposure Level): Level of contamination that should not be exceeded in workplace air, legally enforceable by OSHA.

Photochemical: Concerning chemical reactions that are influenced by light.

Pigment: Any substance, usually in the form of a dry powder, that imparts color to another substance or mixture. A pigment, in contrast to a dye, does not react chemically with the substance to which it imparts color.

> **Active pigment:** One that has additional properties, such as corrosion inhibitors.

PMN (Premanufacture Notification) (see TSCA): TSCA requires manufacturers to notify EPA in advance of the intended introduction into commerce of a new chemical, through PMNs. (Similar notice is required for the intended manufacture or processing of any chemical for a significant new use.) If EPA determines that the chemical may present an unreasonable risk, it may prohibit or limit the use of the chemical in commerce until data are developed to permit a further evaluation of the chemical's effects. If EPA decides that a substance "presents or will present" an unreasonable risk, it may restrict or prohibit the production, use, or disposal of the substance. PMNs are not required for the production of small quantities of chemicals for research and development or test marketing.

Point-of-sale tinting: In retail paint sales, the addition of colorants at the paint store to yield a desired shade. Most retail paint sales employ this approach to generate a wide range of colors from a few basic paint shades.

Polymer: Compounds of very high molecular weight made up of a large number of simple molecules (monomers) that have been caused to combine with each other through chemical reaction. Polymers can be naturally occurring, such as rubber, cellulose, starch, and proteins, or synthetic, such as polystyrene, nylon, polyethylene, and polypropylene.

Polyethylene: A polymer formed by inducing crosslinking into ethylene either by radiation or by chemical crosslinking agents.

Polystyrene: Polymerization of styrene by free radicals with peroxide initiator.

Polyurethane (polyisocyanate): A thermoplastic polymer produced by the condensation reaction of a polyisocyanate and a hydroxyl-containing material.

Polymerization: The process of inducing crosslinking between monomer molecules, so that polymers are formed.

Polyol: A polyhydric alcohol, *i.e.*, one containing three or more hydroxyl groups.

Primer: A type of undercoat that, when applied to filled or unfilled surfaces, promotes adhesion, prevents absorption of later coats by porous surfaces, and gives corrosion resistance over metals.

Spot primer: A primer that is compatible with an existing paint finish, such that it can be applied to small areas in which deteriorated portions of the original finish have been removed, without complete removal of the old finish.

RCRA (Resource Conservation and Recovery Act): Federal "cradle-to-grave" regulations regarding hazardous and nonhazardous (garbage) solid waste.

Repulpable: Describing paper or paperboard that can be reduced to a paper pulp that is suitable for production of new paper.

Resin: Liquid or semi-liquid monomer or semi-polymerized formulation that forms the basis of paint binders. Curing or drying of paint reflects the completion of the polymerization reaction.

"Responsible Care": Embodies the chemical industry's comprehensive commitment to responsible management of chemicals. Implementation of Responsible Care is an obligation of membership in the Chemical Manufacturers Association (CMA) and represents the commitment of the chemical industry to improving performance in six broad areas that cover virtually all of the industry's operations. Responsible Care has two objectives: (1) to improve performance and further ensure that industry operations do not adversely affect the health and safety of the public, of workers, and of the environment; and (2) to listen and respond to the public.

SARA (Superfund Amendments and Reauthorization Act): A 1986 federal law amending the original "Superfund" law. Title III of this law is called the Emergency Planning and Community Right-to-Know Act (EPCRA). Section 313 of EPCRA contains the Toxics Release Inventory requirements.

Smog: A coined word denoting a persistent combination of smoke and fog occurring under appropriate meteorological conditions in large metropolitan or heavy industrial areas. The discomfort and danger of smog are increased by the action of sunlight on the combustion products in the air, especially sulfur dioxide, nitric oxide, and exhaust gases (photochemical smog). Strongly irritant and even toxic substances may be present. Fatalities have resulted from exposure to particularly severe photochemical smogs.

Solids: Any part of a paint or adhesive other than solvents.

Solvent: A substance, usually in liquid form, that serves as a medium in which other substances (solids, liquids, or gases) may be dissolved, but does not react with those substances. The ability of solvents to dissolve other substances allows them to be used for cleaning purposes, as the major component of products such as paints and adhesives, or as the medium in which dissolved chemicals may react with each other.

Stratosphere: The upper atmosphere, extending to a height of 50 kilometers (30 miles) above the earth's surface.

Styrene: Also called vinyl benzene or phenylethylene. A compound composed of a benzene ring with an ethylene molecule substituting for one of the hydrogens.

Teratogen: An agent that causes growth abnormalities in embryos; ionizing radiation can have this effect.

Thermoplastic: A polymer that softens when exposed to heat and returns to its original condition when cooled.

Thermosetting: A polymer that solidifies or "sets" irreversibly when heated. This property is usually associated with a crosslinking reaction of the molecular constituents. One example is the baking of doughs.

Topcoat: The final film of coating applied in a multiple coat operation. May serve to impart desired appearance and/or to protect undercoatings from environmental deterioration.

Toxic: Poisonous. Causing an adverse effect by a specific chemical reaction with a biological molecule. Distinguished from other types of hazards by the specificity of the interaction between the chemical and the biological target. In contrast, a highly reactive chemical might damage biological material by a non-specific interaction (e.g., a chemical bum); this would not be considered to be a toxic effect.

TQM (Total Quality Management): A concept of business management, with the core principles of zero defects, statistical methods to measure success, and empowerment of workers to make improvements.

Triazine: Any of three isomeric compounds, $C_3H_3N_3$, each having three carbon and three nitrogen atoms in a six-membered ring.

Troposphere: The atmosphere from the ground's surface to a height of 6 - 10 kilometers (3-6 miles).

TSCA (Toxic Substances Control Act): Federal law enacted in 1976 that authorizes EPA to regulate the manufacture, distribution, and use of chemical substances.

Urethane (see also Polyurethane): Also called ethyl carbamate, ethyl urethane. A resin, whose structural formula is $CO(NH_2)OC_2H_5$. True urethane coatings have two components that cure when an isocyanate (the catalyst) initiates the chemical reaction that unites them.

Vapor pressure: The pressure characteristic at any given temperature of a vapor in equilibrium with its liquid or solid form.

Viscosity: The internal resistance to flow exhibited by a fluid.

VOC (Volatile Organic Compound): In strict usage, any chemical that both contains carbon (organic compounds) and has a measurable vapor pressure. For regulatory purposes, definitions have been narrowed to exclude chemicals that have not been identified as contributing to smog formation or stratospheric ozone depletion. (Contact **INFORM** for regulatory definitions of VOCs from a variety of sources). In practice, VOC concentrations in paints and adhesives (and other products) are generally determined by measuring the total content of volatile materials and then correcting for the presence of water (which is volatile, but not organic).

Waste: The unavoidable and undesirable chemical byproducts of a process, resulting from process inefficiencies and discarded products containing chemicals.

Hazardous: Under federal environmental law, refers specifically to hazardous discharges disposed of as solid waste (not air pollutants) that are regulated under the federal Resource Conservation and Recovery Act (RCRA).

Solid: Any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities. Does not include solid or dissolved material in domestic sewage or solid or dissolved materials in irrigation return flows or direct industrial discharges to air or water.

Water-dispersible: Chemical substance or mixture that can be effectively dispersed in water, although it is not soluble in water.

Water-soluble coatings: Coatings where the binder is dissolved in water. Upon evaporation of the water, the binder will remain water-sensitive unless converted to an insoluble form by some means such as polymerization. This can be accomplished by incorporating a drying oil in the molecule or crosslinking by baking.

Waterborne paints: Latex paints and paints containing water-soluble binders or binders in an aqueous dispersion. For paints and adhesives, used to note the contrast from systems that depend on organic solvents.

Abbreviations and Acronyms

33/50 EPA's program for voluntary industry reductions of emissions of 17 chemicals by 50 percent by 1995

ACGIH American Conference of Governmental Industrial Hygienists

AFM American Formulating Manufacturers

ASTM American Society for Testing and Materials

BAAQMD Bay Area Air Quality Management District

CAA Clean Air Act

CAS Chemical Abstracts Service

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund)

CFC Chlorofluorocarbon

CMA Chemical Manufacturers Association

CONEG Council of Northeast Governors

CPSC Consumer Product Safety Commission

EPCRA Emergency Planning and Community Right-to-Know Act

FC Fluorocarbon

FDA Food and Drug Administration

FFDCA Federal Food, Drug, and Cosmetic Act

FIFRA Federal Insecticide, Fungicide, and Rodenticide Act

GRAS Generally regarded as safe

HCFC Hydrochlorofluorocarbon

HFC Hydrofluorocarbon

LBPPPA Lead-Based Paint Poisoning Prevention Act

LCA Life Cycle Analysis

MSDS Material Safety Data Sheet

NAAQS National Ambient Air Quality Standards

OEM Original Equipment Manufacturer

OSHA Occupational Safety and Health Administration

PEL Permissible Exposure Level

PFC Perfluorocarbon

PMN Premanufacture Notification

RCRA Resource Conservation and Recovery Act

SARA Superfund Amendments and Reauthorization Act

SIP State Implementation Plan

TQM Total Quality Management

TRI Toxics Release Inventory

TSCA Toxic Substances Control Act

USCAR United States Council for Automotive Research

USEPA US Environmental Protection Agency

UV Ultraviolet

VOC Volatile Organic Compound

WRAM Waste Reduction and Management

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Publications

Municipal Solid Waste Selected Publications

Case Reopened: Reassessing Refillable Bottles (David Saphire), 1994, 366 pp., $25.

Germany, Garbage, and the Green Dot: Challenging the Throwaway Society (Bette K. Fishbein), 1994, 276 pp., $25.

Delivering the Goods: Benefits of Reusable Shipping Containers (David Saphire), Fall 1994, ca. 40 pp., $20.

Making Less Garbage: A Planning *Guide for Communities* (Bette K. Fishbein and Caroline Gelb), 1993, 192 pp., $30.

Business Recycling Manual (copublished with Recourse Systems, Inc.), 1991, 202 pp., $85.

Burning Garbage in the US: Practice vs. State of the Art (Marjorie J. Clarke, Maarten de Kadt, Ph.D., and David Saphire), 1991, 288 pp., $47.

Reducing Office Paper Waste (Robert Graff and Bette Fishbein), 1991, 28 pp., $15.

Chemical Hazards Prevention Selected Publications

Preventing Industrial Toxic Hazards: A Guide for Communities (Marian Wise and Lauren Kenworthy), 1993, 208 pp., $25.

Environmental Dividends: Cutting More Chemical Wastes (Mark H. Dorfman, Warren R. Muir, Ph.D., and Catherine G. Miller, Ph.D.), 1992, 288 pp., $75.

Tackling Toxics in Everyday Products: A Directory of Organizations (Nancy Lilienthal, Michele Ascione, and Adam Flint), 1992, 192 pp., $19.95.

Toward a More Informed Public: Recommendations for Improving the Toxics Release Inventory (Jacqueline B. Courteau and Nancy Lilienthal), 1991, 26 pp., $10.

Preventing Pollution Through Technical Assistance: One State's Experience (Mark H. Dorfman and John Riggio), 1990, 72 pp., $15.

Cutting Chemical Wastes: What 29 Organic Chemical Plants Are Doing to Reduce Hazardous Wastes (David J. Sarokin, Warren R. Muir, Ph.D., Catherine G. Miller, Ph.D., and Sebastian R. Sperber), 1986, 548 pp., $47.50.

Energy and Air Quality

Paving the Way to Natural Gas Vehicles (James S. Cannon), 1993, 192 pp., $25.

Other INFORM Publications

For a complete publications list, including materials on land and water conservation and a quarterly newsletter, or for more information, call or write to **INFORM.**

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