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EPA Office of Compliance Sector Notebook Project:

Profile of the Plastic Resin and Manmade Fiber Industries

September 1997

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PLASTIC RESIN AND MANMADE FIBER INDUSTRIES
(SIC 2821, 2823, and 2824)

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AFS -	AIRS Facility Subsystem (CAA database)
AIRS -	Aerometric Information Retrieval System (CAA database)
BIFs -	Boilers and Industrial Furnaces (RCRA)
BOD -	Biochemical Oxygen Demand
CAA -	Clean Air Act
CAAA -	Clean Air Act Amendments of 1990
CERCLA -	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS -	CERCLA Information System
CFCs -	Chlorofluorocarbons
CO -	Carbon Monoxide
COD -	Chemical Oxygen Demand
CSI -	Common Sense Initiative
CWA -	Clean Water Act
D&B -	Dun and Bradstreet Marketing Index
ELP -	Environmental Leadership Program
EPA -	United States Environmental Protection Agency
EPCRA -	Emergency Planning and Community Right-to-Know Act
FIFRA -	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS -	Facility Indexing System
HAPs -	Hazardous Air Pollutants (CAA)
HSDB -	Hazardous Substances Data Bank
IDEA -	Integrated Data for Enforcement Analysis
LDR -	Land Disposal Restrictions (RCRA)
LEPCs -	Local Emergency Planning Committees
MACT -	Maximum Achievable Control Technology (CAA)
MCLGs -	Maximum Contaminant Level Goals
MCLs -	Maximum Contaminant Levels
MEK -	Methyl Ethyl Ketone
MSDSs -	Material Safety Data Sheets
NAAQS -	National Ambient Air Quality Standards (CAA)
NAFTA -	North American Free Trade Agreement
NAICS -	North American Industrial Classification System
NCDB -	National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP -	National Oil and Hazardous Substances Pollution Contingency Plan
NEIC -	National Enforcement Investigation Center
NESHAP -	National Emission Standards for Hazardous Air Pollutants
NO_2 -	Nitrogen Dioxide
NOV -	Notice of Violation
NO_x -	Nitrogen Oxides
NPDES -	National Pollution Discharge Elimination System (CWA)
NPL -	National Priorities List
NRC -	National Response Center
NSPS -	New Source Performance Standards (CAA)

OAR -	Office of Air and Radiation
OECA -	Office of Enforcement and Compliance Assurance
OPA -	Oil Pollution Act
OPPTS -	Office of Prevention, Pesticides, and Toxic Substances
OSHA -	Occupational Safety and Health Administration
OSW -	Office of Solid Waste
OSWER -	Office of Solid Waste and Emergency Response
OW -	Office of Water
P2 -	Pollution Prevention
PCS -	Permit Compliance System (CWA Database)
POTW -	Publicly Owned Treatments Works
RCRA -	Resource Conservation and Recovery Act
RCRIS -	RCRA Information System
SARA -	Superfund Amendments and Reauthorization Act
SDWA -	Safe Drinking Water Act
SEPs -	Supplementary Environmental Projects
SERCs -	State Emergency Response Commissions
SIC -	Standard Industrial Classification
SO_2 -	Sulfur Dioxide
SO_x -	Sulfur Oxides
SPI -	Society of Plastics Industry
TOC -	Total Organic Carbon
TRI -	Toxic Release Inventory
TRIS -	Toxic Release Inventory System
TCRIS -	Toxic Chemical Release Inventory System
TSCA -	Toxic Substances Control Act
TSS -	Total Suspended Solids
UIC -	Underground Injection Control (SDWA)
UST -	Underground Storage Tanks (RCRA)
VOCs -	Volatile Organic Compounds

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Integrated environmental policies based upon comprehensive analysis of air, water and land pollution are a logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education/ outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial “sector-based” approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was originally initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, states, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded to its current form. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing this system. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the industry sector described in this notebook approximates the national occurrence of facility types within the sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. The Office of Compliance encourages state and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume. If you are interested in assisting in the development of new notebooks for sectors not already covered, please contact the Office of Compliance at 202-564-2395.

II. INTRODUCTION TO THE PLASTIC RESIN AND MANMADE FIBER INDUSTRIES

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the plastic resin and manmade fiber industries. Facilities described within this document are described in terms of their Standard Industrial Classification (SIC) codes.

II.A. History of the Plastic Resin and Manmade Fiber Industries

The Origin of Plastic Resins

Plastics today are one of the most used materials in U.S. industrial and commercial life. Table 1 lists selected plastic resins and synthetic fibers by year of development and their principal uses. The first plastics were invented in the 1800s when people experimented to produce everyday objects out of alternative materials. The first plastic was developed in 1851 when hard rubber, or ebonite, was synthesized. This was the first material that involved a distinct chemical modification of a natural material.

Table 1: Introduction of Selected Plastic Resins and Manmade Fibers

Year	Material	Example
1868	Cellulose Nitrate	Eyeglass frames
1900	Viscose Rayon	Lining in clothing, curtains
1909	Phenol-Formaldehyde	Telephone Handset
1927	Cellulose Acetate	Toothbrushes, lacquers
1927	Polyvinyl Chloride	Wall Covering, pipe, siding
1936	Acrylic	Brush Backs, display signs
1938	Polystyrene	Housewares, toys
1939	Nylon	Fibers, films, gears
1942	Low Density Polyethylene	Packaging, squeeze bottles
	Unsaturated Polyester	Boat Hulls
1952	Polyethylene terephthalate	Clothing, fiberfill
1957	Polypropylene	Safety Helmets
1964	Polyimide	Bearings
1970	Thermoplastic Polyester	Electrical/Electronic Parts
1978	Linear Low Density Polyethylene	Extruded Film
1985	Liquid Crystal Polymers	Electrical/Electronic Parts

Source: This table has been adapted from *Facts and Figures of the U.S. Plastics Industry,* (1995 Edition) prepared annually by The Society of the Plastics Industry, Inc., Washington, DC. Please refer to that document for a more complete listing of plastic resin development.

The first plastics in the U.S. were developed while John Wesley Hyatt was experimenting to produce a billiard ball from materials other than ivory. In 1870, John and his brother Isaiah took out a patent for a process producing a horn-like material using cellulose nitrate and camphor.

Another important precursor to modern plastics was the development of formaldehyde resins. Early experiments to produce white chalkboards in Germany around the turn of the 20th century led to the development of formaldehyde resins. These resins were first produced by reacting casein (milk protein) with formaldehyde.

During the 1930s, the initial commercial development of today's major thermoplastics took place. These included polyvinyl chloride, low density polyethylene, polystyrene, and polymethyl methacrylate. Demand for plastics escalated during World War II when substitutes for scarce natural materials, like rubber, were in high demand. Large-scale production for synthetic rubbers triggered extensive research into polymer chemistry and new plastic materials.

In the 1940s, polypropylene and high density polyethylene were developed, and in 1978, linear low density polyethylene was developed. Large-scale production of these materials reduced their cost substantially, which allowed these new plastics materials to compete with traditional materials like wood and metal. The introduction of alloys and blends of various polymers has made it possible to tailor properties to fit certain performance requirements that a single resin could not provide. Demand for plastics has steadily increased, and now plastics are accepted as basic materials along with the more traditional materials in designs and engineering plans (SPI, 1995).

The Origin of Manmade Fibers

In 1664, Robert Hooke first suggested that manmade yarn could be produced. He speculated, in *Micrographia*, that synthetic fibers could be patterned after the excretion of silk by silkworms.

> And I have often thought, that probably there might be a way, found out, to make an artificial glutinous composition, much resembling, if not full as good, nay better, than the Excrement, or whatever other substances it be out of which, the Silk-worm winds and draws his clew. If such a composition were found, it were certainly an easier matter to find very quick ways of drawing it into small wires for use (Linton, 1966).

During the 19th century, scientists were busy making precursor solutions of the first manmade fibers, cellulosic fibers. In 1840, F. Gottlob Keller of Germany devised a technique for making pulp for paper by squeezing powdered wood taken from a grindstone. This enabled the future production of rayon and other cellulosic items. During that same year, Louis Schwabe, an English silk manufacturer, developed the first spinnerette through which a spinning solution could be extruded (Linton, 1966).

The first manmade fibers commercially manufactured in the U.S. were the cellulosics, led by rayon in 1910 and acetate in 1924. Cellulosic fibers are manufactured by first treating cellulose with chemicals, dissolving, and then regenerating the fibers. Cellulose is an abundant naturally occurring organic compound which makes up a large portion of the world's vegetable matter. Often referred to as artificial silk, rayon retained many of the same physical properties as cotton, such as high moisture absorption and subsequent swelling of the fibers. While cellulose acetate was first developed as a plastic in 1865, it was not successfully spun into a fiber until the 1920s. The first U.S. acetate production took place at the Cumberland, Maryland plant of British Celanese (now Hoechst Celanese).

In 1926, Du Pont Laboratories began a chemical research program that led to the advent of the synthetic, or noncellulosic, fiber industry. Unlike cellulosic fibers, synthetic fibers are wholly compounded from chemicals. The first synthetic fiber that Du Pont developed was Fiber 66. Now known as nylon-6,6, the fiber began widespread production for markets, such as nylon hosiery, in 1939. During World War II, nylon was used in producing parachutes, uniforms, and a host of other military equipment. Started primarily as a hosiery yarn, the use of nylon spread after the war into other applications like carpeting and woven fabrics.

Wrinkle-resistant and strong, the first polyester fiber, Terylene, was developed by a British scientist group called the Calico Printers Association. In 1946, Du Pont secured exclusive rights to produce this polyester fiber in the U.S. In December 1950, Du Pont announced plans to build its first plant at Kinston, North Carolina at a capacity of 36 million pounds a year and a cost of $40 million. Du Pont first unveiled the new fiber, named Dacron, at a famous press conference where it was displayed in a swimsuit that had been worn 67 days continuously without ironing. After polyester fibers were first produced commercially in the U.S. in 1953, the fibers were rapidly used to make men's suits, women's blouses, and men's shirts.

Since then, most technological advances in manmade fibers have occurred in synthetics, which now make up almost all of the U.S. production of manmade fibers. Synthetic fibers have many advantages to cellulosic fibers, such as controlled shrinkage, crease retention, and wrinkle resistance. Synthetic fibers have developed to seem more natural, softer, easier to care for, more lustrous, and more comfortable.

II.B. Introduction, Background, and Scope of the Notebook

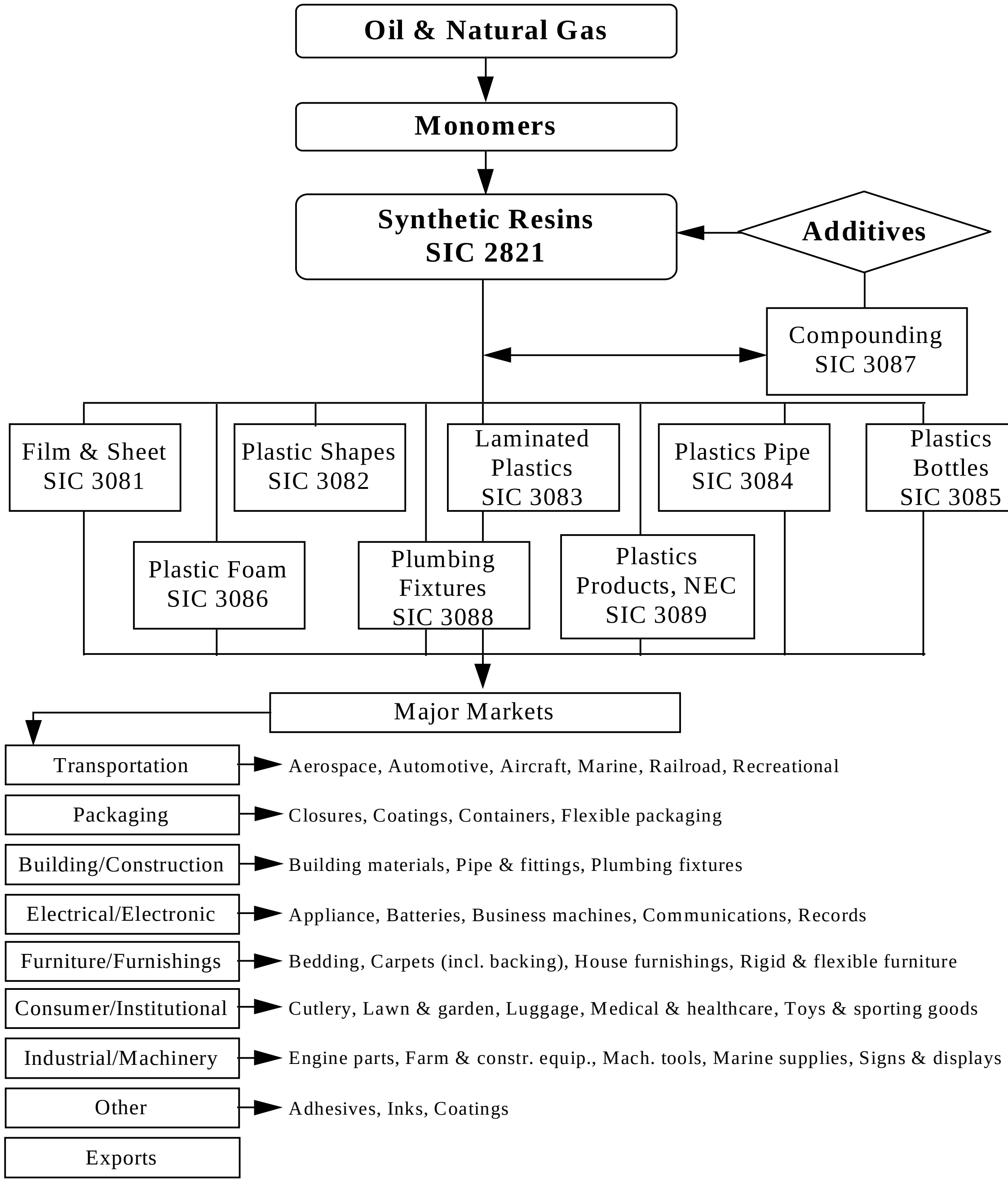
This notebook focuses on industrial processes and environmental issues relevant to the plastic resin and manmade fiber industries. These industries were chosen for this notebook because they have certain industrial processes in common, such as polymerization and extrusion. Both the plastic resin industry and the manmade fiber industry use refined petroleum products and synthetic organic chemicals to make selected polymers, which are large molecules made up of simple repeating chemical units. Facilities then process the polymers into plastic pellets and manmade fibers. Figures 1 and 2 provide an overview of the raw material inputs, products, and end uses of plastic resin and manmade fiber.

The plastic resin industry is classified by the Office of Management and Budget (OMB) as Plastics Materials and Resins, Standard Industrial Classification (SIC) code 2821. This classification corresponds to SIC codes which were established by the OMB to track the flow of goods and services within the economy. SIC 2821 corresponds to facilities that manufacture manmade resin, plastic materials, and nonvulcanizable elastomer. Table 2 lists products that are classified under SIC 2821. The manmade fiber industry is made up of two categories: Cellulosic Manmade Fibers, SIC 2823, and Organic Fibers, Noncellulosic, SIC 2824. Cellulosic Manmade Fibers includes facilities that make cellulosic fibers, like rayon and cellulose acetate. The category, Organic Fibers, Noncellulosic, covers facilities that make other manmade fiber, including nylon and polyester. Manmade fiber products that fall under SIC Codes 2823 and 2824 are listed in Table 3.

OMB is in the process of changing the SIC code system to a system based on similar production processes called the North American Industrial Classification System (NAICS). In the NAIC system, the manufacturing of plastic resins, synthetic rubber, artificial and synthetic fibers and filaments are all classified as NAIC 3252. Resin and synthetic rubber manufacturing are further classified as NAIC 32521, and artificial and synthetic fibers and filaments manufacturing are further classified as NAIC 32522.

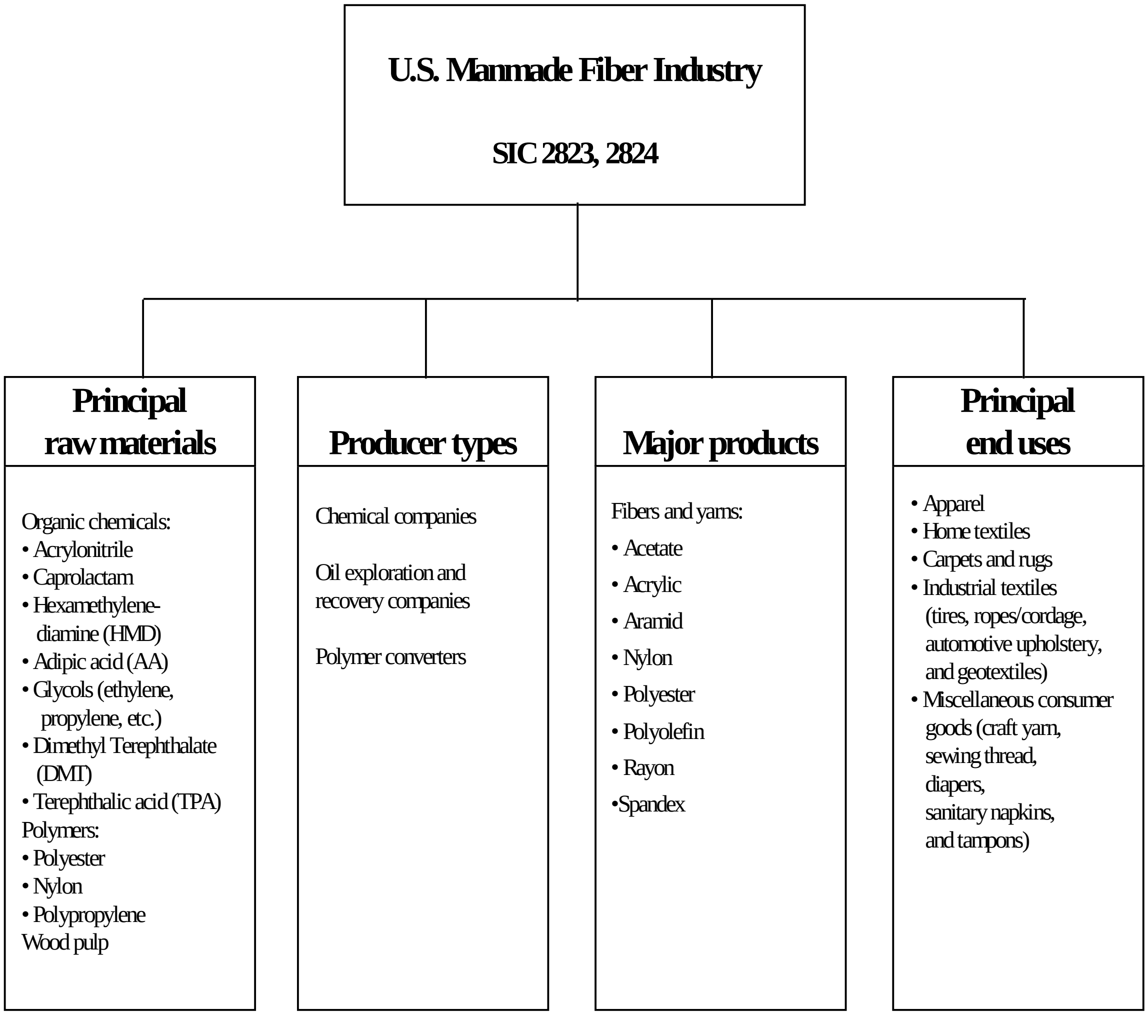
Only the manufacturing of plastic resin and manmade fiber is covered in this notebook. Companies that perform upstream processing, such as synthesizing reactants, and companies that perform downstream operations, such as processing plastic resins into plastic bottles or processing manmade fibers into fabric, are not covered in this notebook. For information on companies that manufacture organic chemicals (SIC 286) used in plastic resin and manmade fiber manufacture, refer to the Organic Chemicals Sector Notebook. For facilities that process resins into plastic products of different shapes, sizes, and physical properties, refer to the Rubber and Plastics Sector Notebook. Refer to the Textiles Sector Notebook for information on facilities that process manmade fibers into yarn and fabric. Note that compounding operations, where additives are incorporated into polymers, are not covered in this notebook.

Figure 1: Plastic Resins: From raw material to finished product



Source: *Facts and Figures of the U.S. Plastics Industry*, (1995 Edition) prepared annually by The Society of the Plastics Industry, Inc., Washington, DC.

Figure 2: U.S. Manmade Fiber Industry: Principal raw materials, producer types, major products, and principal end uses



U.S. Manmade Fiber Industry

SIC 2823, 2824

Principal raw materials

Organic chemicals:
- Acrylonitrile
- Caprolactam
- Hexamethylene-diamine (HMD)
- Adipic acid (AA)
- Glycols (ethylene, propylene, etc.)
- Dimethyl Terephthalate (DMT)
- Terephthalic acid (TPA)

Polymers:
- Polyester
- Nylon
- Polypropylene

Wood pulp

Producer types

Chemical companies

Oil exploration and recovery companies

Polymer converters

Major products

Fibers and yarns:
- Acetate
- Acrylic
- Aramid
- Nylon
- Polyester
- Polyolefin
- Rayon
- Spandex

Principal end uses

- Apparel
- Home textiles
- Carpets and rugs
- Industrial textiles (tires, ropes/cordage, automotive upholstery, and geotextiles)
- Miscellaneous consumer goods (craft yarn, sewing thread, diapers, sanitary napkins, and tampons)

Source: *Industry and Trade Summary: Manmade Fibers,* U.S. International Trade Commission, Washington, DC, 1995.

II.C. Characterization of the Plastic Resin and Manmade Fiber Industries

II.C.1. Product Characterization

Plastic Resins

The plastic resin industry produces resins which are further treated in plastics processing facilities and sold largely to the packaging, building and construction, and consumer markets. Specific product formulations and manufacturing parameters are often kept as trade secrets since the competitiveness of many companies depends on the ability to produce resins with different physical characteristics, such as strength, toughness, and flexibility (Brydson, 1995).

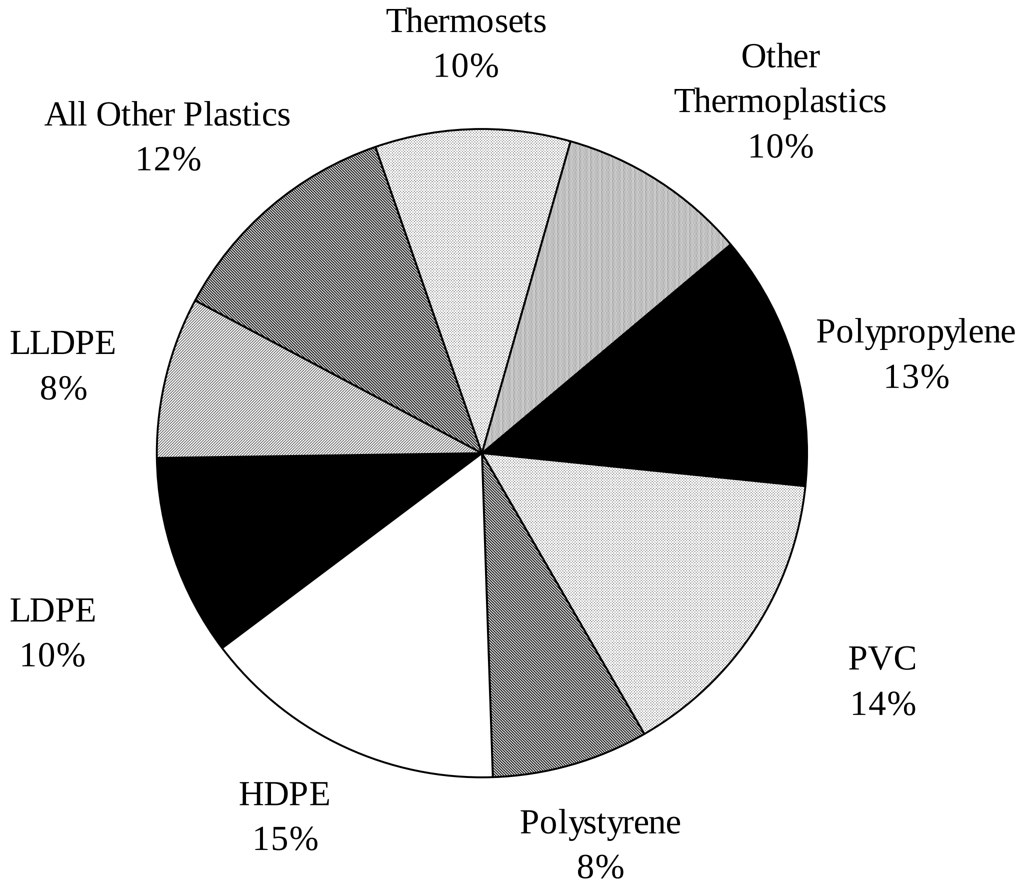
Plastic resins are typically broken down into two categories: thermoplastics and thermosets. Thermoplastic resins are resins that can be heated and molded into shapes repeatedly, while thermoset resins are resins that can be heated and molded only once. Thermoplastic resins dominate plastic resin sales and production. In 1994, thermoplastics made up about 90 percent, or

Table 2: Plastics Materials, Synthetic Resins, and Nonvulcanizable Elastomers (as listed under SIC 2821)

acetal resins
acetate, cellulose (plastics)
acrylic resins
acrylonitrile-butadiene-styrene resins
alcohol resins, polyvinyl
alkyd resins
allyl resins
butadiene copolymers, containing less than 50 percent butadiene
carbohydrate plastics
casein plastics
cellulose nitrate resins
cellulose propionate (plastics)
coal tar resins
condensation plastics
coumarone-indene resins
cresol resins
cresol-furfural resins
dicyandiamine resins
diisocyanate resins
elastomers, nonvulcanizable (plastics)
epichlorohydrin bisphenol
epichlorohydrin diphenol
epoxy resins
ester gum
ethyl cellulose plastics
ethylene-vinyl acetate resins
fluorohydrocarbon resins
ion exchange resins
ionomer resins
isobutylene polymers
lignin plastics
melamine resins
methyl acrylate resins
methyl cellulose plastics
methyl methacrylate resins molding compounds, plastics
nitrocellulose plastics (pyroxylin)
nylon resins
petroleum polymer resins
phenol-furfural resins
phenolic resins
phenoxy resins
phthalic alkyd resins
phthalic anhydride resins
polyacrylonitrile resins
polyamide resins
polycarbonate resins
polyesters
polyethylene resins
polyhexamethylenediamine adipamide resins
polyisbutylenes
polymerization plastics, except fibers
polypropylene resins
polystyrene resins
polyurethane resins
polyvinyl chloride resins
polyvinyl halide resins
polyvinyl resins
protein plastics
pyroxylin
resins, synthetic
rosin modified resins
silicone fluid solution (fluid for sonar transducers)
silicone resins
soybean plastics
styrene resins
styrene-acrylonitrile resins
tar acid resins
urea resins
vinyl resins

Source: *Standard Industrial Classification Manual*, Office of Management and Budget, 1987.

Figure 3: Percentage Distribution of Plastic Resins: Sales and Captive Use, 1994



Source: SPI Committee on Resin Statistics as compiled by Association Services Group, LLC, 1995.

63.3 billion pounds, of plastic resin production by dry weight and accounted for 82 percent, or $27.2 billion dollars of the total value of shipments for plastic resin (SPI, 1995). Commercially important thermoplastics include polyethylene (all forms), polyvinyl chloride, polypropylene, and polystyrene and are shown in Figure 3. These four thermoplastics make up over 69 percent of plastic resin sales. These thermoplastics are considered general purpose, or commodity plastics since they are usually manufactured in large quantities using well established technology and are typically geared towards a small number of high volume users.

In 1994, thermosets accounted for about 10 percent, or 7.5 billion pounds, of plastic resin production by dry weight and 17 percent of the value of shipments for the plastic resin industry. The leading thermosets in sales were phenolic resins, urea resins, and unsaturated polyester resins. Specialty plastic resins, which often include thermosets, are produced on a customized basis in small production runs and typically involve significant research and development costs (Department of Commerce, 1994).

Manmade Fibers

Manmade fibers are produced primarily for use as raw materials for the textile industry. In 1993, about 34 percent of manmade fibers were sold to the carpets and rugs market, 28 percent was sold to the industrial and miscellaneous consumer products market, and 25 percent was sold to the apparel market (International Trade Commission, 1995). The increasing use of manmade fibers in a variety of markets has enabled manmade fibers to account for 57% of all fibers, natural and manmade, consumed in the U.S. Figure 4 illustrates manmade fiber consumption with respect to other fibers and shows the leading manmade fibers. The price and quality of manmade fibers are important determinants in the quality and competitiveness of apparel, home textiles, and industrial and consumer products (Department of Commerce, 1994; AFMA, 1997).

There are two main types of manmade fibers: noncellulosic (SIC 2824) and cellulosic (SIC 2823). Noncellulosic, or synthetic, fibers consist of fibers that are formed by the polymerization and subsequent fiber formation of synthetic organic chemicals and refined petroleum products.

Table 3: Manmade Fibers (as listed by SIC code)

Cellulosics (SIC 2823)	Noncellulosics (SIC 2824)
Acetate fibers Cellulose acetate monofilament, yarn, staple, or tow Cellulose fibers, manmade Cigarette tow, cellulosic fiber Cuprammonium fibers Fibers, rayon Horsehair, artificial: rayon Nitrocellulose fibers Rayon primary products: fibers, straw, strips, and yarn Rayon yarn, made in chemical plants Regenerated cellulose fibers Textured yarns and fibers, cellulosic: made in chemical plants Triacetate fibers Viscose fibers, bands, strips, and yarn Yarn, cellulosic: made in chemical plants	Acrylic fibers Acrylonitrile fibers Anidex fibers Casein fibers Elastomeric fibers Fibers, manmade: except cellulosic Fluorocarbon fibers Horsehair, artificial: nylon Linear esters fibers Modacrylic fibers Nylon fibers and bristles Olefin fibers Organic fibers, synthetic: except cellulosic Polyester, fibers Polyvinyl ester fibers Polyvinylidene chloride fibers Protein fibers Saran fibers Soybean fibers (manmade textile materials) Textured fibers and yarns, noncellulosic: made in chemical plants Vinyl fibers Vinylidene chloride fibers Zein fibers

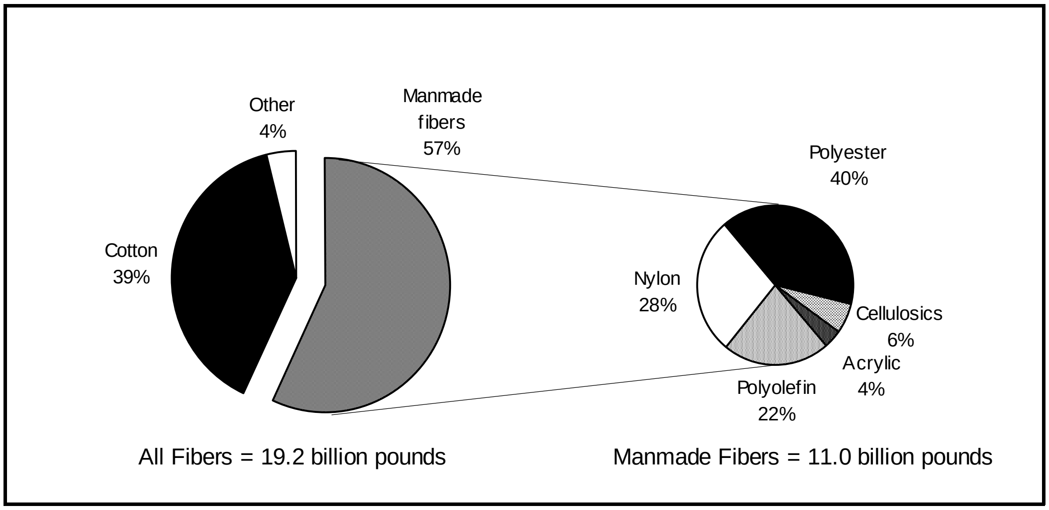
Source: *Standard Industrial Classification Manual*, Office of Management and Budget, 1987.

In 1992, noncellulosic fibers were responsible for 88 percent, or $11.1 billion dollars, of the total value of shipments for the industry. Industry statistics from the Fiber Economics Bureau reported $10.6 billion as the value of shipments for the noncellulosic fiber industry for 1996 (ATMI, 1997b). Major noncellulosic fibers include nylons, polyesters, polyolefins, and acrylics. Polyolefins include polyethylene and polypropylene. Figure 4 shows a breakdown of U.S. fiber consumption by material.

Most cellulosic fibers are formed by the conversion of the cellulose into a soluble derivative, followed by reforming as filaments. Cellulose is an abundant naturally occurring organic compound which makes up one-third of the world's vegetable matter. In some cases, the cellulose derivative is retained in the new fiber (e.g., cellulose acetate), and sometimes the cellulose derivative is degraded and cellulose is regenerated (e.g., rayon). Lyocel is a new class of cellulosic fibers made by direct solution of cellulose (and not a derivative) in organic solvents (e.g., amine oxides) and evaporation of the solvent to form the new filaments. In 1992, the cellulosic fiber industry had a value of shipments of $1.7 billion according to the U.S. Department of Commerce. This is compared to $850 million for the 1996 value of shipments for the cellulosic fiber industry as reported by the Fiber Economics Bureau

(ATMI, 1997b). Commercially important cellulosic fibers include rayon and cellulose acetate.

Figure 4: U.S. Fiber Consumption: Percentage distribution by principal fibers, 1993



Source: *Industry and Trade Summary: Manmade Fibers,* U.S. International Trade Commission, Washington, DC, 1995.

II.C.2. Industry Characterization

Petroleum refining and synthetic organic chemical manufacturing facilities produce the raw material feedstocks used to make plastic resin and manmade fibers (except cellulosic fibers). In some cases, these facilities also make plastic resins and manmade fibers. Because of integration between the industries, the development of the petrochemical industry has contributed strongly to the growth of the plastic resin and manmade fiber industries.

Plastic Resin Industry

In 1992, the Department of Commerce reported 240 plastic resin companies and 449 establishments in 1992. The value of shipments for the industry was $31.3 billion dollars. The largest four companies accounted for 24 percent of the value of shipments, and the largest 20 companies accounted for 63 percent. Table 4 summarizes revenue and company size statistics for the industry.

Table 4: Size and Revenue for the Plastic Resin and Manmade Fiber Industries

Item	Plastic Resins	Manmade Fibers	
	(SIC 2821)	Cellulosic (SIC 2823)	Noncellulosic (SIC 2824)
Establishments (no.)	449[c]	7[d]	71[e]
Companies (no.)[a]	240	5	42
Values of Shipments (millions of dollars)[b]	31,303.9	1,748.1	11,113.7
Total Employees (000's)	60.4	11.0	44.4

Source: *1992 Census of Manufactures, Industry Series: Plastics Materials, Synthetic Rubber, and Manmade Fibers,* US Department of Commerce, Bureau of the Census, June 1995.
Note: 1992 Census of Manufacturers data are the most recent available. Changes in the number of facilities, location, and employment figures since 1992 are not reflected in these data.

[a] Defined as a business organization consisting of one establishment or more under common ownership or control.
[b] Value of all products and services sold by establishments in the plastics and manmade fibers industries.
[c] Dun and Bradstreet information reports 1553 facilities indicating SIC 2821 as one of their top five SIC codes.
[d] Dun and Bradstreet information reports 29 facilities indicating SIC 2823 as one of their top five SIC codes.
[e] Dun and Bradstreet information reports 152 facilities indicating SIC 2824 as one of their top five SIC codes.

Employment for the industry increased from 54,700 employees in 1982 to 60,400 employees in 1992. Most employees, about 60 percent, are considered production workers. Although a small number of large, integrated companies dominate sales and production, the majority of individual establishments tend to be small. About 71 percent of establishments have less than 100 employees. In terms of geographic distribution, four states - Texas, Illinois, Michigan, and Pennsylvania - accounted for about 40 percent of industry employment and 23 percent of establishments in 1992. Employment and geographic distribution figures appear in Table 5.

Table 5: Establishment Size and Geographic Distribution of the Plastic Resin and Manmade Fiber Industries

Item	Plastic Resins	Manmade Fibers	
	(SIC 2821)	Cellulosic (SIC 2823)	Noncellulosic (SIC 2824)
% of establishments with less than 20 employees	24	0	4.2
% of establishments with less than 100 employees	71	14	25
Major states in which industry is concentrated, based on employment	TX, PA, MI, LA	TN, SC, VA, AL	SC, NC, VA, TN
% of industry's employment attributable to four major states	40	100	77

Source: *1992 Census of Manufactures, Industry Series: Plastics Materials, Synthetic Rubber, and Manmade Fibers,* US Department of Commerce, Bureau of the Census, June 1995.
Note: 1992 Census of Manufacturers data are the most recent available. Changes in the number of facilities, location, and employment figures since 1992 are not reflected in these data.

Manmade Fibers

The manmade fiber industry is dominated by a small number of large plants that manufacture or purchase basic organic chemicals and then synthesize them into fiber-forming polymers. These larger fiber producers often manufacture polymer for internal use and to sell to smaller firms which only process purchased polymers into fibers. The dominant firms tend to fall into one of the following categories: 1) large, multi-product chemical companies; 2) highly integrated petrochemical companies, or 3) widely diversified industrial firms with large chemicals- or materials-related segments (EPA, 1995). Few firms process fibers into end-use consumer products (International Trade Commission, 1995).

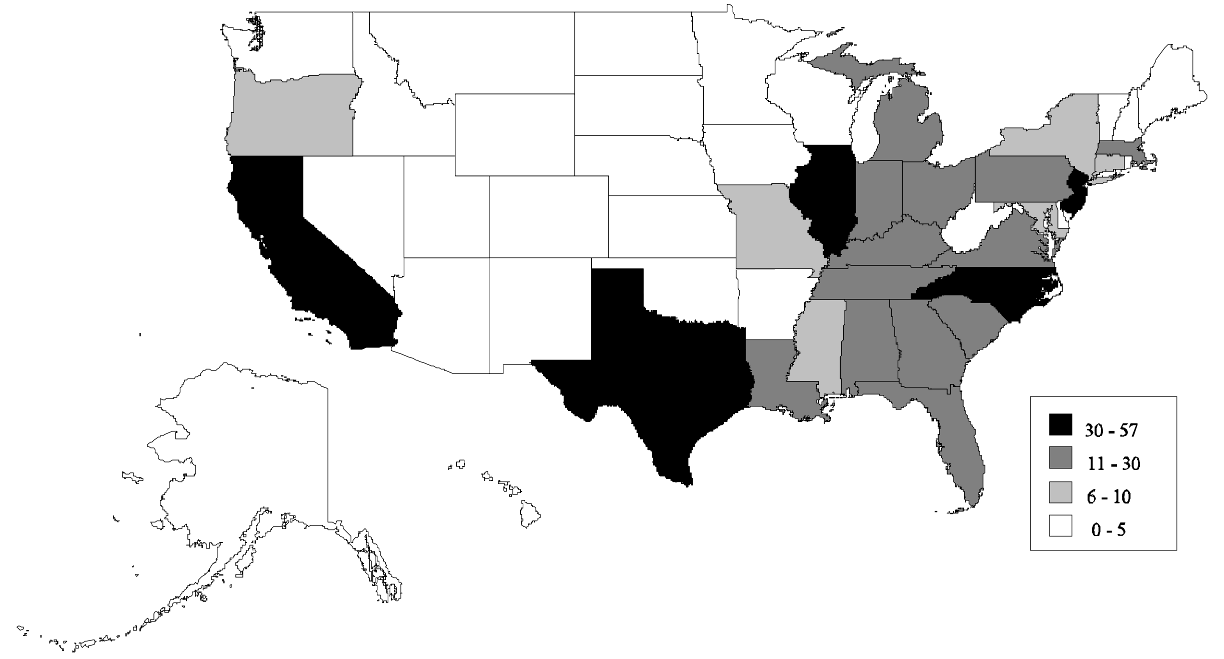
In 1992, the Department of Commerce reported 5 companies involved in cellulosic fiber manufacture and 42 companies involved in noncellulosic fiber manufacture. The value of shipments for the industry was $12.8 billion dollars in 1992. Noncellulosic fiber manufacturing accounted for 88 percent of the value of shipments for the industry. Table 4 highlights industry statistics, including value of shipments. Industry statistics reported by the Fiber Economics Bureau indicated that the value of shipments for the manmade fiber industry was $11.5 billion in 1996, with noncellulosic fiber manufacturing accounting for 93 percent of the value of shipments for the industry (ATMI, 1997b).

The U.S. manmade fiber industry is highly concentrated. According to the U.S. International Trade Commission, nine firms accounted for roughly 70 percent of U.S. production capacity in 1994, while the remaining 30 percent was held by about 85 other firms. The number of firms and level of industry concentration varies by fiber type. In 1994, only two firms produced acrylic and three produced rayon. Although roughly 30 produced polyester and nylon and 60 produced polyolefins, seven producers accounted for about 85 percent of total U.S. nylon and polyester capacity, and three accounted for over one-half of polyolefin capacity. Recently, the number of polyolefin producers has increased to meet increasing demand and availability of low-volume production equipment.

Since the mid-1980s, the manmade fiber industry has greatly consolidated and reorganized. Facilities have tried to expand and diversify by purchasing existing plants, enlarging capacity, or starting up new capacity in other parts of the world. In an effort to improve profit margins and market share, several companies have sold their smaller fiber businesses in order to concentrate on their strongest fiber operations (International Trade Commission, 1995).

While numbers of companies and establishments remained steady from 1982 to 1992, employment for the industry dramatically decreased from 60,200 employees to 44,400 employees. Most employees, about 75 percent, are considered production workers. Roughly 25 percent of establishments have less than 100 employees. Most of the manmade fiber facilities are located in the Southeast, where the main customer, the textile mill industry, is concentrated. Three states - Tennessee, South Carolina, and Virginia - accounted for about 62 percent of industry employment in 1992. Table 5 shows employment data for the industry. Figure 5 highlights those states which have the largest number of plastic resin and manmade fiber manufacturing facilities. Note that industry statistics from the Fiber Economics Bureau indicated that there were 42,000 employees for the manmade fiber industry in 1996. About 39,000 employees were employed by the noncellulosic fiber industry, and 3,000 employees were employed by the cellulosic fiber industry (ATMI, 1997b).

Figure 5: Geographic Distribution of Plastic Resin (SIC 2821) and Manmade Fiber (SIC 2823, 2824) Manufacturing Facilities



Source: *1992 Census of Manufactures, Industry Series: Plastics Materials, Synthetic Rubber, and Manmade Fibers,* US Department of Commerce, Bureau of the Census, June 1995.

Leading Companies for the Plastic Resin and Manmade Fiber Industries

Table 6 shows the top U.S. companies with plastic resin and manmade fiber operations, according to the 1997 Dun & Bradstreet's *Million Dollar Directory*. This directory compiles financial data on U.S. companies including those operating within the plastic resin and manmade fiber industries. Dun and Bradstreet's ranks U.S. companies, whether they are a parent company, subsidiary or division, by sales volume within their assigned 4-digit SIC code. Readers should note that companies are assigned a 4-digit SIC code that most closely resembles their principal industry and that sales figures include total company sales, including subsidiaries and operations not related to plastic resins and manmade fibers. Additional sources of company specific financial information include Standard & Poor's *Stock Report Services,* Moody's Manuals, and annual reports.

Table 6: Top U.S. Companies in the Plastic Resin and Manmade Fiber Industries

Plastics Resins (SIC 2821)				Manmade Fibers, Cellulosic and Noncellulosic (SIC 2823, 2824)			
Rank	Company	1996 Sales (millions of dollars)	4-digit SIC code	Rank	Company	1996 Sales (millions of dollars)	4-digit SIC code
1	Huntsman Chemical Corp. Salt Lake City, UT	1,472	2821	1	Monsanto Company Saint Louis, MO	8,962	2824
2	The Geon Company Avon Lake, OH	1,268	2821	2	Hoechst Celanese Corp. Bridgewater, NJ	7,395	2824, 2823
3	Albemarle Corp. Baton Rouge, LA	1,244	2821	3	Wellman Inc. Shrewsbury, NJ	1,109	2824
4	A Schulman, Inc. Akron, OH	1,027	2821	4	Nan-Ya Plastics Corp. Livingston, NJ	365	2824
5	Aristech Chemical Corp. Pittsburgh, PA	945	2821	5	Cookson Fibers Inc. Bristol, VA	175	2824
6	Condea Vista Company Houston, TX	882	2821	6	Du Pont EI de Nemours and Co. Camden, SC	175	2824
7	Carlisle Companies Inc. Syracuse, NY	823	2821	7	Allied Signal Inc. Chester, VA	160	2824
8	Novacor Chemicals Inc. Leominster, MA	756	2821	8	Amoco Performance Products Alpharetta, GA	124	2824
9	Amoco Fabrics and Fibers Co. Atlanta, GA	721	2821	9	BASF Corp. Anderson, SC	123	2824
10	Shintech Inc. Houston, TX	700	2821	10	Lenzing Fibers Corp. Lowland, TN	120	2823

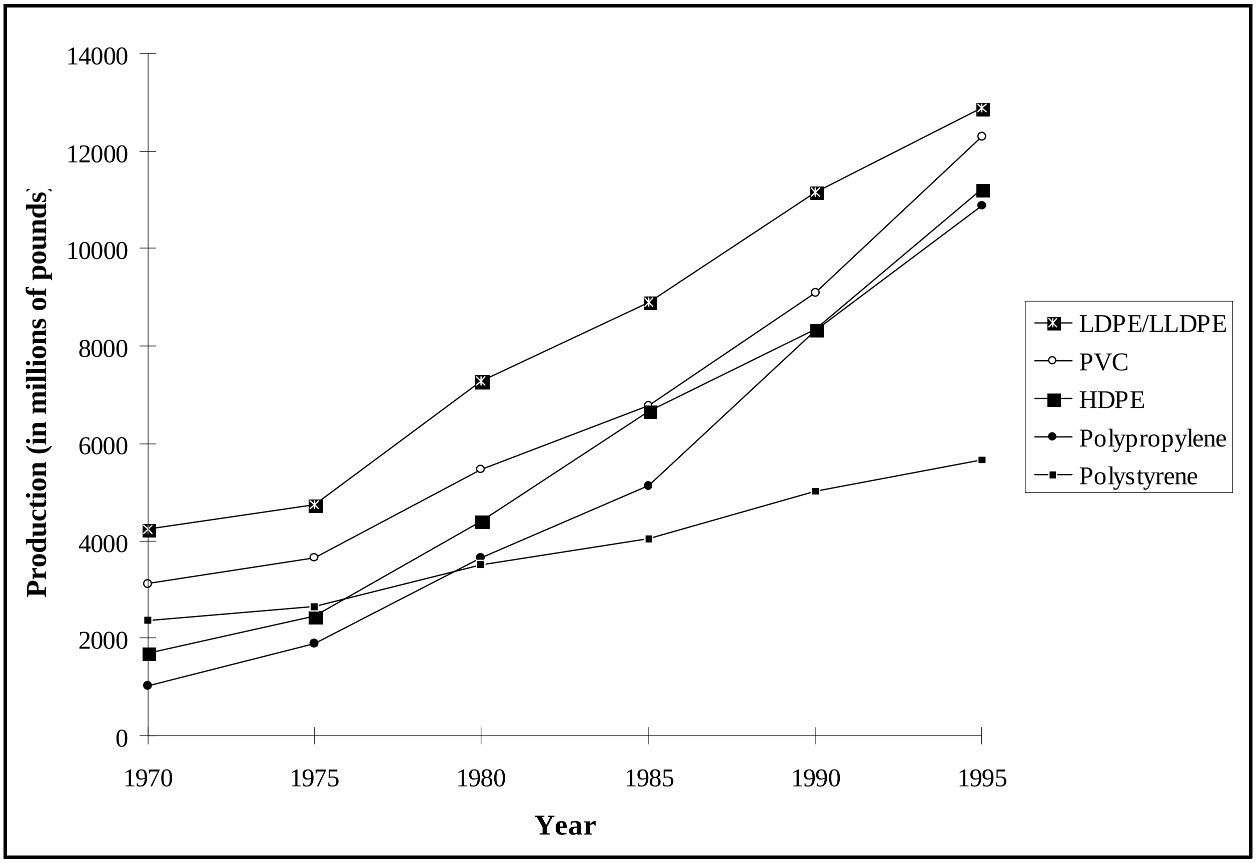
Source: Dun & Bradstreet’s *Million Dollar Directory*, 1997.

II.C.3. Economic Outlook

Plastic Resin Industry

The U.S. is a major exporter of plastics. Figure 6 shows trends in U.S. production of selected plastic resins for the past 25 years. Trade with Canada and Mexico accounted for about one-third of total U.S. plastics exports in 1992. Chronic worldwide overcapacity in plastics has continued to depress and slow growth rates. Since the industry is mature, the plastic resin industry was greatly affected by the depression in the global economy in the early 1990s. Plant closures and capacity cutbacks were partly successful in preventing further price declines during this period (Department of Commerce, 1994). From 1993 to 1998, global consumption of plastic resins is projected to increase 4 percent annually.

Figure 6: U.S. Production of Selected Resins, in millions of pounds



Source: U.S. Tariff Commission (for 1970 data); SPI Committee on Resin Statistics as compiled by the Association Services Group (for 1975-1995 data).

As the global economy rebounds from the recession of the early 1990s, growth is expected to be stimulated by upswings in the packaging, building, and construction markets. This growth is expected to occur primarily in countries along the Pacific Rim and in Latin America as these countries continue rapid industrialization, increased consumer spending, and substitution of other materials by plastics. Plastic resin production capacity is also increasing in these regions in response to the high demand.

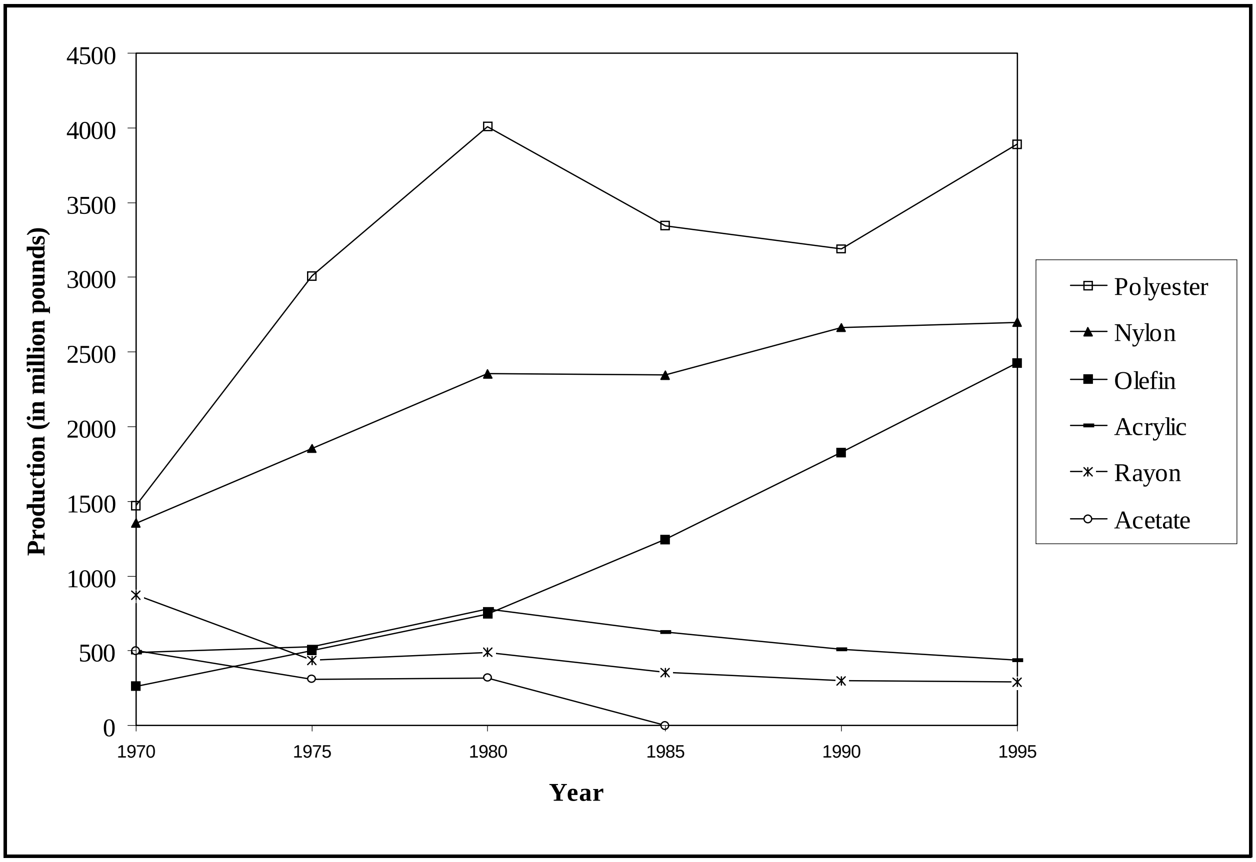
The U.S. represents the largest single plastics market in the world, based on factors such as large domestic markets, readily available capital and technology, and relatively inexpensive raw material and energy costs. In the U.S., consumption and production are not experiencing high growth rates. This is, in part, the high level of substitution of traditional materials (like wood or metal) for plastics currently in place and the fact that the commodity plastics market is well-developed. As a result, major plastic resin manufacturers are merging and swapping production lines. Large multinational chemical companies are arranging licensing agreements as a way to tap into foreign markets. The plastic resin industry is also focusing on upgrading its production to higher-value-added and specialty resins tailored for niche markets. Research on plastic resins has started to focus on refining existing resins through blends and alloys and also improving catalyst technology to produce new grades of polymers. For instance, several companies are planning to produce specialty grades of polypropylene using new metallocene catalysts (McGraw-Hill, 1994).

Advances in plastic resin properties is expected to spur growth and foster the development of new end-use markets. For instance, the cost, low weight, and versatility advantages of newer plastic resins will make them more attractive in the auto assembly industries. Environmental regulations and concerns have an impact on many facets of the plastic resin industry. The demand for recycled and biodegradable plastic resins is expected to continue and drive development of more economical recycling technologies (Department of Commerce, 1994).

Manmade Fiber Industry

One-half of all fibers consumed are manmade. In 1992, global demand for manmade fibers increased by 3 percent. In the past, developed countries have dominated the manmade fiber industry. Between 1980 and 1993, the developing countries of Asia led by China, Taiwan, and Korea have accounted for most of the growth in manmade fiber production. During that period, these countries increased their aggregate share of world production from 15 to 42 percent. Developing countries are expected to continue increasing production and capability as their consumption and demand levels increase.

Figure 7: Manmade Fiber Production Data for Selected Fibers 1970-1995



Source: Fiber Economics Bureau, Inc., 1996.

On the other hand, production in the U.S. has remained relatively stagnant. Figure 7 shows U.S. production trends from 1970 to 1995 for selected cellulosic and noncellulosic fibers. Figure 7 shows that production of polyester and nylon fibers was significantly greater than the production of cellulosic fibers, such as acetate and rayon. Note that numbers for acetate production and rayon yarn production were not available for 1985 to the present since the industries have shrunk to only a few companies. As a result, data do not appear for acetate from 1985 to 1995, and data for rayon represent rayon yarn and staple production for the period from 1970 to 1980 and rayon staple production only from 1985 to 1995.

In 1993, U.S. manmade fiber imports rose 11 percent due to increases in noncellulosic fiber imports. U.S. exports decreased 1 percent in 1993. Meanwhile, domestic shipments of noncellulosic fibers, such as nylon and polyester, increased by 2 percent. U.S. shipments of cellulosic fibers increased 14 percent to $1.8 billion primarily due to growth in rayon staple fiber demand and production. Rayon production has recently undergone extensive renovation to achieve additional environmental benefits and become more competitive with noncellulosic fibers (U.S. Department of Commerce, 1994).

Barriers to entry into the manmade fiber industry are considerable, since production is highly capital intensive and requires significant technical expertise and economies of scale. Since the mid-1980s, the manmade fiber industry has undergone extensive consolidation and reorganization. During 1989-1993, several fiber companies sold off smaller fiber operations in order to concentrate on their strongest fiber operations, which produced higher value-added products. In addition, large companies, which traditionally produce commodity fibers, have looked to the sale of specialty fibers (e.g. heat-resistant or high-strength fibers) as a way to increase overall profits (Department of Commerce, 1994). Back-integration of the carpet industry, has resulted in the establishment of many new, small fiber producers (AFMA, 1997).

Because the manmade fiber industry is highly developed, the industry's most promising growth is expected to occur through these improvements in fiber characteristics. For instance, the *U.S. Industrial Outlook* states that microfiber yarns and fabrics have enabled manmade fibers to compete more directly with luxury fibers, such as silk and cashmere, in fashion apparel. Fabrics made with these finer fibers are usually more comfortable and softer than other fibers and can be used in a variety of finished apparel. The industry also predicts that lyocel, a new fiber which can be produced with particular environmental benefits, will contribute to cellulosic fiber growth (Department of Commerce, 1994). In addition, the industrial and technical products market is expected to continue to be dominated by manmade fibers (AFMA, 1997). Geotextiles, or manmade fibers used to reinforce civil engineering projects, biological filters, and military uses are end-uses that may create more opportunities for manmade fiber products.

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III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes used within the plastic resin and manmade fiber industries, including the materials and equipment used, and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the interrelationship between the industrial process and the topics described in subsequent sections of this profile -- pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes may be produced in the process. The first subsection, III.A., discusses polymerization processes common to the plastics resins and manmade fibers industries. The following subsection, III.B., discusses subsequent processing steps specific to manmade fiber manufacture. This section concludes with a description of the potential fate (via air, water, and soil pathways) of process-specific waste products.

III.A. Industrial Processes in the Plastic Resins and Manmade Fibers Industries

The plastic resin and manmade fiber industries both use and manufacture polymers. Polymers are large organic molecules (molecular weight ~10^4-10^7) that consist of small repeating molecules. Polymers used in the plastic resin and manmade fiber industries either occur naturally, such as cellulose, or are formed during polymerization when bond-forming reactions cause small repeating molecules to join together. Polymers are typically made from one type of simple chemical unit, or monomer. However, sometimes another compound, or comonomer, is used with the monomer to make a copolymer. Comonomers can be used to make copolymers with random chemical structures, called random copolymers, or organized chemical structures, called impact copolymers.

Polymers are central to plastic resin and manmade fiber manufacture. Many grades of different polymers are produced, each with different physical characteristics such as strength and ease of flow when melted. These different physical characteristics are achieved by changing operating parameters or by using different polymerization processes to change properties, such as polymer density and molecular weight. Polymers which have been dried and shaped into pellets are called plastic resins. These resins are further processed at plastics processing facilities which create plastic products of different shapes, sizes, and physical properties. (Refer to the EPA Rubber and Plastics

Sector Notebook for more information on plastics processing.) Polymers can also be used to make synthetic fibers, which are commonly used to make manmade textile products. Some synthetic fiber manufacturers synthesize polymers on-site, while some purchase plastic resins for use in their fiber operations. Fiber formation processes, including the use of natural polymers to make cellulosic fibers, and particular textile fiber operations will be covered later in this section.

There are several steps that are important to polymerization. First, reactants are purified prior to polymerization. During polymerization, catalysts, heat, pressure, and reaction time are all optimized to maximize polymer conversion and speed the reaction. The polymer is often then separated from the reaction mass through a series of separation and drying steps. (Exceptions to this are acrylic polymers, (AFMA, 1997b).) Finally, the polymer is extruded and pelletized for packaging and shipment. Various supporting steps are important to note because of their potential effect on the environment. These supporting steps include unloading and storage of chemicals and equipment cleaning. Note that methods used to recover raw materials and control pollution are covered in Section III.D. Although there are thousands of types of resins and fibers that may be produced during polymerization, the basic industrial processes are similar. These processes are summarized below:

1) preparation of reactants
2) polymerization
3) polymer recovery
4) polymer extrusion
5) supporting operations

This section briefly describes the processes involved in the manufacture of plastic resins and noncellulosic manmade fibers. These processes vary by facility. For instance, some manufacturers purchase reactants in pure form, while others may synthesize reactants on-site. Other facilities compound or incorporate additives into the finished polymers. Facilities that specialize primarily in compounding polymers are listed under SIC Code 3087 and are not covered in this notebook.

III.A.1. Preparing Reactants

Many chemicals can be used to make polymers. The most important chemicals are monomers, catalysts, and solvents. Monomers are the basic building blocks of polymers. They can be simple in structure (e.g. ethylene CH_2CH_2) or complex (e.g. ester of a dihydric alcohol and terephthalic acid - $HOCH_2CH_2OCOC_6H_4COOH$). Catalysts are chemicals used to speed up or initiate the polymerization reaction. Common catalysts include Ziegler catalysts (titanium chloride and aluminum alkyl compounds), chromium-containing compounds, and organic peroxides. Details of commercially-used catalysts are highly guarded secrets since small differences in catalyst preparation can lead to huge differences in polymerization costs and polymer properties (Kroschwitz, 1986). Solvents are sometimes used to dissolve or dilute the monomer or reactants. The use of solvents facilitates polymer transport through the plant, increases heat dissipation in the reactor, and promotes uniform mixing in the reactor. Other chemicals used in polymerization include suspending and emulsifying agents which disperse monomer in solution.

Reactants, particularly monomers, must be sufficiently pure before they can be charged to the polymerization reactor. Trace amounts of contaminants in monomer, such as water, oxygen, and sulfur compounds in part per million quantities, can impede polymerization and decrease product yield. Most monomers and solvents can be purchased in sufficient purity for polymerization, however, sometimes reactants must be purified to remove contaminants. Facilities may use different purification methods, such as distillation or selective adsorption, to increase monomer purity. Some companies manufacture monomer and other reactants at different chemical facilities and transport them to plastic resin and manmade fiber facilities where the chemicals can be further processed to a sufficient purity level. For example, the nylon-6 monomer, E-caprolactam, is often made on-site, prepared, and charged to the polymerization reactors.

In addition to purification steps, reactants are often diluted, premixed, or otherwise treated before being sent to the reactors. The preparation and charging of reactants often varies by polymerization method. For instance, Ziegler-type catalysts are usually diluted with dry inert solvent and premixed before injection into the polymerization reactor. For suspension and emulsion polymerization, the catalyst, emulsifier, suspending agents, modifier, and activator are dissolved in water and adjusted to the proper concentration before polymerization. In some continuous processes, two agitated make-up tanks are often run in parallel so that catalysts can simultaneously be mixed and charged to the polymerization vessel from one tank while a fresh solution is prepared in the other.

III.A.2. Polymerization

Polymerization is the major process involved in the synthesis of plastic resins and manmade fibers. Two types of polymerization, addition polymerization and polycondensation, are commonly used to make plastic resins and manmade fibers. These two methods use different chemical steps to make polymers.(McKetta, 1992) In addition polymerization, monomer is polymerized using a free radical catalyst (a highly reactive molecule having one or more unpaired electrons) or a coordination catalyst (e.g. Ziegler type) to activate the monomer molecules and trigger polymerization reactions. With polycondensation reactions, typically two or more reactants are first combined in a prepolymerizer reactor to form a monomer before polymerization. During polymerization, two reacting monomers are linked together in condensation reactions where water molecules are split off of the reacting monomers (Lewis, 1993). In polycondensation reactions, water is typically removed by vacuum to speed the reaction. Because addition polymerization processes are widely used to make plastic resins and manmade fibers, this section focuses primarily on addition polymerization processes.

Continuous versus Batch Processes

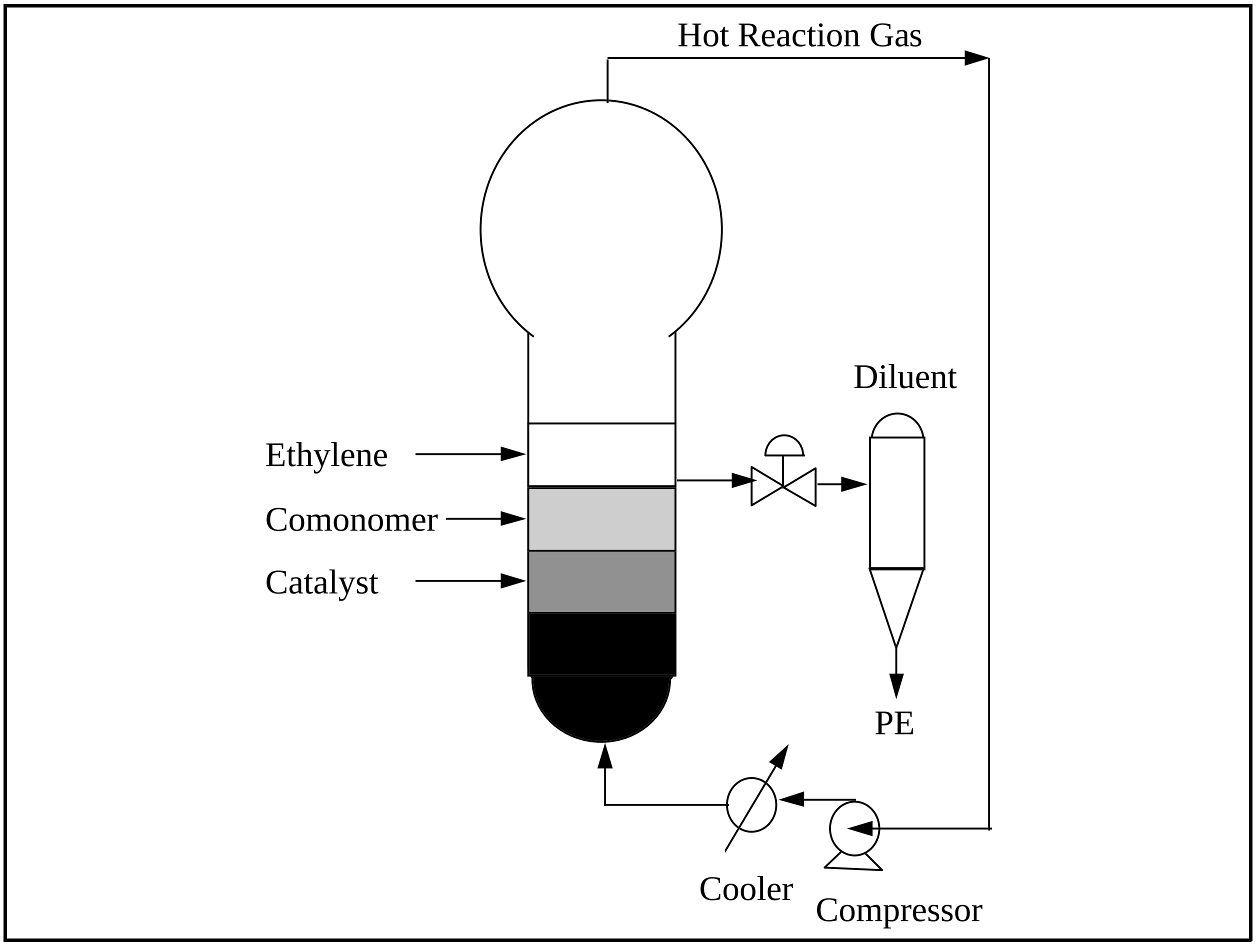
Chemical modifiers are often injected into the reactor to give polymers specific characteristics. Temperature and pressure have a profound effect on polymerization processes and may be varied in order to control conversion, reaction rate and end properties of the polymer produced. Addition polymerization is a highly exothermic reaction, and reactor conditions are tightly monitored to control heat production and reaction stability. Continuous processes are typically used for large-volume, or commodity, polymerizations, while batch or semibatch processes are used for low-volume, or specialty, polymerizations. In continuous processes, the feed is continuously charged into the reactor and effluent is continuously removed. In batch processes, all reagents are added to the reactor and remain in the reactor for the same amount of time. In semibatch processes, some reactants are added at intervals while some byproducts are removed (Kroschwitz, 1986).

Types of Reactors

Two main reactor types are used in polymerization: stirred tank reactors and linear-flow reactors. Stirred-tank reactors (or autoclaves) are usually made of stainless steel and range in size from 1,400-2,800 ft^3 (40-80 m^3), although some reactors as large as 7,000 ft^3 (200 m^3) are in commercial use. The reactors usually consist of a jacketed cylindrical vessel with an agitator and have highly polished stainless steel linings which are noncorrosive and minimize polymer deposits left on walls (Kroschwitz, 1986). Stirred-tank reactors also have thick walls to withstand high pressures and support low heat transfer capacity. Temperature is controlled by heat transfer to the jacket, internal cooling coils, water cooled impellers, external reflux condensers, and external heat exchangers. Typical temperatures range from 160- 570°F (70-300°C), and conversion rates ranges from a low of 2 percent to 85 percent (McKetta, 1992). Due to their versatility, stirred-tank reactors operated for batch processing are used to produce a large portion of polymers in the United States. Often two or more reactors of similar size are used in series to increase monomer to polymer conversion rates, to make maximum use of catalyst productivities, and to reduce separation costs of removing monomer from the diluent. The first reactor is sometimes referred to as the prepolymerizer since monomer conversion rates are low (McKetta, 1992).

Continuous processes are typically operated in gas-phase fluid-bed reactors or linear-flow reactors. Gas-phase fluid-bed reactors are widely used in polymerizing ethylene and propylene by way of coordination catalysts. The reactor is a vertical cylinder containing a bed of solid polymer powder maintained in a fluidized state by passing a stream of reaction gas up from the base of the reactor. Catalyst and monomer are added through the sides of the reactor. The reaction gas is withdrawn from the top of the reactor and heat of reaction is removed with a compressor and cooler before being recirculated back up through the polymer powder. The solid polymer powder is removed periodically as it builds up in the base of the reactor by opening a discharge valve that blows the product powder into a disengaging system. (SRI, 1995) Figure 8 shows a simplified diagram of a gas-phase fluid-bed reactor.

Figure 8: Gas-Phase Fluid-Bed Reactor for Production of Polyethylene

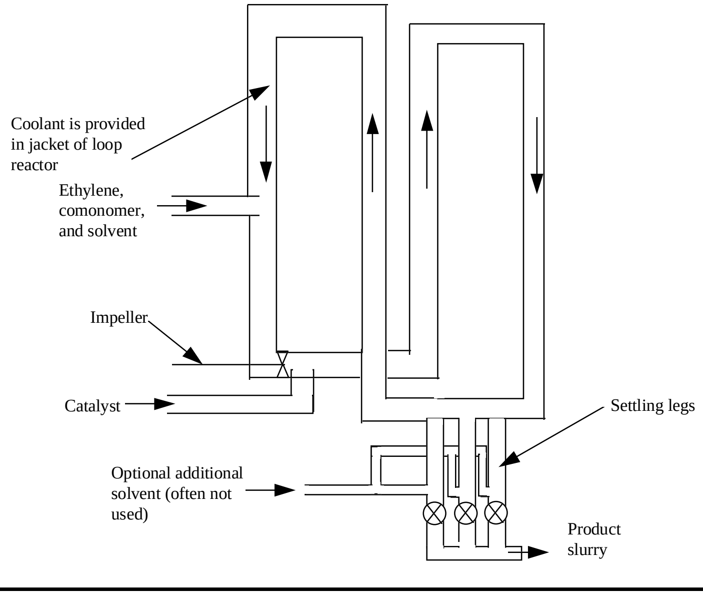


Source: SRI International 1995.

Linear-flow reactors are tubular and jacketed with a heat transfer fluid, like Dowtherm® or water (Kroschwitz, 1986). The tubes may be several hundred meters in length, but are often coiled in helix-like structures as a way to save space and avoid buildup of polymer in elbows. Typical residence time in the reactors varies from 30 to 60 seconds. The reactors have three different zones used for preheating, polymerization, and cooling.

Loop reactors are the most common linear-flow reactors. Loop reactors have long straight lengths of tubing interjected with short bends and are typically 490-540 ft (150-165 m) long. The reaction slurry is circulated around the loop at speeds of 10-30 ft/s (3.3-10 m/s) by axial flow pumps. The residence time of the reactants in the loop reactors ranges from 45 to 60 seconds, and polymerization temperatures range from 390-480°F (200-250°C). A schematic diagram of a typical loop reactor is shown in Figure 9. Polymer slurries containing 20-70 percent solid polymer particles are collected in settling legs located at the base of the reactor. When two loop reactors are used in series, a portion of the slurry in the first loop is continuously withdrawn and pumped into the second reactor, from which polymer is removed as a slurry. Emissions and wastes generated during polymerization include VOC emissions from leaks and spills, solid wastes from off-specification polymer, and spent solvent from incomplete polymerization (Kroschwitz, 1986).

Figure 9: Typical Loop Reactor for Production of Polyethylene



Source: *Encyclopedia of Chemical Processing and Design.* Volume 39. J.J. McKetta (ed.), Marcel Dekker, Inc., New York, 1992.

Methods of Polymerization

The specific polymerization method used is key to polymer manufacturing. Different polymerization conditions and processes are used to synthesize different polymers and to create different grades of a given polymer (McKetta, 1992). Addition polymerization methods are covered primarily in this section. Five general methods are used commercially for polymerization: bulk, solution, suspension, emulsion, and polycondensation. Table 7 lists typical polymerization method and reactants for leading commercial plastic resins. Note that distinctions between these methods are not well-defined and that some companies use a combination of polymerization methods. In addition, details of specific processes are often protected by manufacturers since small process variations can result in significant reductions in operating costs and unique changes in polymer characteristics.

Table 7: General Polymerization Parameters for Selected Polymers

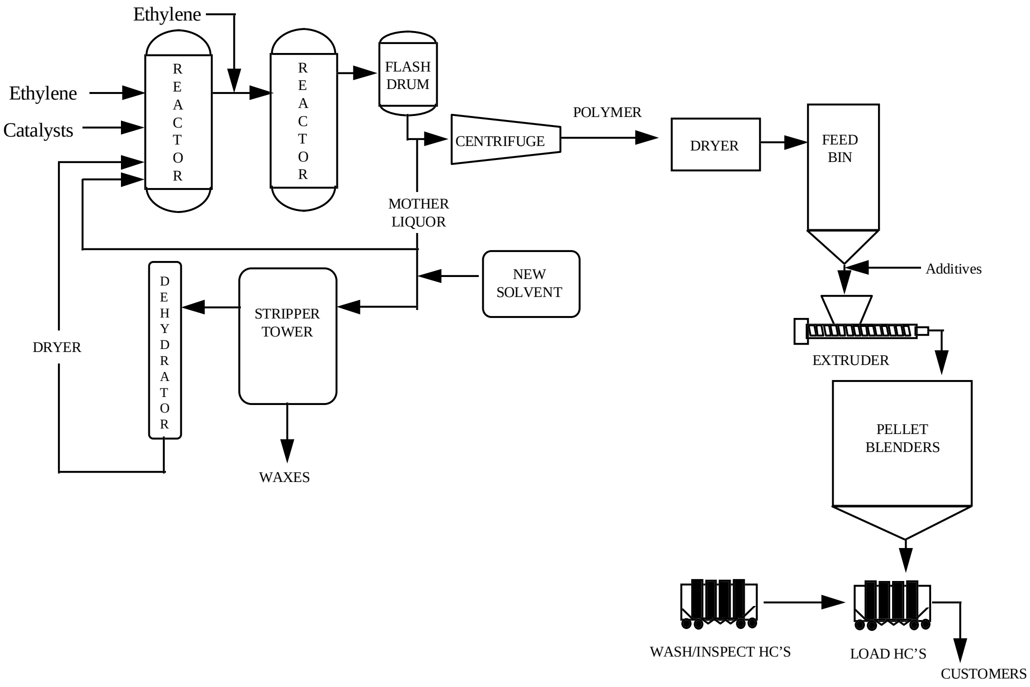
Polymer	**Polymerization Method**	**Monomer**	**Catalyst**	**Solvent**	**Other Possible Reactants**
HDPE	solution, suspension	ethylene	Ziegler-type catalysts	isobutane, hexane	
LDPE	bulk, suspension	ethylene	organic peroxides, peroxyesters	hydrocarbons	
LLDPE	solution	ethylene	Ziegler-type or Phillips chromium oxide catalysts	octene, butene, or hexene	
Polypropylene	bulk, solution, suspension	propylene	Ziegler-Natta catalysts	hexane, heptane, or liquid propylene	
Polystyrene	bulk, suspension, solution	styrene	heat, organic peroxides	styrene, ethylbenzene	
PVC	suspension	vinyl chloride	azo compounds, organic peroxides	water	polyvinyl alcohols (suspending agent)
Acrylic/ Modacrylic	solution, suspension, emulsion	acrylonitrile	organic peroxides, azo compounds, inorganic redox initiators	dimethylacetamide or aqueous inorganic salt solutions	
Nylon-6	bulk; polycondensation	ε-caprolactam	water	---	acetic acid (molecular weight regulator)
Nylon-6,6	bulk; polycondensation	hexamethylene diammonium adipate			adipic acid (viscosity stabilizer), polyphosphoric acid (reaction accelerator)
Polyester (Polyethylene terephthalate)	bulk; polycondensation	terephthalic acid and ethylene glycol	antimony oxides and derivatives	---	

Source: *Encyclopedia of Polymer Science and Engineering,* volume 12, J.I. Kroschwitz (ed.), John Wiley and Sons, New York, 1986; *Encyclopedia of Chemical Processing and Design*, volume 39, J.J. McKetta (ed.), Marcel Dekker, Inc., New York, 1992; AFMA, 1997.

Bulk Polymerization

In bulk polymerization, primarily monomer and a catalyst are used to make polymer. Two reactor vessels are often used to complete polymer conversion and recycle unreacted monomer. Because few solvents or other chemicals are used, bulk processes typically produce purer polymers and generate less pollutants than those produced by other processes. Separation procedures of polymer and reactants are also simplified, reducing expensive solvent recovery equipment costs. Figure 10 shows a flow chart for a high density polyethylene process with simplified separation steps. In the figure, high density polyethylene is separated from the monomer in the flash drum and goes through a series of recovery and finishing steps. The monomer is recovered using a stripper and a dehydrator. Increased conversion rates and decreased recovery costs have made bulk processes increasingly favored in the industry (McKetta, 1992). Note that bulk processes used for polycondensation reactions are discussed later in this section.

Figure 10: High-Density Polyethylene Process Flow Diagram

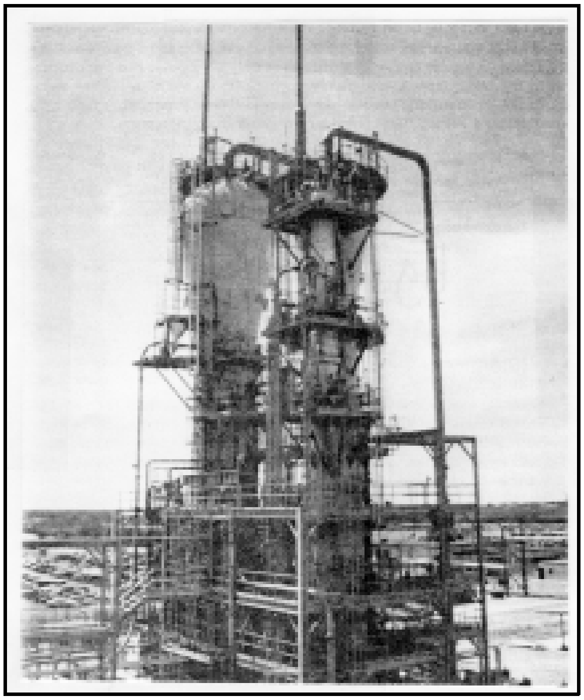


Source: Exxon Chemical Company's *Mont Belvieu Plastics Plant Brochure.*

Bulk processes can be divided into two types based on whether or not the monomer and polymer are soluble in each other. If the monomer and polymer are not soluble in each other, polymer slurries are formed which consist of solid polymer particles mixed with either liquid or gaseous monomer. Polyester and nylon are among many polymers produced in continuous-flow bulk polymerization systems.

Gas-phase polymerization is a type of bulk polymerization primarily used to synthesize polyethylene and polypropylene. Gaseous monomer and comonomer are fed continuously into a reactor that is filled with fluidized polymer particles. Figure 11 shows a photo of two fluid reactors used for making polypropylene. In the Unipol process, up flowing monomer reacts with granular polymer particles suspended in a vertical cylindrical reactor. The bed is typically 40-50 ft (12-15 m) high and 15-16 ft (4.5-5 m) in diameter. Pressures range from 265 to 310 psi (18-21 atm), and temperatures range from 176 to 212°F (80-100°C). A distributor plate is attached to the bottom of the reactor to maintain uniform flow of monomer and even distribution of polymer and catalyst throughout the bed. Monomer gas is cooled and partially condensed in an external cooler to remove reaction heat. Only 2 percent of monomer reacts per pass, so large volumes of gas are recycled. Large polymer particles collect in the bottom of the reactor where they are semicontinuously removed (McKetta, 1992).

Figure 11: Fluid Reactors Used for Making Polypropylene



Source: *Principals of Polymer Systems, 4th Edition,* Ferdinand Rodriguez, Taylor and Francis, Washington, DC, 1996. Reproduced with permission. All rights reserved.

Solution Polymerization

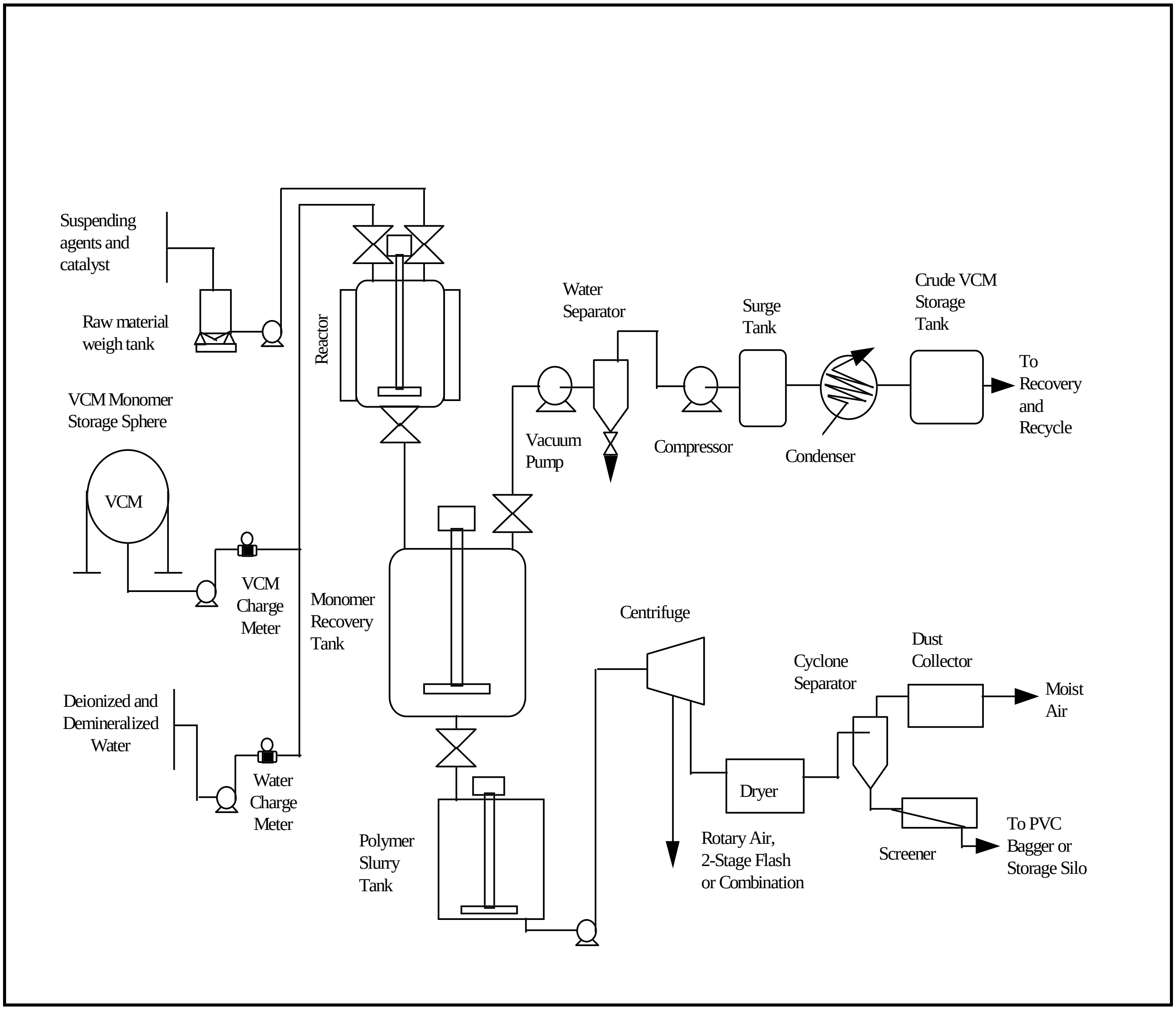
Solution polymerization is commonly used to make plastic resins and textile fibers. In solution polymerization, a solvent is mixed with monomer in the reactor. Use of solvents reduces reaction mass viscosity, improves heat transfer rates, and increases mixing efficiency during polymerization. Choice of solvent can have a large effect on polymer properties and the rate of polymerization. Because solution polymerization requires additional processing and recovery steps, companies typically try to optimize solvent to monomer ratios to reduce polymerization costs and emissions (Kroschwitz, 1986). Reactors are often operated in series for continuous operations.

In solution polymerization, the polymer may be soluble or insoluble in the solvent. When the polymer is insoluble in the solvent, a slurry is formed of solid polymer particles dispersed in solvent. Slurry processes can be divided into two categories, light slurry and heavy slurry, based on the molecular weight of the solvent. Slurry processes are commonly used in the continuous production of high-density polyethylene, linear low-density polyethylene, and polypropylene. Polymers are typically formed at temperatures of 320-480°F (160-250°C), with a dissolved polymer content of usually 10-15 percent. Loop reactors are often used, although some companies use a series of stirred autoclaves as polymerization vessels. Typical solvents used include isobutane (light slurry) and hexane (heavy slurry). Typical slurry composition by weight is 30 percent particulates, 68 percent solvent, and 2 percent monomers. Reaction pressure is about 650 psi (44 atm) and reaction temperature is about 225°F (107°C). Typical polymer concentrations are 50-70 percent (McKetta, 1992).

Suspension Polymerization

In suspension polymerization, agitation and suspending agents are used to suspend monomer and polymer particles in water. The suspending agents also maximize heat transfer, maintain uniform mixing, and prevent polymer clumping in the suspension. Catalysts are added to initiate the reaction and typically include azo compounds, organic peroxides, or peroxydic carbonates. In suspension processes, polymerization is initiated in the monomer droplets and proceeds as miniature bulk reactions. The polymer droplets, usually 0.006-0.20 in (0.15-5 mm) in diameter, settle out of solution as soon as agitation is stopped. Figure 12 shows the typical flow diagram for the suspension polymerization of polyvinyl chloride (PVC). Note that monomers and polymers produced by suspension and emulsion processes undergo additional recovery steps than those produced by bulk or solution processes. For example, Figure 12 shows that the polymer slurry is centrifuged and separated following polymerization. Monomer undergoes additional recovery and drying steps to remove water from the monomer.

Figure 12: Typical Process Flow Diagram for Suspension Polymerization of PVC



Source: *Encyclopedia of Chemical Processing and Design*, Volume 40, J.J. McKetta (ed.), Marcel Dekker, Inc., New York, 1992.

Industrial suspension processes generally use batch reactors. Suspension polymerization processes are used for about 90 % of all PVC produced. Stirred-tank reactors for PVC production range in size from 1,000-50,000 gallons, and reaction temperatures typically range from 110-160°F (45-70°C). Note that polymers produced by suspension processes must undergo additional monomer and polymer recovery steps than those produced by bulk and solution processes (Kroschwitz, 1986).

Emulsion Polymerization

Emulsion polymerization is similar in method to suspension polymerization but uses smaller monomer and polymer particles. Emulsion polymerization uses emulsifiers and additives to suspend monomer and polymer particles in water. In emulsion polymerization, surfactant accumulates around monomer particles, forming micelles that act as tiny polymerization vessels. Polymers form as more monomers react. Agitation optimizes reaction rate by dispersing monomer, catalyst, and polymer and by transporting heat to the reactor surface. Emulsion processes typically produce moderately viscous reaction masses. About 10% of PVC and some polystyrene are produced by emulsion processes. Emulsion polymerization methods typically produce polymers that are smaller and more difficult to process than those produced by suspension polymerization methods. Polymers produced by emulsion processes are also characterized by high polymer viscosity, high heat transfer rates, and more difficult transport and agitation of the polymer slurry. For those reasons, emulsion processes are frequently replaced with suspension polymerization methods (Kroschwitz, 1986).

Polycondensation

Polycondensation reactions are used to make polymers, such as polyesters, polyamides (or nylons), polyurethanes, phenolics, urea resins, and epoxies. Polycondensation is an equilibrium reaction that depends on temperature, pressure, and the efficient removal of reactants and the catalyst (Kroschwitz, 1986). Typically, two or more reactants are first combined to form a monomer. The monomer is then charged to a polymerizer where monomers link together in condensation reactions. Condensation reactions occur when two molecules are linked together from the splitting of water molecules from the reacting molecules. Reaction temperatures range from 446 to 545°F (230 to 285°C) for nylon-6,6 and polyester. These reactions are endothermic, unlike addition polymerization reactions, and therefore, require the addition of heat to complete polymerization (ATMI, 1997b).

For nylon-6,6, polycondensation of nylon salt is carried out continuously for commodity nylon production and batchwise for special grade nylon production. The reaction typically takes place in several stages. The first stage takes place in a tank or tubes under pressure greater than 250 psig.

Water vapor is removed through a throttle valve or in a subsequent separator. The last stage of the polycondensation occurs under atmospheric or subatmospheric pressure to further facilitate water removal. Additives are often introduced during polycondensation to impart desirable properties to resins and chips. Viscosity stabilizers, such as acetic acid, are sometimes used to limit the degree of polymerization. Reaction accelerators, such as phosphoric acid, sometimes used to speed the reaction (McKetta, 1992).

III.A.3. Polymer Recovery

Once polymerization is completed, a reaction mixture is produced which consists of polymer, monomer, and trace amounts of catalyst. Because reaction mixture consistency varies according to which polymerization method is used, different polymer separation and recovery steps are required of different polymerization methods. To recover the polymer, the reaction mixture typically goes through a series of three separation and purification steps: 1) unreacted monomer is separated from the polymer; 2) liquids and solids are separated; and 3) residual water or solvents trapped in the polymer are purged by drying the polymer.

The first step in polymer recovery is flashing, in which solvents and unreacted monomers are volatilized from the reaction mixture and drawn off for recovery. Flashing is achieved by lowering the pressure in a staged separation system, which causes monomers and solvents with low boiling points to evaporate. A large portion of monomer and solvent is removed during this step. Remaining monomer in the polymer can be removed in a low-pressure degasser, as in bulk polymerization processes, or by gravity, as in gas-phase processes. In some cases, combinations of heating, flashing, thin-film evaporation, and vacuum stripping are used to separate residual solvent from the polymer.

For reaction mixtures that contain heavy solvents or liquids, further steps are used to separate the polymer from the reaction mixture. Typically, the mixture is centrifuged or filtered to separate the solid polymer granules from the liquids. The polymer is then washed and stripped of residual solvent and monomers.

Most polymer recovery operations include a drying step. Polymers are usually solvent or water-wet and are dried after being centrifuged. Drying removes water and residual solvents from the polymers. Flash drier-fluidized bed systems with gas recycle are commonly used for polypropylene and high-density polyethylene. Combination dryers, such as single and multistage fluidized-bed systems, are also used. In the flash dryer-fluidized bed system, the flash dryer removes surface water in a matter of seconds, while the fluidized bed completes moisture removal by holding the polymer at drying temperatures for about 30 minutes. In rotary dryers, a hot gas passes over the polymer particles, transferring heat and vaporizing solvent and water molecules. Rotary dryers and two-stage flash dryer-fluidized-bed systems have also been used to dry the wet PVC cakes resulting from polymerization. Polyester is often dried by hot, dry air or inert gas in tumble, column, or fluidized-bed dryers at about 180°C. Wastes generated from drying operations include primarily VOC emissions (Kroschwitz, 1986).

III.A.4. Polymer Extrusion

Most polymers undergo further processing steps to form plastic pellets. The polymer is usually extruded and pelletized before being packaged and incorporated with additives to prevent product deterioration. After polymer recovery, the polymer is fed to a screw extruder which melts the polymer. The molten polymer is then fed to a pelletizer, which may be capable of producing up to 5000 pounds of pellets per hour. The pelletizer extrudes molten polymer out of small orifices, forming continuous strands 0.08-0.16 in (2-4 mm) in diameter. These strands are cooled and then cut using either a fixed or rotating knife. The pellets are then dried to remove any dissolved monomer that would exude from the pellets during storage. Additives are often added directly to the extruder, to a blender prior to the extrusion step, or later in a highly concentrated master batch. Often antioxidants are added to prevent deterioration of product properties during storage, shipment, and product fabrication. Other additives may be added to increase ultraviolet light stability, reduce the tendency for static electrical charges, or add color and pigment (McKetta, 1992).

III.A.5. Supporting Operations

Various supporting steps to the manufacture of plastic resins and manmade fibers are important to note because of their effect on the environment. Supporting steps include the unloading and storage of chemicals and equipment cleaning. Some of these supporting processes are discussed below. Note that supporting operations, such as raw material recovery and pollution control, are mentioned in Section III.C.

Equipment Cleaning

Cleaning of equipment, such as reactors and storage vessels, is performed periodically as routine maintenance on the plant. Polymerization reactors are cleaned often to remove buildup of polymer on heat transfer surfaces which can result in contamination between batch runs of different polymers or different grades of polymers. Reactor cleaning is particularly important for suspension and emulsion polymerization processes since the reaction mass is very viscous. Deposits on reactors may consist of polymer gels or coagulum. Spray rinse valves are often installed in the reactor top to facilitate washing while the reactor is emptied. High pressure water-jet streams and hydraulic reactor cleaners are also used to remove hard deposits. Solvents and manual scraping are also sometimes used (Kroschwitz, 1986).

Cleaning of loading vehicles and storage vessels is performed both before and after loading. Before plastic pellets can be loaded into rail hopper cars or bulk trucks, the vehicles are cleaned to remove residual trapped and clinging pellets as well as other contaminants that may be present. Pellets are removed first using suctioning and then using wash water. The rinse water is collected into the facility drainage and containment system where residual pellets are recaptured via a series of dams, skimmers, and surface booms. Wastes from equipment cleaning also include wastewater contaminated with dilute concentrations of organics, acids, and salts (EPA, 1992).

Unloading and Storage of Reactants

Unloading and storing reactants is an important step in polymerization. These operations are closely monitored to avoid contamination of reactants, runaway or accidental polymerization, and fugitive emissions. To reduce fugitive emissions, gaseous compounds are often unloaded from tank cars by pressurizing the tank car with vapors from the storage tank. Compressor valves are then reversed to remove and transfer vapor from tank cars to storage tanks.

Chemicals are typically stored in large stainless steel storage tanks equipped with both external and internal covers. Tank design is mostly concerned with safety, since materials may be flammable, toxic, or autocatalytically polymerized. Autocatalytic polymerization occurs when monomer starts polymerizing spontaneously in the storage tank. Monomers are typically stored in pressure vessels equipped with excess flow valves on the outlet connection. These valves safeguard against complete discharge in the event of pipe rupture. In addition, monomer storage tanks are often equipped with systems to avoid unwanted polymerization including systems to inject inhibitor into reactors to stop polymerization and insulation and coiling coils to prevent polymerization.

Liquids with high boiling points are stored in vented atmospheric tanks. Solvents are usually stored under a blanket of nitrogen gas to minimize air contamination. Some catalysts, such as the Ziegler-type, are so explosive when in contact with water and air that they are diluted with hydrocarbons for easier handling (Kroschwitz, 1986). For these safety reasons, tanks are usually located outdoors and away from production facilities. Because of stringent dust and moisture standards for polymerization, unloading and storage systems may have elaborate air conditioning and ventilation systems. Emissions generated from storage operations include air emissions of VOCs (EPA, 1993).

Conveyance

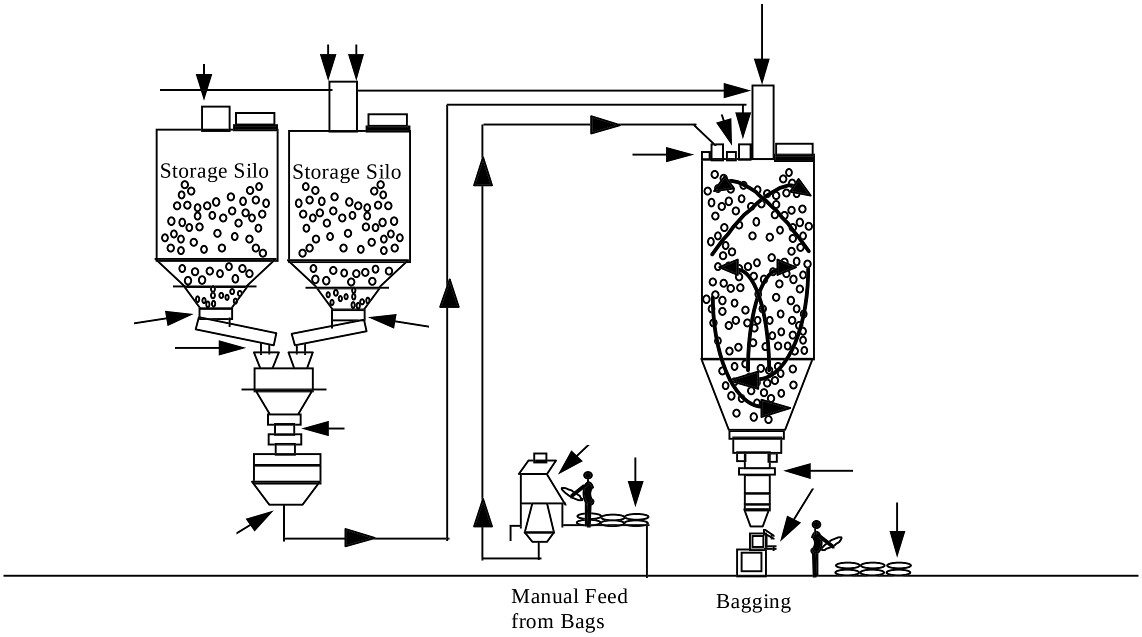
Charging reactants to reactors is one of the most important conveyance steps in plastic resin and manmade fiber production. Charging reactants and polymer must be controlled carefully to avoid producing off-spec product and causing polymer buildup in the pipes. Polymerization feed is automatically measured and charged into the reactors. Measuring and charging reactants varies depending on whether the process is batch or continuous and what accuracy of formulation is required. Batch methods use weigh tanks, volumetric charge tanks, and flow meters to feed the polymerization vessels. For continuous processes, reactants are fed continuously at a specific rate into the reactor. Reactor heat-up, purge, evacuation, charge, and discharge are all controlled by automatic control systems equipped with temperature and pressure overrides.

Conveying systems are also used to move plastic pellets between plant operations. An example of a pneumatic conveying system in a pellet blending operation is shown in Figure 13. Pellets are conveyed using pneumatic or mechanical systems to move pellets between the pelletizers and drying systems and between storage silos and shipping containers. In pneumatic systems, high-pressurized air can be used to transport pellets through the plant. Mechanical systems are generally used to transport pellets across short distances using rigid driven screws to force pellets through a conduit. Pellet spills can occur during each conveyance and can be avoided by controlling the rate of pellet entry and delivery from the conveying system. Wastes generated during conveying operations may include VOC emissions from leaks and spills (EPA, 1992).

Pellet Storage

Plastic pellets must be stored carefully to avoid product contamination or accidental spills. EPA has identified preventive measures to minimize pellet loss and entry into water streams which apply to plastic resin and manmade fiber plants and downstream processing plants. After polymer finishing, the plastic pellets are transferred to intermediate storage vessels consisting of 30,000 to 100,000 pound silos. The pellets are then transferred to silo lots where they are sampled, bagged for shipment, and transferred to downstream processes for hot-melt mixing and incorporation of additives. Pellets are packaged in containers ranging from 50 pound bags to 100,000 pound railway hopper cars. Wastes from pellet storage include solid wastes or wastewater containing plastic pellets (EPA, 1992; SPI, 1994).

Figure 13: Typical Pneumatic Conveying System in a Pellet Blending Operation



Source: U.S. EPA, *Plastic Pellets in the Aquatic Environment: Sources and Recommendations*, Office of Water, December 1992.

III.B. Industrial Processes Specific to the Manmade Fiber Industry

The manufacture of manmade fibers is closely linked with the synthesis of plastic resins. Fibers are the fundamental unit of textiles and fabrics and can be defined as a unit of matter having a length at least 100 times its width or diameter (Rodriguez, 1996). Fiber spinning processes may be similar for some noncellulosic fibers and cellulosic fibers. Manmade fibers can be produced from polymers that have been continuously or batch polymerized, or by dissolving cellulosic materials. The polymer or cellulosic solution is then forced through tiny holes of spinnerets (which function much like bathroom shower heads) and extruded into fibers (International Trade Commission, 1995). In manmade fiber plants, polymerization of the fiber polymer can occur at the same facility that produces the fiber, with continuous polymerization equipment linked directly to a fiber spinning unit (EPA, 1995). Subsequent processing steps typically include drawing, crimping, texturizing, and twisting. The following sections will discuss polymerization, primary methods of spinning, and fiber processing steps.

III.B.1. Polymerization

Many of the leading commercial manmade fibers, such as polyethylene terephthalate (PET) and polypropylene, use polymers similar to those derived from commodity plastic resins. Other manmade fibers are manufactured from polymers formed using similar polymerization methods as those mentioned in the preceding section. For instance, nylon and polyester are polymerized using polycondensation or melt polymerization methods. Recall that some manmade fibers are manufactured using natural polymers, such as cellulosic fibers, and do not undergo polymerization.

In some plants, polymerization equipment is hooked up directly to fiber spinning equipment. For continuous manufacture of polyester fiber, terephthalic acid and ethylene glycol are first passed through primary and secondary esterifiers to form the monomer. The melt is then passed to low and high polymerizers to achieve higher conversion rates. The high polymerizer is usually equipped with a high vacuum and high walls to allow excess ethylene glycol to escape, promoting chain extension. The polymer is then fed to several banks of direct fiber melt spinning heads or a solid polymer chipping system (Kroschwitz, 1986). Wastes generated during polymerization may include VOC emissions from leaks, spills, and vents; solid wastes from off-specification polymer; and spent solvent from incomplete polymerization (AFMA, 1997).

III.B.2. Spinning

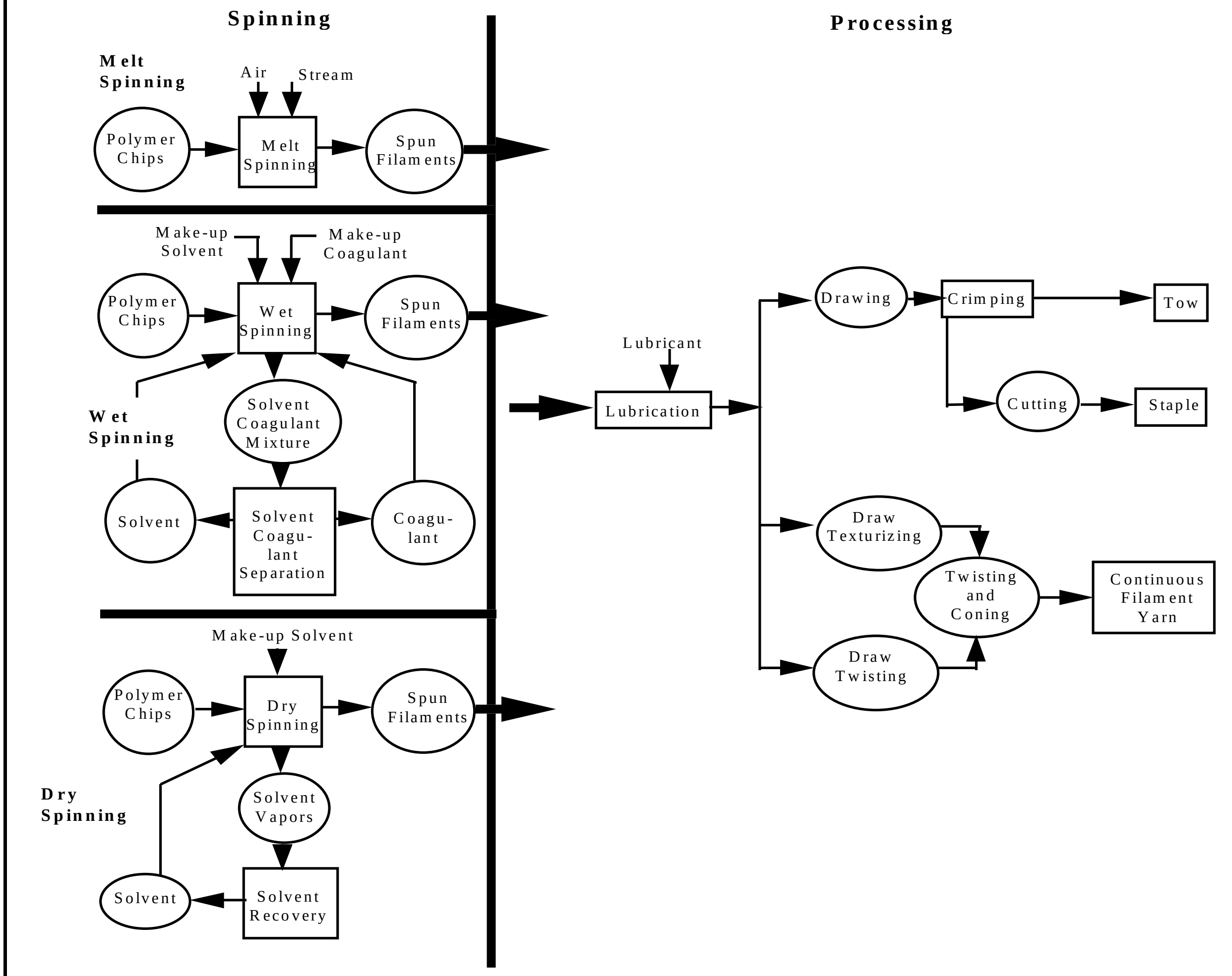
Spinning, in terms of manmade fibers, refers to the overall process of polymer extrusion and fiber formation. Fibers are formed by forcing a viscous fluid or polymer solution through the small orifices of a spinneret and immediately solidifying or precipitating the resulting filaments. Facilities typically produce fibers of different thickness or denier, where denier is defined as the weight in grams of 9,000 meters (9,846 yards) of filament yarn. Fiber denier can range from less than one to 3,600 denier (McKetta, 1992).

The three primary methods of spinning are melt, dry solvent, and wet solvent, which are shown in Figure 14. A fourth and less commonly used method is reaction spinning. Table 8 lists the different types of spinning methods with the fiber types and typical reactants used for each method. The spinning process used for a particular polymer is determined by the polymer's melting point, melt stability, and solubility in organic and/or inorganic (salt) solvents, as well as the end use of the fibers (AFMA, 1997; EPA, 1993). Spinning processes involve spinning units which are made up of meter pumps, filter packs, spinnerets, and quench cells. Meter pumps are used to transport polymer through the spinning units at a constant rate. The polymer is passed through a filter and a spinneret. Note that fibers may be colored by including pigments prior to extrusion (AFMA, 1997).

The spinnerets are plates containing holes, of varying diameters and shapes, through which molten or dissolved polymer is extruded. Pressures can reach as high as 2900 psi (20 MPa). The spinnerets are usually made of stainless steel or nickel alloy for melt and dry spinning processes, although for more corrosive wet spinning processes they are usually made of glass or a platinum alloy. The spinneret may be a recessed flat plate (melt spinning) or a protruding thimble shape (dry and wet spinning). The spinnerets for molten polymers are relatively thick 0.1-0.4 in (3-10 mm) and have hole diameters of 0.007-0.030 in (175-750 µm). For solution polymers, the spinnerets are slightly thinner with smaller hole diameters.

The number of holes in a spinneret ranges from a few to several thousand. These holes may be divided into groups to produce, for instance, two 30-filament yarns from a 60-hole spinneret. The exit hole is usually circular, however fibers may have lobed, dumbbell-, or dogbone-like cross-sections (dry-spun fibers) or round, lobed, serrated, or bean-shaped cross-sections (wet-spun fibers). Wastes generated during spinning operations include VOC emissions and wastewater contaminated with solvents.

Figure 14: General Process Diagram for Melt, Dry, and Wet Spun Synthetic Fibers



Source: U.S. EPA, *AP-42,* Office of Air and Radiation, 1993.

Table 8: Typical Fiber Spinning Parameters for Selected Fibers

Spinning Method	Fiber Type	Solvents or Other Reactants
Melt Spinning	nylon-6 nylon-6,6 polyester polyolefin	N/A
Solvent Spinning		
Dry solvent spinning	acrylic/modacrylic	dimethylacetamide
	cellulose acetate/ cellulose triacetate	acetone or chlorinated hydrocarbon
	spandex	di-isocyanate, ethylenediamine, monoamine (stabilizer)
Wet solvent spinning	acrylic/modacrylic	dimethylacetamide
Reaction Spinning	spandex	di-isocyanate, ethylenediamine, toluene
	rayon (viscose process)	sodium hydroxide, carbon disulfide, sulfuric acid

Source: U.S. EPA, *AP-42,* Office of Air and Radiation, 1993; AFMA, 1997.

Types of Spinning

Melt Spinning

Melt spinning processes use heat to melt polymer which can then be extruded through the spinneret. Spinning assemblies are fed by either electrically-heated screw extruders, which convert powdered or chipped polymer into a polymer melt, or directly from a continuous melt polymerization process. Many nylon and polyester plants use continuous melt polymerization and send molten polymer from polymerization units directly to the spinning units. During polymerization or extrusion, various additives may be incorporated to impart special properties to the fibers, such as heat stability, anti-static, and eased dyeing.

Polymer chips or polymer melt is then passed through metering gear pumps, which feed the molten polymer to a filter system at pressures of 500-1000 psi (7,400-14,700 atm). The filter system screens out large solid or gel particles through a series of metal gauzes interspersed in layers of graded sand (EPA, 1993). The filter may also screen out catalyst residues or precipitated additives (McKetta, 1992). The filter may be enclosed in a Dowtherm-heated manifold to maintain uniform temperature. After passing through the filter, the molten polymer is fed to the spinneret (Kroschwitz, 1986). A narrow zone below the spinneret may be filled with inert gas to prevent deposits of degradation products around the holes for oxidation-sensitive polymers.

Extruded filaments are quenched by a cool, filtered airstream which solidifies the filaments.

Dry Spinning

Dry spinning is typically used for easily dissolved polymers such as cellulose acetate, acrylics, and modacrylics. In dry spinning processes, the polymer is first dissolved in an organic solvent. The solution (or spinning dope) is then blended with additives, filtered, and charged to a spin cell. The spin cell contains a feed vessel, a heat exchanger, a spinneret, and a quench cell. The spin cell may be 5-10 m (5.5-11 yards) long and 13-23 cm (5.1-9.1 in) in diameter (Grayson, 1984). The solution is heated to a temperature above the solvent boiling point and is then extruded through the spinneret into a zone of heated gas. The solvent evaporates into the gas stream, leaving solidified filaments. The heated gas stream is typically air although inert gas, such as nitrogen and super-heated solvents, can also be used. Fibers are then passed through baths to wash residual solvent from the fibers. To reduce costs and pollution, the wash water from these baths is typically recycled. These baths may be followed by activated carbon systems used to adsorb solvent from process air (AFMA, 1997). Fibers produced by dry spinning contain less void space than those produced by melt spinning and therefore have higher densities and lower dyeability than those produced by other methods (Kroschwitz, 1986). Of the three primary spinning methods, dry spinning operations have the largest potential VOC emissions `to the air (EPA, 1993).

Wet Spinning

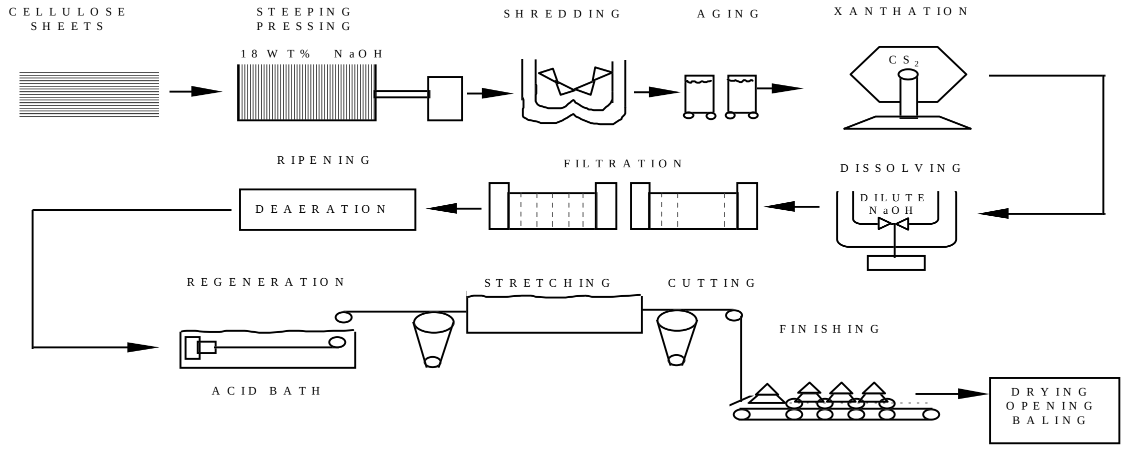
Wet spinning processes also use solvents, such as dimethylacetamide or aqueous inorganic salt solutions, to prepare spinning dope (AFMA, 1997). In wet spinning, the polymer is dissolved in solvent in a solution vessel and is forced through a spinneret which is submerged in a coagulation bath. As the polymer solution emerges in the coagulating bath, the polymer is either precipitated or chemically regenerated. In precipitation, the fiber is formed when solvent diffuses out of the thread and coagulant diffuses into the thread. For some processes, a chemical reaction occurs during precipitation which generates fibers. Coagulated filaments pass over a guide to godets or drive rollers. Windup speeds are about 150 m/min. The yarn is then passed through additional baths for washing and residual solvent removal (Kroschwitz, 1986).

Reaction Spinning

Reaction spinning methods are typically used to make spandex and rayon. The process begins with the preparation of a viscous spinning solution containing a dissolved low molecular weight polymer, such as polyester, in a suitable solvent and a reactant, such as di-isocyanate. The spinning solution is then forced through spinnerets into a solution containing a diamine (similar to wet spinning) or is combined with a third reactant and then dry spun. The primary distinguishing characteristic of reaction spinning processes is that the final cross-linking between the polymer molecule chains in the filament occurs after the fibers have been spun. The fiber is then transported from the bath to an oven, where solvent is evaporated (EPA, 1993).

In the U.S., most rayon is made by the viscose process. This process is worth noting because it is typically associated with a large volume of air emissions. Shown in Figure 15, the viscose process converts cellulose from one form (dissolved pulp) to another (rayon). Although the manufacturing process further purifies the cellulose, alters the physical form of the fiber, and modifies the molecular orientation within the fiber and its degree of polymerization, the product is essentially the same chemical as the raw material. Since the product retains the same chemical structure, all other chemicals used in the process and all byproducts formed in the process must be removed.

Figure 15: Typical Process Flowchart for Synthesis of Rayon Fibers Using the Viscose Process



Source: U.S. EPA, *AP-42,* Office of Air and Radiation, 1993.

The series of chemical reactions in the viscose process used to make rayon consists of the following stages. First, purified cellulose pulp is steeped in a solution of sodium hydroxide and water, producing an alkali cellulose slurry. The excess sodium hydroxide solution is removed from the slurry, producing alkali cellulose crumb. The crumb is shredded and fed into silos for aging, a process which controls the degree of polymerization of the cellulose molecules. After aging, the alkali cellulose is reacted in large reactors with carbon disulfide, producing sodium cellulose xanthate, which is then dissolved in dilute aqueous sodium hydroxide. That solution is known as viscose.

The viscose solution is then aged (ripened), during which a series of chemical reactions takes place. The most important of these reactions is the splitting off of carbon disulfide and the regeneration of cellulose. These include the redistribution of the carbon disulfide on the cellulose molecules and the formation of small amounts of sulfur byproducts. The viscose is filtered several times and deaerated prior to spinning. The viscose is then extruded through spinnerettes, typically containing thousands of very small holes, into a spinning bath of dilute sulfuric acid, sodium sulfate, zinc sulfate, various spinning aids, and water. The cellulose xanthate, in the viscose, reacts with the acidic spinning bath, forming an unstable xantheic acid derivative which loses carbon disulfide to yield regenerated cellulose. The carbon disulfide is released from the xanthate, and the sulfur byproducts created during aging react to form hydrogen sulfide.

After spinning the fibers are collected together, stretched to orient the cellulose molecules along the axis of the fibers, processed to remove the residual chemicals from the cellulose, finished, dried, and packaged. The fibers may be cut after stretching but prior to further processing, producing rayon staple (cut) fiber, or they may be processed without cutting, producing rayon filament or tow (AFMA, 1997; EPA, 1993).

III.B.3. Fiber Processing

In most cases, the extruded product from melt, dry, wet, or reaction spinning is further processed to impart particular qualities to the fibers and facilitate downstream processing. Fibers can be processed as filament yarn or as staple. Figure 14 illustrates general fiber processing steps.

After fibers have been formed, spin finish is usually applied by collecting the extruded filaments on a grooved ceramic guide or rotating roller coated with spin finish. The spin finish, which includes lubricants and finishing oils, facilitates further processing steps by reducing friction and static, and improving further mechanical processing (AFMA, 1997). Mineral oils have historically been used as lubricants, and organic compounds have been used to reduce static. Spin finishes vary according to fiber type and are critical to the processing of fibers into yarns and fabrics. Insufficient lubrication of fibers can lead to strains in the fabric which may produce uneven dyeing, decreased strength, or unpleasing aesthetic qualities (Grayson, 1984).

Filament Yarn

After finish is applied, a thread guide converges the individual filaments to produce a continuous filament yarn that contains between 15 and 1000 filaments (AFMA, 1997). The spun yarn is then either immediately wound onto bobbins and collected in cans or is further treated to impart special fiber qualities (EPA, 1993). Filaments are typically drawn to align and orient the polymer molecules and strengthen the filament. In melt spinning operations, companies have moved towards high-speed spinning processes which combine spinning and drawing operations. Filaments may be forwarded at speeds of 300 to 6,000 m/min for subsequent processing. For polyester, the different commercial melt-spinning processes are classified according to the degree of molecular orientation in the fiber. For instance, polyester spinning processes operating at speeds of 500 to 1,500 m/min give low oriented spun yarn (LOY), while processes operating at between 4,000 and 6,000 m/min give partially oriented yarn (POY) (Kroschwitz, 1986).

Thermoplastic fibers can be further modified by thermomechanical annealing treatments, including texturing. Texturing uses curling, crimping, and tangling apparatuses to give straight, rod-like filament fibers the appearance, structure, and feel of natural fibers (EPA, 1995). Filaments may be mechanically distorted by compressing the fibers in a stuffing box or between rolls or by false twisting, where twisting is followed by heat setting and releasing or reversing the twist. Textured yarns are either fine denier (15-200 denier) for woven, knitted stretch and textured fabrics for apparel or heavy (1,000-3,600 denier) for carpet (McKetta, 1992). Recall that denier is the weight in grams of 9,000 meters (9,846 yards) of yarn.

Staple

Many manmade fiber operations produce staple, or yarn that is cut into specific lengths, for use by textile manufacturers. To make staple, a tow is formed by collecting thousands of continuous filaments into large rope-like bundles. These bundles are combined from all the spinning positions and thrown into a large “creel can” at speeds of 1,000 to 2,000 m/min. This bundle of filaments is 50,000 to 250,000 total denier, with as-spun denier ranging from 2.5 to 9.0 (Dekker, 1992). The bundles are then spread out into a flat band winding over the feed rolls and draw rolls of the draw machine. After drawing, the fiber may be heat set and crimped to change the tensile properties. The tow can be shipped for further processing, or it can be converted into staple-length fiber by simply cutting it into specified lengths, usually an inch to several inches long. When manmade fibers are produced for blending with natural fibers, they are cut into similar lengths as the natural fibers, typically 1.5-5.0 in (3.8-12.5 cm) (Kroschwitz, 1986). A baling unit following the cutting machine collects and bales the cut fiber (Kent, 1992).

Wastes generated during fiber processing operations arise from the spin finish application and drying steps (Wellman, 1997). During processing, fiber finishes can be sources of volatile and hazardous air pollutants that may be emitted into the air and into wastewater (AFMA, 1997).

III.B.4. Supporting Operations

Solvent Recovery

Solvents used in spinning processes are typically recovered by distillation. Other recovery systems include gas adsorption and condensation and are specific to either fiber type or spinning method. Dry spinning processes typically use condenser or scrubbers for recovering solvent from the spin cell. Distillation columns are used to recover solvent from the condenser, scrubber, and wash water. Efficient solvent recovery is particularly important in dry spinning since solvent is used at three to five times the quantity of polymer. Wet spinning processes typically use distillation to recover solvent from the spinning bath, drawing, and washing operations. Scrubbers and condensers are used to recover solvent emissions from the spinning cells and the dryers. Carbon adsorption is used to recover emissions from storage tank vents and from mixing and filtering operations (EPA, 1993). Refer to Section III.A. for a more detailed discussion of pollution control equipment.

III.C. Raw Material Inputs and Pollution Outputs in the Production Line

Raw material inputs to plastic resin and manmade fibers industries primarily consist of synthetic organic chemicals, such as ethylene glycol and acrylonitrile, and refined petroleum products, such as ethylene. The majority of these chemicals are used either as monomers or as monomer precursors. Other uses are as solvents, catalysts, and additives. Because chemical processes rarely convert 100 percent of raw materials to desired products, byproducts and unreacted monomer may constitute a large part of facilities' wastestreams. Pollutant outputs generally include VOCs, off-spec or contaminated polymer, and wastewater from equipment cleaning. Typical wastestreams associated with processes involved in plastic resin and manmade fiber manufacture are listed in Table 9. Wastestreams vary depending on what polymer is being synthesized, what fiber spinning method is used, and whether a batch or continuous process is used. Small-scale batch facilities that make polymers to order often have complex and variable wastestreams (New Jersey Hazardous Waste Facilities Siting Commission, 1987).

Air Emissions

Over 70 percent of TRI releases for plastic resin and manmade fiber plants are in the form of air emissions. Commonly released chemicals include carbon disulfide, methanol and other volatile solvents and monomers. Typical chemicals released are listed in the following section on TRI releases and transfers. Air emissions from plastic resin and manmade fiber plants arise from point sources and fugitive emission sources, such as valves, pumps, tanks, compressors, etc. Point sources of air emissions may include monomer storage and feed dissolver tanks and reactors.

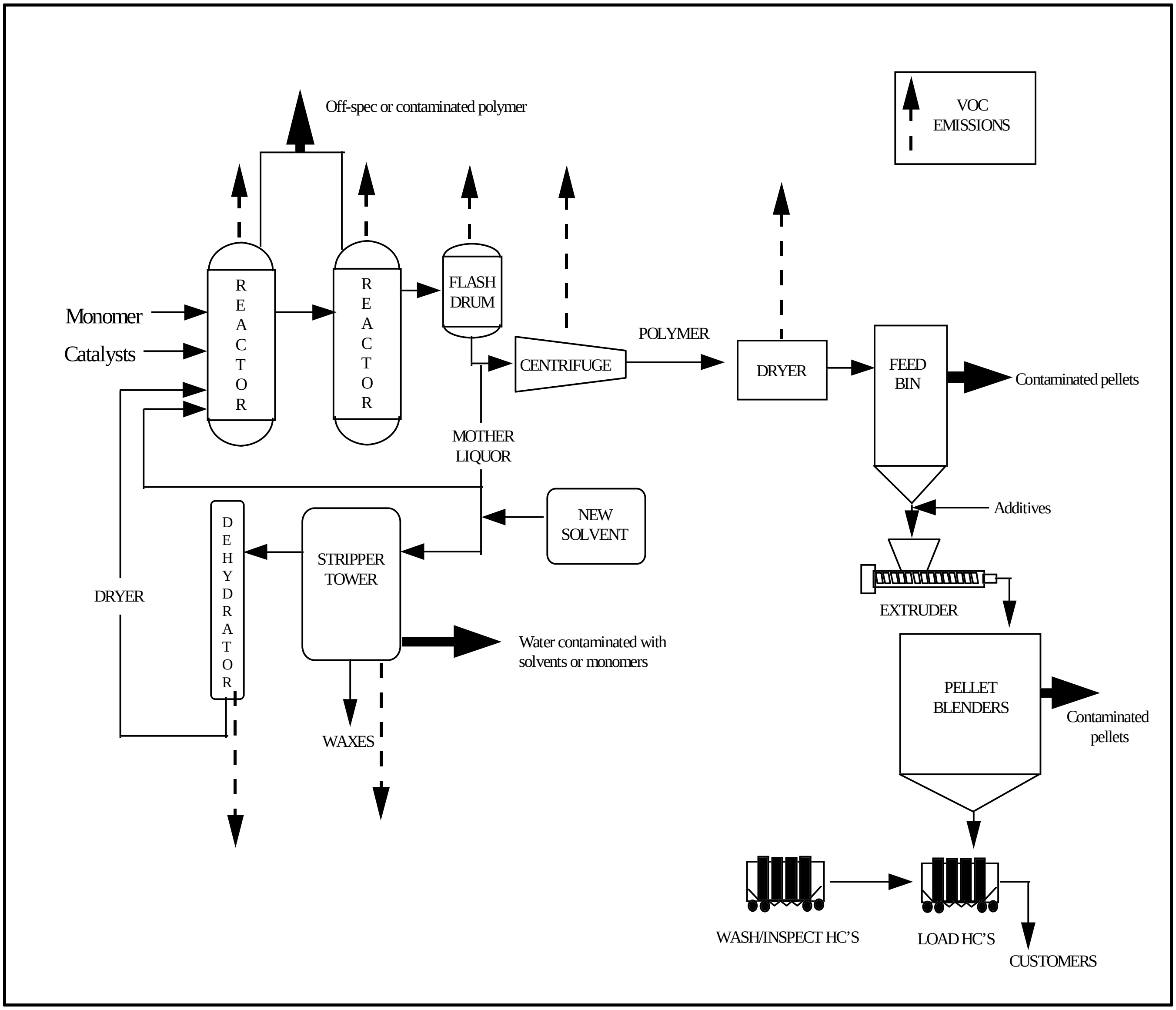
While individual leaks are typically small, the sum of all fugitive leaks at a plant can be one of its largest emission sources. Fugitive emissions can be emitted continuously or intermittently. Continuous air emissions may be emitted from monomer recovery systems, dryer stacks and miscellaneous solid handling vents, centrifuge vents, and blending operations. Fugitive emissions can also result from volatilization of monomers, solvents, and other volatile organic compounds during polymerization; sublimation of solids during resin production; wastewater treatment; and volatilization of solvents during storage and handling of resins. These emissions are largely controlled by solvent and monomer recovery systems. Potential VOC emission release points for a typical polymerization method are shown in Figure 16. In the figure, volatile organic compounds emitted from particular operations are shown as dashed lines, and solid wastes and water wastes are shown by bolded arrows.

Table 9: Summary of Potential Releases Emitted During Plastic Resin and Manmade Fiber Manufacturing

Process	Air Emissions	Process Wastewater	Residual Wastes
Preparing Reactants	volatilized monomer, solvents	little or no wastewater produced	raw material drum residuals
Polymerization	volatilized monomer, solvents, reaction byproducts	little or no wastewater produced	off-specification or contaminated polymer, reaction byproducts, spent equipment oil, spent solvent, catalyst manufacture waste, gas purification catalyst waste
Polymer Recovery	volatilized solvents and unreacted monomer	little or no wastewater produced	little or no residual waste produced
Polymer Extrusion	volatilized solvents and unreacted monomer	extruder quench water	off-specification or contaminated polymer
Equipment Cleaning	volatilized solvents and unreacted monomer	reactor and floor wash water contaminated with organics, acids, and salts; equipment rinse water	little or no residual waste produced
Unloading and Storage of Reactants	volatilized monomer and solvents	Rinse water from cleaning out transport vehicles containing solvents, monomers, and other reactants	little or no residual waste produced
Conveyance and Pellet Storage	volatilized residual monomer or solvents from plastic pellets	little or no wastewater produced	plastic pellets from leaks or spills
Spinning	volatilized residual monomer solvents, additives, other organics, volatilized finishes	water contaminated with residual monomer solvents, additives, other organics, finishes	off-spec polymer, off-spec fiber, and residual finishes
Fiber Processing	volatilized residual monomer solvents, additives, other organics, volatilized finishes	water contaminated with residual monomer, solvents, additives, other organics	residual monomer and solvents; off-spec fibers
Pollution Control Systems	volatilized solvents and unreacted monomer	water contaminated with residual solvents and unreacted monomer; air stripper water	little or no residual waste produced

Source: U.S. EPA, *AP-42*, Office of Air and Radiation, 1993; U.S. EPA, *Best Management Practices for Pollution Prevention in the Textile Industry,* Office of Research and Development, 1995; *SOCMA Pollution Prevention Study,* Prepared for SOCMA, Washington, DC, 1993; Randall, P.M., "Pollution Prevention Strategies for Minimizing of Industrial Wastes in the Vinyl Chloride Monomer - Polyvinyl Chloride Industry," in *Environmental Progress,* volume 13, no. 4, November 1994; AFMA, 1997; Wellman, 1997.

Figure 16: Potential Emissions from Plastic Resin Manufacturing Operations



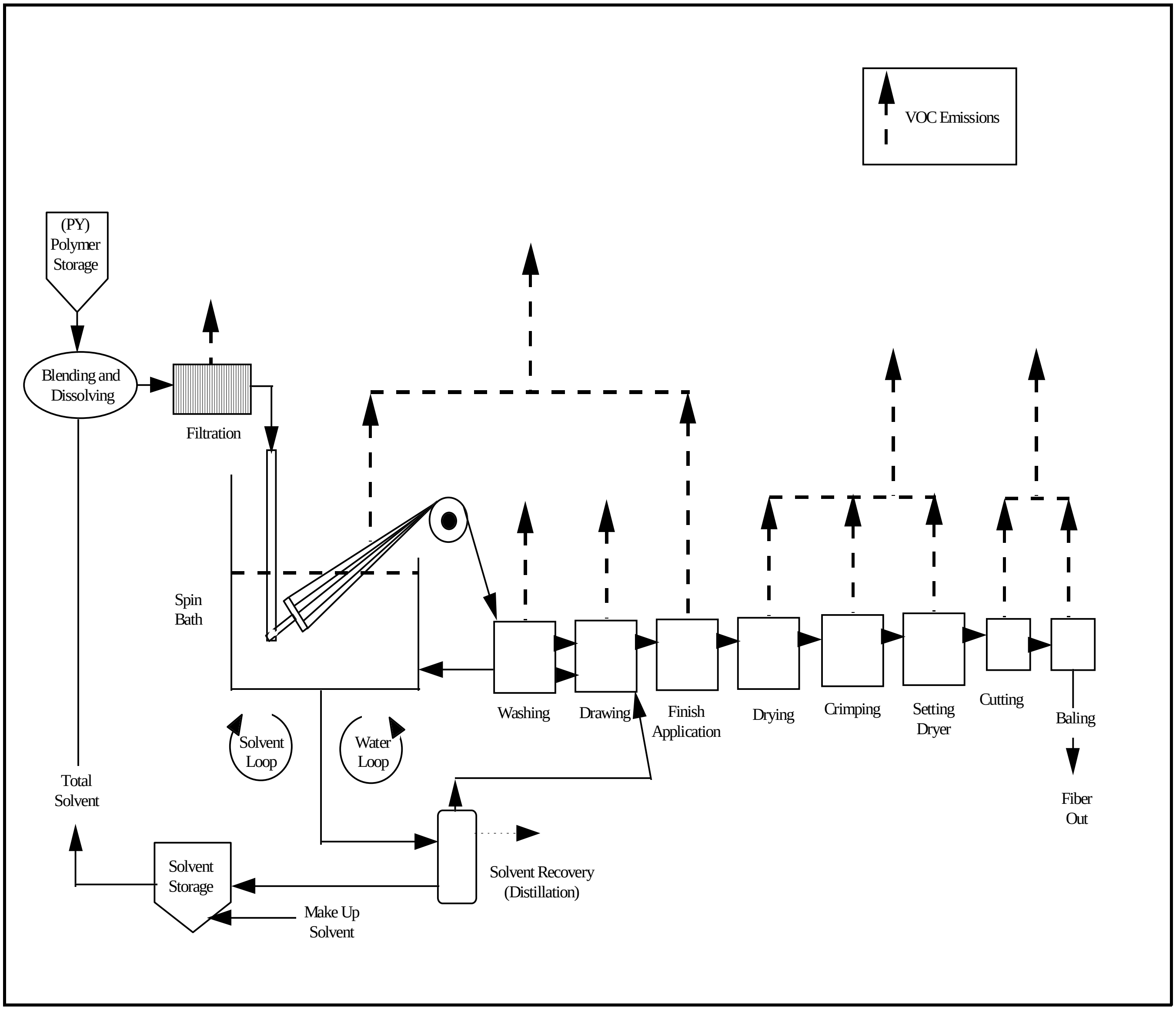
Adapted from *Exxon Chemical Company's Mont Belvieu Plastics Plant Brochure*; Synthetic Organic Chemical Manufacturers Association, *SOCMA Pollution Prevention Study,* Prepared for SOCMA, Washington, DC, 1993; Randall, P.M., "Pollution Prevention Strategies for Minimizing of Industrial Wastes in the Vinyl Chloride Monomer - Polyvinyl Chloride Industry," in *Environmental Progress,* volume 13, no. 4, November 1994; U.S. EPA, *AP-42,* Office of Air and Radiation, 1993.

Sources of intermittent air emissions typically include unloading and charging operations, reactors, safety valves, stripping towers, pumps, flanges, filters, strainers, and seals (Randall, 1994). Fugitive emissions can be reduced through a number of techniques, including installing leak resistant equipment such as sealless pumps and bellows valves, reducing the number of tanks and other potential sources, and in the case of light liquid or vapor systems, implementing an ongoing leak detection and repair program (Wellman, 1997).

In addition to pollutants emitted during polymerization, fiber finishes are sources of volatile and hazardous air pollutants emitted from manmade fiber processing operations. Because melt spinning does not require the use of solvents, melt spinning emits significantly less VOCs than dry or wet spinning processes. Dry spinning typically emits the largest amounts of VOC per pound of fiber produced of the three main spinning methods. Dry spinning can emit from 5 to 150 kg total non-methane organic carbons (TNMOC) per Mg of product, while melt spinning can emit less than 5 kg TNMOC per Mg product. Wet spun fibers typically emit 5 to 20 kg TNMOC per MG product. Air pollutant emissions include volatilized residual monomer, fiber lubricants, organic solvents, additives, and other organic compounds used in fiber processing (EPA, 1993).

Unrecovered solvent accounts for some of the VOC emissions from fiber spinning processes, particularly for acetate production. Typically, 94 to 98 percent of the solvents used in fiber spinning processes is recovered. The largest amounts of unrecovered solvent are emitted from the fiber spinning and drying steps. Other emission sources include dope preparation (dissolving the polymer, blending the spinning solution, and filtering the dope), fiber processing (drawing, washing, crimping), and solvent recovery. Figure 17 illustrates the potential release points of VOCs in a typical fiber spinning operation (EPA, 1993). Other pollutants emitted during manufacturing include air pollutants emitted during combustion. Criteria air pollutants, such as SO_x, NO_x, CO, and CO_2, are emitted from combustion equipment used to heat reactors, dryers, and other process equipment.

Figure 17: VOC Emissions from Fiber Processing Operations



Source: U.S. EPA, *AP-42,* Office of Air and Radiation, 1993.

Wastewater

Plastic resin and manmade fiber facilities generate relatively large amounts of wastewater from processes, cooling operations, utilities and maintenance, and air pollution control systems. Unless solvents are used in polymerization processes, wastewater contaminants are usually restricted to off-spec polymer, polymer, and raw materials (EPA, 1987). Wastewater streams from polymerization operations typically contain dilute concentrations of organics, acids, and salts. Process wastewater may be generated from water that comes into direct contact with raw materials, intermediate products, finished products, byproducts, or waste product. Process wastewater may also be generated from indirect contact process water discharged from vacuum jets and steam ejectors. Cooling water makes up a large portion of water used in the industries and can either be generated from water that contains contaminants or from water used in noncontact processes, such as water treatment wastes and boiler blowdown (EPA, 1987).

Effluent containing contaminants may also be discharged from batch operations during equipment cleaning. Wastes generated from cleaning operations include vessel wash waters, floor wash waters, equipment draining, sump draining, and air stripper water effluent. These discharges can be minimized by initiating water conservation programs and by cleaning reactors using high-pressure water or process solvents which can be recycled into the reactor (SOCMA, 1993).

Wastewater is also generated during monomer and polymer recovery processes, such as centrifuging, monomer stripping, and slurry tanks. Process sources generate liquid wastes with relatively high concentrations of contaminants, including equipment oil, spent solvent, and raw material drum residuals. Leaks and spills also generate waste and often occur at pumps, flanges, valves, and agitator seals. Loading/unloading operations and bag filling operations also are common sources of leaks and spills (Randall, 1994). In addition to pollutants emitted during polymerization, fiber finishes are sources of volatile and hazardous pollutants found in manmade fiber plant wastewater. Spin finishes may increase biological oxygen demand (BOD) and chemical oxygen demand (COD) and some may be toxic to aquatic life (EPA, 1995).

Residual Wastes

Residual wastes make up a significant portion of wastes from plastic resin and manmade fiber facilities. Unless solvents are used in polymerization processes, residual wastes are usually restricted to off-spec polymer, polymer, and raw material chemicals (EPA, 1987). Typical contaminants include contaminated polymer, catalyst manufacture waste, gas purification catalyst waste, reaction by-products, waste oil, and general plant wastes (Clements and Thompson, 1993). Although properly run and maintained plants with new technology may be capable of obtaining 95 percent or higher polymer yields, off-spec and contaminated polymer is still generated and makes up a sizeable portion of the wastestream. Unreacted or improperly reacted polymer synthesis or regeneration residues may include monomers, oligomers, metals, degradation products, solvents, and coagulants (EPA, 1995). Other sources of residual waste include cleanup absorbents, spent activated carbon, laboratory wastes, and air pollution control residues (SOCMA, 1993). Process-related residual waste can be reduced by implementing better inventory control practices, personnel training, and enhanced process control systems. Process changes and raw material substitutions can also be used to reduce residual waste pollution.

III.D. Pollution Control Systems

Recovery of raw materials, such as solvents and monomers, is widely practiced in the industries and is highly integrated into industrial processes as a means to reduce costs associated with raw materials and subsequent treatment of waste. During the polymer separation step, often solvent and monomers are flashed from the reaction mixture. The flashed monomer and solvent are then condensed into liquids using a compressor and separated using vacuum distillation. Monomer and comonomer are passed through a series of distillation columns to increase purity. These chemicals may then be sent to either a monomer recovery unit or an incinerator to be burned as fuel or to reduce air emissions through thermal destruction. Wastewater can be generated during monomer and polymer recovery processes, such as centrifuging, monomer stripping, and slurry tanks (AFMA, 1997; EPA, 1987). Selected equipment and methods used by the industries to recover raw materials and reduce air and water pollution are described below.

Air Pollution Control Systems

Condensers. Condensers are widely used in the plastic resin and manmade fiber industries to recover monomers and solvents from process operations (a process condenser) and as air pollution control devices to remove VOCs from vented gases. Process condensers differ from condensers used as air pollution control devices as the primary purpose of a process condenser is to recover material as an integral part of a unit operation. The process condenser is the first condenser located after the process equipment and supports a vapor-to-liquid phase change for the vapors produced in the process equipment. Examples of process condensers include distillation condensers, reflux condensers, process condensers in line before the vacuum source, and process condensers used in stripping or flashing operations (EPA, 1978). Vents on condensers can be sources of VOC emissions.

Adsorption. Adsorption is another method for removing VOCs from individual process wastestreams through organic vapor recovery. This method can be used to filter out and recover solvents by passing process streams through a packed column of activated carbon or any other porous surface which has a microcrystalline structure. As the gas stream passes through the column, the VOCs adsorb to the column surface. Eventually, the adsorption material in the column becomes clogged with adsorbed contaminants and must be either regenerated or disposed (Masters, 1991; EPA, 1987; CMA, 1989).

Scrubbers. Scrubbers or gas absorbers are used to remove one or more constituents from a gas stream by treatment with a liquid. When using a scrubber as an air pollution control device, the solubility of the constituents in the gas stream in the absorbing liquid must be determined. The main types of scrubbers are the packed tower, plate or tray tower, venturi scrubber, and spray tower (EPA, 1978).

Combustion or Incineration. Another method for controlling VOC emissions is combustion or incineration. Although combustion systems can achieve high removal efficiencies, these systems are typically more expensive to install, operate, and maintain and have secondary emissions associated with their operation. Additionally, scrubbers may be required to control inorganic gases produced as byproducts of combustion (EPA, 1978).

Water Pollution Control Systems

Distillation. Distillation is used to separate liquids for recovery. Two widely used types of distillation are batch and continuous (or fractionation). Batch distillation is used when components' vapor pressures vary widely. In batch distillation, solvent waste is first placed inside a container where heat is applied and condensed overhead vapor is removed simultaneously. Continuous distillation is commonly used to separate multiple fluids from a wastestream and uses a column that contains multiple trays or packing materials to provide high vapor-liquid surface area. Vapors that rise to the top of the heated column are condensed and removed, while a portion is returned to the column for further fractionation. Lower boiling solvents progressively enter the vapor, leaving a liquid with less volatile contaminants at the bottom of the column (CMA, 1989).

Gas Stripping (Air and Steam). Stripping can be used to remove relatively volatile components that are dissolved or emulsified in wastewater. This is achieved through the passage of air, steam, or other gas through the liquid. The stripped volatiles are usually processed by further recovery or incineration. In air stripping processes, a liquid containing dissolved gases is brought into contact with air in a stripping tower, causing an exchange of gases between the air and the solution. If the concentrations of gases are low, the gases can be emitted directly to the air. If the concentrations are high, these gases are passed to air pollution control devices.

In steam stripping processes, volatile components are distilled by fractionation from a wastewater stream. Steam stripping towers operate by passing preheated wastewater downward through the distillation column. Superheated steam and organic vapors flow countercurrent to the wastewater stream, rising up from the bottom of the column. Contact between the two streams progressively reduces the concentrations of VOCs in the wastewater as it approaches the bottom of the column. Reflux condensing may be used to alter the composition of the vapor stream taken from the stripping column (EPA, 1987).

III.E. Management of Chemicals in the Production Process

The Pollution Prevention Act of 1990 (PPA) requires facilities to report information about the management of Toxics Release Inventory (TRI) chemicals in waste and efforts made to eliminate or reduce those quantities. These data have been collected annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years from 1994 through 1997 and are meant to provide a basic understanding of the quantities of waste handled by the industries, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

While the quantities reported for 1994 and 1995 are estimates of quantities already managed, the quantities reported for 1996 and 1997 are projections only. The PPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy. Future-year estimates are not commitments that facilities reporting under TRI are required to meet.

Table 10 shows that the TRI reporting plastic resin manufacturing facilities managed about 1.4 billion pounds of production related wastes (total quantity of TRI chemicals in the waste from routine production operations in column B) in 1995. The yearly data in column B indicate that plastic resin manufacturing facilities substantially lowered the amount of production-related waste managed between 1994 and 1995. Projections for production-related waste management indicate slight increases between 1995 and 1996 followed by a slight decrease in 1997. Values in column C are intended to reveal the percentage of TRI chemicals that are either transferred off-site or released to the environment. Column C is calculated by dividing the total TRI transfers and releases (reported in Sections 5 and 6 of the TRI Form R) by the total quantity of production-related waste (reported in Section 8). The percentage of TRI chemicals transferred off-site or released to the environment by the plastic resin industry increased more than three fold between 1994 and 1995.

The data indicate that about 82 percent of the TRI wastes are managed onsite through recycling, energy recovery, or treatment (columns D, E, and F, respectively) in 1995. About 13 percent of the wastes were managed off-site. The remaining portion of TRI chemical wastes (about 5 percent), shown in column J, were released to the environment through direct discharges to air, land, water, and underground injection, or were disposed off-site. The overall proportions of wastes managed onsite (columns G, H, and I) and off-site (columns D, E, and F) are expected to remain relatively constant between 1995 and 1997. Note that between 1994 and 1995 the proportion of waste treated on-site decreased by 12.5 percent and the proportion of waste recycled on-site increased by almost 16 percent.

Table 10: Source Reduction and Recycling Activity for the Plastic Resin Industry (SIC 2821) as Reported Within TRI

A	B	C	On-Site			Off-Site			J
			D	E	F	G	H	I	
Year	Quantity of Production-Related Waste (10^6 lbs.)[a]	% Released and Transferred[b]	% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated	% Released and Transferred[b]
1994	4,116	5.1	23.5	11.8	43.2	1.7	7.4	3.7	8.8
1995	1,363	18.8	39.3	11.9	30.6	6.2	4.4	2.6	5.1
1996[p]	1,448	N/A	36.1	15.8	27.7	7.3	3.8	2.1	7.2
1997[p]	1,432	N/A	37.0	15.2	28.3	7.4	3.6	2.0	6.5

Source: *U.S. EPA, Toxic Release Inventory Database, 1995.*

[a] Within this industry sector, non-production related waste < 1% of production related wastes for 1995.

[b] Total TRI transfers and releases as reported in Section 5 and 6 of Form R as a percentage of production related wastes.

[c] Percentage of production related waste released to the environment and transferred off-site for disposal.

[p] Represents projected wastes for 1996 and 1997.

Table 11 shows that the TRI reporting manmade fiber manufacturing facilities managed about 689 million pounds of production related wastes (total quantity of TRI chemicals in the waste from routine production operations in column B) in 1995. The yearly data in column B indicate that fiber manufacturing facilities project yearly increases in production-related waste between 1994 and 1997. Values in column C are intended to reveal the percentage of TRI chemicals that are either transferred off-site or released to the environment. Column C is calculated by dividing the total TRI transfers and releases (reported in Sections 5 and 6 of the TRI Form R) by the total quantity of production-related waste (reported in Section 8). The percentage of TRI chemicals transferred off-site or released to the environment by the manmade fiber industry decreased slightly between 1994 and 1995.

The data indicate that about 79 percent of the TRI wastes are managed onsite through recycling, energy recovery, or treatment (columns D, E, and F, respectively) in 1995. About 7 percent of the wastes were managed off-site. The remaining portion of TRI chemical wastes (about 14 percent), shown in column J, were released to the environment through direct discharges to air, land, water, and underground injection, or were disposed off-site. The overall proportions of wastes managed onsite (columns G, H, and I) are expected to increase by 7.3 percent between 1995 and 1997. The overall proportions of wastes managed off-site (columns D, E, and F) are expected to decrease by 1.9 percent between 1995 and 1997. Note that between 1995 and 1997 the proportion of waste treated on-site is expected to decrease by 12.3 percent and the proportion of waste recycled on-site is expected to increase by about 20 percent.

Table 11: Source Reduction and Recycling Activity for the Manmade Fiber Industry (SIC 2823, 2824) as Reported Within TRI

A	B	C	On-Site			Off-Site			J
			D	E	F	G	H	I	
Year	Quantity of Production-Related Waste (10^6 lbs.)[a]	% Released and Transferred[b]	% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated	% Released and Transferred[b]
1994	634	21.0	23.0	0.70	55.5	7.6	0.50	0.13	12.9
1995	689	20.8	30.5	0.75	48.0	6.2	0.23	0.29	14.2
1996[p]	814	N/A	43.5	0.65	39.7	4.8	0.13	0.29	10.9
1997[p]	908	N/A	50.3	0.56	35.7	4.3	0.13	0.40	8.6

Source: *U.S. EPA, Toxic Release Inventory Database, 1995.*

[a] Within this industry sector, non-production related waste < 1% of production related wastes for 1995.
[b] Total TRI transfers and releases as reported in Section 5 and 6 of Form R as a percentage of production related wastes.
[c] Percentage of production related waste released to the environment and transferred off-site for disposal.
[p] Represents projected wastes for 1996 and 1997.

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IV. CHEMICAL RELEASE AND TRANSFER PROFILE

This section is designed to provide background information on the pollutant releases that are reported by this industry. The best source of comparative pollutant release information is the Toxic Release Inventory (TRI). Pursuant to the Emergency Planning and Community Right-to-Know Act, TRI includes self-reported facility release and transfer data for over 600 toxic chemicals. Facilities within SIC Codes 20 through 39 (manufacturing industries) that have more than 10 employees, and that are above weight-based reporting thresholds are required to report TRI on-site releases and off-site transfers. The information presented within the sector notebooks is derived from the most recently available (1995) TRI reporting year (which includes over 600 chemicals), and focuses primarily on the on-site releases reported by each sector. Because TRI requires consistent reporting regardless of sector, it is an excellent tool for drawing comparisons across industries. TRI data provide the type, amount and media receptor of each chemical released or transferred.

Although this sector notebook does not present historical information regarding TRI chemical releases over time, please note that in general, toxic chemical releases have been declining. In fact, according to the 1995 Toxic Release Inventory Public Data Release, reported onsite releases of toxic chemicals to the environment decreased by 5 percent (85.4 million pounds) between 1994 and 1995 (not including chemicals added and removed from the TRI chemical list during this period). Reported releases dropped by 46 percent between 1988 and 1995. Reported transfers of TRI chemicals to off-site locations increased by 0.4 percent (11.6 million pounds) between 1994 and 1995. More detailed information can be obtained from EPA's annual Toxics Release Inventory Public Data Release book (which is available through the EPCRA Hotline at 800-535-0202), or directly from the Toxic Release Inventory System database (for user support call 202-260-1531).

Wherever possible, the sector notebooks present TRI data as the primary indicator of chemical release within each industrial category. TRI data provide the type, amount and media receptor of each chemical released or transferred. When other sources of pollutant release data have been obtained, these data have been included to augment the TRI information.

TRI Data Limitations

Certain limitations exist regarding TRI data. Release and transfer reporting are limited to the approximately 600 chemicals on the TRI list. Therefore, a large portion of the emissions from industrial facilities are not captured by TRI. Within some sectors, (e.g. dry cleaning, printing and transportation equipment cleaning) the majority of facilities are not subject to TRI reporting because they are not considered manufacturing industries, or because they are below TRI reporting thresholds. For these sectors, release information from other sources has been included. In addition, many facilities report more than one SIC code reflecting the multiple operations carried out onsite. Therefore, reported releases and transfers may or may not all be associated with the industrial operations described in this notebook.

The reader should also be aware that TRI "pounds released" data presented within the notebooks is not equivalent to a "risk" ranking for each industry. Weighting each pound of release equally does not factor in the relative toxicity of each chemical that is released. The Agency is in the process of developing an approach to assign toxicological weightings to each chemical released so that one can differentiate between pollutants with significant differences in toxicity. As a preliminary indicator of the environmental impact of the industry's most commonly released chemicals, the notebook briefly summarizes the toxicological properties of the top five chemicals (by weight) reported by each industry.

Definitions Associated With Section IV Data Tables

General Definitions

SIC Code -- the Standard Industrial Classification (SIC) is a statistical classification standard used for all establishment-based Federal economic statistics. The SIC codes facilitate comparisons between facility and industry data.

TRI Facilities -- are manufacturing facilities that have 10 or more full-time employees and are above established chemical throughput thresholds. Manufacturing facilities are defined as facilities in Standard Industrial Classification primary codes 20-39. Facilities must submit estimates for all chemicals that are on the EPA's defined list and are above throughput thresholds.

Data Table Column Heading Definitions

The following definitions are based upon standard definitions developed by EPA’s Toxic Release Inventory Program. The categories below represent the possible pollutant destinations that can be reported.

RELEASES -- are an on-site discharge of a toxic chemical to the environment. This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

Releases to Air (Point and Fugitive Air Emissions) -- Include all air emissions from industry activity. Point emissions occur through confined air streams as found in stacks, vents, ducts, or pipes. Fugitive emissions include equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems.

Releases to Water (Surface Water Discharges) -- encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water. Releases due to runoff, including storm water runoff, are also reportable to TRI.

Releases to Land -- occur within the boundaries of the reporting facility. Releases to land include disposal of toxic chemicals in landfills, land treatment/application farming, surface impoundments, and other land disposal methods (such as spills, leaks, or waste piles).

Underground Injection -- is a contained release of a fluid into a subsurface well for the purpose of waste disposal. Wastes containing TRI chemicals are injected into either Class I wells or Class V wells. Class I wells are used to inject liquid hazardous wastes or dispose of industrial and municipal wastewaters beneath the lowermost underground source of drinking water. Class V wells are generally used to inject non-hazardous fluid into or above an underground source of drinking water. TRI reporting does not currently distinguish between these two types of wells, although there are important differences in environmental impact between these two methods of injection.

TRANSFERS -- is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI. Chemicals reported to TRI as transferred are sent to off-site facilities for the purpose of recycling, energy recovery, treatment, or disposal. The quantities reported represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, the reported quantities do not necessarily represent entry of the chemical into the environment.

Transfers to POTWs -- are wastewaters transferred through pipes or sewers to a publicly owned treatments works (POTW). Treatment or removal of a chemical from the wastewater depends on the nature of the chemical, as well as the treatment methods present at the POTW. Not all TRI chemicals can be treated or removed by a POTW. Some chemicals, such as metals, may be removed, but are not destroyed and may be disposed of in landfills or discharged to receiving waters.

Transfers to Recycling -- are sent off-site for the purposes of regenerating or recovery by a variety of recycling methods, including solvent recovery, metals recovery, and acid regeneration. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

Transfers to Energy Recovery -- are wastes combusted off-site in industrial furnaces for energy recovery. Treatment of a chemical by incineration is not considered to be energy recovery.

Transfers to Treatment -- are wastes moved off-site to be treated through a variety of methods, including neutralization, incineration, biological destruction, or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

Transfers to Disposal -- are wastes taken to another facility for disposal generally as a release to land or as an injection underground.

IV.A. EPA Toxic Release Inventory for the Plastic Resin and Manmade Fiber Industries

This section summarizes TRI data of plastic resin and manmade fiber manufacturing facilities reporting SIC codes 2821, 2823, or 2824 as the primary SIC code for the facility.

According to the 1995 Toxics Release Inventory (TRI) data, 444 plastic resin and manmade fiber manufacturing facilities reporting SIC 2821, 2823, or 2824 released (to the air, water, or land) and transferred (shipped off-site or discharged to sewers) a total of 399 million pounds of toxic chemicals during calendar year 1995. This represents approximately seven percent of the 5.7 billion pounds of releases and transfers from all manufacturers (SICs 20-39) reporting to TRI that year. The top three chemicals released by volume are carbon disulfide, nitrate compounds, and ethylene. These three account for about 51 percent (82 million pounds) of the industries' total releases. Ethylene glycol, used in making polyester, accounts for 45 percent (107 million pounds) of the total TRI chemicals transferred by the industries. The variability in facilities' TRI chemical profiles may be attributed to the variety of processes and products in the industries. Note that over half of the chemicals were reported by fewer than ten facilities.

Plastic Resins

Releases

Table 12 presents the number and volumes of chemicals released by plastic resin manufacturing facilities reporting SIC 2821 in 1995. About 410 plastic resin facilities reported TRI emissions for 184 chemicals in 1995. The total volume of releases was 64.1 million pounds or 25 percent of the total volume of chemicals reported to TRI by the plastic resin industry (i.e. releases and transfers). The top five chemicals released by this industry, in terms of volumes, include: ethylene, methanol, acetonitrile, propylene, and ammonia. The very volatile nature of these chemicals is apparent in the fact that about 74 percent (48 million pounds) of the industry's releases are to the air. About 49 percent (31.4 million pounds) of all the TRI chemicals released by the plastic resin industry were released to air in the form of point source emissions, and 25 percent (16.3 million pounds) were released as fugitive air emissions. Roughly 21 percent (13.3 million pounds) of releases were by underground injection. The remaining five percent were released as water discharges and disposals to land.

Transfers

Table 13 presents the number and volumes of chemicals transferred by plastic resin manufacturing facilities reporting SIC 2821, in 1995. The total volume of transfers was 192 million pounds or 75 percent of the total volume of chemicals reported to TRI by the plastic resin industry (i.e. releases and transfers). Transfers to recycling and energy recovery accounted for the largest amount, 46 percent (88.5 million pounds) and 31 percent (60.2 million pounds), respectively. About 16 percent (30.5 million pounds) was transferred off-site for treatment, with the remaining seven percent (13.2 million pounds) transferred for either disposal or POTW treatment. Four chemicals (ethylene glycol, N-hexane, xylene (mixed isomers), and vinyl acetate) accounted for about 59 percent of the 192 million pounds of total transfers for this industry. Ethylene glycol alone accounted for about 34 percent (65.0 million pounds) of the total transfers and was primarily recycled.

Manmade Fibers

Releases

Table 14 presents the number and volumes of chemicals released by manmade fiber manufacturing facilities reporting SIC 2823 or 2824 in 1995. Thirty-four manmade fiber facilities reported TRI emissions for 116 chemicals in 1995. The total volume of releases was 95.9 million pounds or 67 percent of the total volume of TRI chemicals reported by the manmade fiber industry (i.e. releases and transfers). The top five chemicals released by this industry, in terms of volumes, include: carbon disulfide, nitrate compounds, hydrochloric acid, formic acid, and methanol.

A typical manmade fiber facility averaged 2.8 million pounds of releases and 1.4 million pounds of transfers. The high release average is attributed largely to the release of carbon disulfide by four facilities. Carbon disulfide, used in making rayon, accounted for about 62 percent (59.5 million pounds) of TRI releases for the industry. Even eliminating carbon disulfide from the average release calculation reveals that manmade fiber facilities still average about 1.1 million pounds of releases per facility. These relatively high releases and transfers per facility may reflect the large volumes of material processed at a relatively small number of facilities.

About 72 percent (69.5 million pounds) of all the chemicals released by the manmade fiber industry were released to air in the form of point source emissions, and six percent (6.3 million pounds) were released as fugitive air emissions. Roughly 19 percent (17.9 million pounds) of releases were by underground injection. The remaining three percent were released as water discharges and disposals to land.

Transfers

Table 15 presents the number and volumes of chemicals transferred by manmade fiber manufacturing facilities reporting SIC 2823 or 2824, in 1995. The total volume of transfers off-site was 47.3 million pounds or 33 percent of the total volume of chemicals reported to TRI by the manmade fiber industry (i.e. releases and transfers). Transfers to recycling accounted for 90 percent of all transfers (42.5 million pounds). The remaining 10 percent (4.8 million pounds) was transferred for disposal, treatment, energy recovery, or to a POTW. Ethylene glycol accounted for about 90 percent of the industry's transfers (42.5 million pounds), and was primarily recycled.

Table 12: 1995 TRI Releases for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
STYRENE	169	691,663	2,194,288	724	0	13,524	2,900,199	17,161
METHANOL	117	1,151,653	3,514,948	300,637	231,524	609	5,199,371	44,439
ETHYLENE GLYCOL	94	565,134	878,651	136,554	0	130,051	1,710,390	18,196
TOLUENE	87	507,664	543,594	1,130	0	1,175	1,053,563	12,110
XYLENE (MIXED ISOMERS)	87	287,506	541,365	318	0	40	829,229	9,531
AMMONIA	83	283,371	724,002	98,963	1,900,000	8,307	3,014,643	36,321
METHYL METHACRYLATE	80	148,666	329,859	386	0	1,056	479,967	6,000
FORMALDEHYDE	78	213,263	554,705	117,744	26,000	26,029	937,741	12,022
BUTYL ACRYLATE	75	40,469	40,180	172	0	559	81,380	1,085
ETHYLBENZENE	67	102,350	184,558	452	0	261	287,621	4,293
VINYL ACETATE	58	488,372	1,462,610	8,088	0	1,717	1,960,787	33,807
MALEIC ANHYDRIDE	57	9,117	15,050	12	0	1,000	25,179	442
ZINC COMPOUNDS	56	2,282	1,015	11,759	0	110,087	125,143	2,235
ACRYLIC ACID	54	18,559	123,816	57	780,000	47	922,479	17,083
PHTHALIC ANHYDRIDE	54	12,122	27,083	649	0	396	40,250	745
PHENOL	47	107,358	137,001	957	0	4,497	249,813	5,315
HYDROCHLORIC ACID (1995 AND AFTER "ACID AEROSOLS" ONLY)	47	90,798	1,060,560	5	0	0	1,151,363	24,497
CERTAIN GLYCOL ETHERS	46	15,868	9,408	1,531	0	0	26,807	583
DIISOCYANATES	45	13,923	7,042	5	0	5	20,975	466
N-BUTYL ALCOHOL	43	73,768	29,381	67,850	0	750	171,749	3,994
ETHYL ACRYLATE	42	45,868	33,253	495	0	523	80,139	1,908
METHYL ETHYL KETONE	40	78,863	222,717	41	0	14	301,635	7,541
ACRYLONITRILE	39	109,000	523,858	2,809	2,200,000	617	2,836,284	72,725
ETHYLENE	36	3,792,909	7,042,370	0	0	0	10,835,279	300,980
CHLORINE	32	34,923	77,838	8,403	0	0	121,164	3,786
PHOSPHORIC ACID	31	1,867	4,078	5	0	10	5,960	192
ANTIMONY COMPOUNDS	30	915	977	171	250	19,172	21,485	716
4,4'-ISOPROPYLIDENEDIPHENOL	30	34,581	1,694	3,445	0	0	39,720	1,324
NAPHTHALENE	30	46,149	6,860	66	0	59	53,134	1,771
1,2,4-TRIMETHYLBENZENE	30	18,396	7,395	276	0	0	26,067	869
N-HEXANE	29	519,196	1,225,066	244	80	0	1,744,586	60,158

Table 12 (cont.): 1995 TRI Releases for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
1,3-BUTADIENE	28	129,591	329,654	19	0	0	459,264	16,402
PROPYLENE	26	1,637,967	1,944,230	0	0	0	3,582,197	137,777
DICYCLOPENTADIENE	25	44,152	32,195	250	0	0	76,597	3,064
SULFURIC ACID	25	3,777	45	1	0	0	3,823	153
TOLUENE DIISOCYANATE (MIXED ISOMERS)	24	1,040	175	0	0	250	1,465	61
VINYL CHLORIDE	23	170,307	626,332	335	0	1	796,975	34,651
METHYL ACRYLATE	23	21,964	70,767	5,662	0	0	98,393	4,278
ACRYLAMIDE	22	2,554	2,911	1,329	1,600,000	121	1,606,915	73,042
CUMENE	22	141,079	149,870	262	0	5	291,216	13,237
METHYL ISOBUTYL KETONE	22	12,785	54,766	281	0	28	67,860	3,085
DICHLOROMETHANE	20	2,092,888	277,492	409	0	0	2,370,789	118,539
SEC-BUTYL ALCOHOL	20	4,760	2,526	65	0	5	7,356	368
TRIETHYLAMINE	16	32,968	3,259	170	0	0	36,397	2,275
BIPHENYL	15	65,291	3,482	1,354	0	0	70,127	4,675
N-METHYL-2-PYRROLIDONE	15	21,744	18,180	102	0	0	40,026	2,668
NITRATE COMPOUNDS	14	0	0	1,012,654	640,000	5	1,652,659	118,047
CHLORODIFLUOROMETHANE	14	262,468	95,831	5	0	0	358,304	25,593
BENZENE	13	76,370	47,516	77	200	209	124,372	9,567
ACETALDEHYDE	13	122,381	914,889	12,647	24,000	0	1,073,917	82,609
TERT-BUTYL ALCOHOL	13	26,600	8,207	308	0	750	35,865	2,759
N-METHYLOLACRYLAMIDE	13	392	1,270	47	0	34	1,743	134
BENZOYL PEROXIDE	12	87	260	0	0	0	347	29
CYCLOHEXANE	12	73,351	140,347	1,509	0	0	215,207	17,934
1,1-DICHLORO-1-FLUOROETHANE	12	194,482	31,909	0	0	0	226,391	18,866
DIETHANOLAMINE	11	370	84	5	0	0	459	42
CHROMIUM COMPOUNDS	10	549	26	487	400	0	1,462	146
COBALT COMPOUNDS	10	250	96	93	440	9,340	10,219	1,022
COPPER COMPOUNDS	9	533	1,214	7,595	0	980,018	989,360	109,929
TOLUENE-2,4-DIISOCYANATE	9	22	510	0	0	0	532	59
LEAD COMPOUNDS	8	273	510	1,723	0	0	2,506	313
FORMIC ACID	8	4,525	282	139	16,000	0	20,946	2,618

Table 12 (cont.): 1995 TRI Releases for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
N,N-DIMETHYLFORMAMIDE	8	5,533	30,083	255	0	5	35,876	4,485
PROPYLENE OXIDE	8	4,689	17,257	250	0	250	22,446	2,806
EPICHLOROHYDRIN	8	7,782	2,247	0	0	0	10,029	1,254
NITRIC ACID	8	9,986	1,892	0	0	1	11,879	1,485
CHLOROMETHANE	7	37,052	220,010	571	0	5	257,638	36,805
HYDROQUINONE	7	636	128	19	43,000	0	43,783	6,255
DECABROMODIPHENYL OXIDE	7	2,698	387	250	0	0	3,335	476
CRESOL (MIXED ISOMERS)	7	5,730	3,692	30	0	0	9,452	1,350
TITANIUM TETRACHLORIDE	7	182	135	0	0	0	317	45
1,1,1-TRICHLOROETHANE	6	14,203	17,473	48	0	0	31,724	5,287
CHLOROETHANE	6	412,746	329,336	121	0	0	742,203	123,701
1-CHLORO-1,1-DIFLUOROETHANE	6	67,266	1,223,217	1	0	0	1,290,484	215,081
TRICHLOROETHYLENE	6	76,245	8,795	0	0	0	85,040	14,173
DI(2-ETHYLHEXYL) PHTHALATE	6	271	310	15	0	0	596	99
HYDROGEN FLUORIDE	6	1,766	146,625	0	0	0	148,391	24,732
NICKEL COMPOUNDS	5	250	5	322	11,000	0	11,577	2,315
ETHYLENE OXIDE	5	5,085	7,118	250	0	5	12,458	2,492
PHOSGENE	5	123	20	0	0	0	143	29
O-XYLENE	5	68,038	41,387	0	0	0	109,425	21,885
1,2-DICHLOROETHANE	5	98,265	116,224	273	0	0	214,762	42,952
1,4-DIOXANE	5	3,810	1,763	17,246	0	22	22,841	4,568
BARIUM COMPOUNDS	4	255	255	0	0	0	510	128
CARBON TETRACHLORIDE	4	10	140	80	0	0	230	58
CARBON DISULFIDE	4	110,755	958,275	0	0	0	1,069,030	267,258
VINYLIDENE CHLORIDE	4	4,542	97,440	5	0	0	101,987	25,497
TRICHLOROFLUOROMETHANE	4	6,227	1,522	0	0	0	7,749	1,937
CUMENE HYDROPEROXIDE	4	112	1,169	5	0	0	1,286	322
ALLYL ALCOHOL	4	331	7,529	0	55,000	0	62,860	15,715
N,N-DIMETHYLANILINE	4	1,065	0	0	0	0	1,065	266
PROPIONALDEHYDE	4	24,914	16,094	0	0	0	41,008	10,252
CARBONYL SULFIDE	4	7,720	47,748	0	0	0	55,468	13,867
BORON TRIFLUORIDE	4	3,079	165	0	0	0	3,244	811

Table 12 (cont.): 1995 TRI Releases for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
CYANIDE COMPOUNDS	3	0	16	1,232	770,000	0	771,248	257,083
MANGANESE COMPOUNDS	3	250	271	290	250	2,420	3,481	1,160
ANILINE	3	4,036	13,848	2	0	0	17,886	5,962
CHLOROFORM	3	556	5,905	392	0	0	6,853	2,284
HYDROGEN CYANIDE	3	25,000	34,700	0	0	0	59,700	19,900
PROPYLENEIMINE	3	555	0	0	0	0	555	185
FREON 113	3	11,667	219,650	38	0	0	231,355	77,118
DIBUTYL PHTHALATE	3	250	827	0	0	0	1,077	359
TOLUENE-2,6-DIISOCYANATE	3	5	13	0	0	0	18	6
O-CRESOL	3	500	3,746	5	0	0	4,251	1,417
4,4'-METHYLENEDIANILINE	3	685	48	0	0	0	733	244
ACROLEIN	3	56	1,978	0	3,500	0	5,534	1,845
1,3-PHENYLENEDIAMINE	3	1,215	25	0	0	0	1,240	413
CHLOROBENZENE	3	256,001	159,000	6	0	0	415,007	138,336
2-METHOXYETHANOL	3	5,760	3,665	6,000	0	0	15,425	5,142
BUTYRALDEHYDE	3	17,399	35,115	263	0	0	52,777	17,592
DIMETHYL PHTHALATE	3	939	34	29	0	0	1,002	334
HYDRAZINE	3	6	47	0	0	0	53	18
ZINC (FUME OR DUST)	3	5	354	0	0	0	359	120
CADMIUM COMPOUNDS	2	5	6	5	0	0	16	8
DIETHYL SULFATE	2	3,407	19	0	0	0	3,426	1,713
DICHLORODIFLUOROMETHANE	2	49,194	4,404	0	0	0	53,598	26,799
DIMETHYL SULFATE	2	5	6	0	0	0	11	6
ISOBUTYRALDEHYDE	2	1,824	1,677	0	0	0	3,501	1,751
O-TOLUIDINE	2	6,480	1,560	5	0	5	8,050	4,025
ACETOPHENONE	2	3,190	2,100	640	0	0	5,930	2,965
4,4'-METHYLENEBIS(2-CHLOROANILINE)	2	0	0	0	0	0	0	0
ALLYL CHLORIDE	2	870	2,311	0	0	0	3,181	1,591
2-ETHOXYETHANOL	2	575	9,908	0	0	0	10,483	5,242
PYRIDINE	2	2,773	3,250	314	140,000	0	146,337	73,169
ANTHRACENE	2	179	12	2	0	0	193	97
TETRACHLOROETHYLENE	2	628	4,500	0	0	0	5,128	2,564

Table 12 (cont.): 1995 TRI Releases for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
TETRACHLOROETHYLENE	2	628	4,500	0	0	0	5,128	2,564
NICKEL	2	65	0	0	0	0	65	33
COPPER	2	0	0	0	0	0	0	0
SODIUM NITRITE	2	0	0	0	0	0	0	0
ARSENIC COMPOUNDS	1	0	0	0	200	0	200	200
SILVER COMPOUNDS	1	0	0	0	0	0	0	0
PIPERONYL BUTOXIDE	1	0	0	0	0	0	0	0
ACETAMIDE	1	5	0	0	490,000	0	490,005	490,005
THIOUREA	1	0	0	12	0	0	12	12
ISOPROPYL ALCOHOL (MANUFACTURING, STRONG-ACID PROCESS ONLY, NO SUPPLIE	1	250	250	0	0	0	500	500
HEXACHLOROETHANE	1	1	2	0	0	0	3	3
BROMOMETHANE	1	8,600	370,000	3	0	0	378,603	378,603
ACETONITRILE	1	9,000	20,000	0	4,300,000	0	4,329,000	4,329,000
TRICHLOROACETYL CHLORIDE	1	0	1	0	0	0	1	1
DICHLOROTETRAFLUOROETHANE (CFC-114)	1	0	44,035	.	0	0	44,035	44,035
1,2-DICHLOROPROPANE	1	11,818	146,880	1,056	0	0	159,754	159,754
1,1,2-TRICHLOROETHANE	1	898	0	0	0	0	898	898
1,1,2,2-TETRACHLOROETHANE	1	0	0	0	0	0	0	0
1,2-DICHLOROBENZENE	1	91,000	14,000	170	0	100	105,270	105,270
4,4'-DIAMINODIPHENYL ETHER	1	5	17	0	0	0	22	22
2,4-DIMETHYLPHENOL	1	90	150	5	0	0	245	245
P-XYLENE	1	84,000	63,000	0	0	0	147,000	147,000
P-CRESOL	1	250	250	250	0	0	750	750
1,4-DICHLOROBENZENE	1	7,342	435	11	0	0	7,788	7,788
P-PHENYLENEDIAMINE	1	3,200	0	12	0	0	3,212	3,212
CHLOROMETHYL METHYL ETHER	1	2	2,854	10	0	0	2,866	2,866
M-CRESOL	1	250	250	5	0	0	505	505
CYCLOHEXANOL	1	0	0	0	0	0	0	0
2-METHYLPYRIDINE	1	5	0	0	20,000	0	20,005	20,005
PROPOXUR	1	0	5	0	0	0	5	5
CHLORENDIC ACID	1	0	6	0	0	0	6	6

Table 12 (cont.): 1995 TRI Releases for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
DIPHENYLAMINE	1	1,029	2,197	0	0	0	3,226	3,226
DIMETHYLAMINE	1	0	70	0	0	0	70	70
METHACRYLONITRILE	1	0	0	0	990	0	990	990
CHLOROPRENE	1	125	0	0	0	0	125	125
POTASSIUM DIMETHYLDITHIOCARBAMATE	1	0	0	0	0	0	0	0
METHYL PARATHION	1	0	192	0	0	0	192	192
1-CHLORO-1,1,2,2-TETRAFLUOROETHANE	1	0	502,000	.	0	0	502,000	502,000
1,2-DICHLOROETHYLENE	1	253	1,408	0	0	0	1,661	1,661
LITHIUM CARBONATE	1	0	0	0	0	0	0	0
2,6-DIMETHYLPHENOL	1	1,720	780	12	0	0	2,512	2,512
C.I. BASIC RED 1	1	0	0	0	0	0	0	0
MOLYBDENUM TRIOXIDE	1	250	0	0	38,000	0	38,250	38,250
ASBESTOS (FRIABLE)	1	1	1	0	0	0	2	2
ALUMINUM OXIDE (FIBROUS FORMS)	1	0	640	0	0	0	640	640
2-CHLORO-1,1,1,2-TETRAFLUOROETHANE	1	0	127,700	.	0	0	127,700	127,700
CROTONALDEHYDE	1	0	0	0	1,500	0	1,500	1,500
LEAD	1	0	0	0	0	0	0	0
ANTIMONY	1	0	64	110	0	7,544	7,718	7,718
CADMIUM	1	0	5	0	0	0	5	5
CHROMIUM	1	0	120	0	0	0	120	120
COBALT	1	0	0	340	0	2,900	3,240	3,240
TETRAMETHRIN	1	0	0	0	0	0	0	0
PHOSPHORUS (YELLOW OR WHITE)	1	0	0	0	0	0	0	0
BROMINE	1	0	29	0	0	0	29	29
DIAMINOTOLUENE (MIXED ISOMERS)	1	5	5	250	0	5	265	265
OXYFLUORFEN	1	0	0	3	0	0	3	3
PERMETHRIN	1	0	0	0	0	0	0	0
	410	16,247,638	31,388,839	1,842,689	13,292,334	1,324,533	64,096,033	156,332

Table 13: 1995 TRI Transfers for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
STYRENE	169	49,155	80,514	3,473	2,484,986	2,859,959	5,478,087	32,415
METHANOL	117	4,137,730	1,293	2,392,756	1,600,406	4,189,501	12,321,699	105,314
ETHYLENE GLYCOL	94	1,405,804	33,917	57,503,330	2,356,337	3,653,009	64,952,397	690,983
TOLUENE	87	1,343	158,651	1,025,109	275,707	4,588,473	6,049,283	69,532
XYLENE (MIXED ISOMERS)	87	8,881	58,701	2,823,319	6,829,205	6,647,313	16,367,419	188,131
AMMONIA	83	488,000	2,037	.	24,293	5,353	519,683	6,261
METHYL METHACRYLATE	80	249,367	11,407	.	83,811	1,068,305	1,412,890	17,661
FORMALDEHYDE	78	271,686	84,144	8,689	83,875	302,857	751,253	9,631
BUTYL ACRYLATE	75	24,243	2,045	28,229	61,428	67,694	183,639	2,449
ETHYLBENZENE	67	1,949	9,545	141,149	675,363	1,107,753	1,935,759	28,892
VINYL ACETATE	58	187,114	29,140	513,204	8,197,006	5,985,939	14,912,403	257,110
MALEIC ANHYDRIDE	57	876	9,676	.	76,650	21,283	108,485	1,903
ZINC COMPOUNDS	56	24,491	465,019	70	1,314,536	16,350	1,820,466	32,508
ACRYLIC ACID	54	4,096	23	11,455	100,686	189,911	306,171	5,670
PHTHALIC ANHYDRIDE	54	1,503	38,060	2	102,164	40,877	182,606	3,382
PHENOL	47	1,335,607	234,309	12,965	1,091,655	713,248	3,387,784	72,081
HYDROCHLORIC ACID (1995 AND AFTER "ACID AEROSOLS" ONLY)	47	5	45	.	4,743	.	4,793	102
CERTAIN GLYCOL ETHERS	46	1,244,409	36,776	250	305,896	1,023,988	2,611,319	56,768
DIISOCYANATES	45	10	4,941	.	262,788	3,550	271,289	6,029
N-BUTYL ALCOHOL	43	87,572	39,528	282	134,483	451,391	713,256	16,587
ETHYL ACRYLATE	42	25,191	1,079	8	46,005	40,017	112,300	2,674
METHYL ETHYL KETONE	40	81,049	20,856	15,519	128,995	685,946	932,365	23,309
ACRYLONITRILE	39	20,905	802	.	462,028	141,921	625,656	16,042
ETHYLENE	36	17	.	.	14,001	10,615,169	10,629,187	295,255
CHLORINE	32	0	.	.	450	.	450	14
PHOSPHORIC ACID	31	0	1,225	0	14,220	0	15,445	498
ANTIMONY COMPOUNDS	30	11	50,873	252	80,717	2,157	134,010	4,467
4,4'-ISOPROPYLIDENEDIPHENOL	30	101	59,099	.	1,978	330	61,508	2,050
NAPHTHALENE	30	35	8,050	.	118,877	498,457	625,419	20,847
1,2,4-TRIMETHYLBENZENE	30	514	695	.	14,465	199,733	215,407	7,180
N-HEXANE	29	8,080	66,651	8,995,720	356,032	8,275,874	17,702,357	610,426

Table 13 (cont.): 1995 TRI Transfers for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
1,3-BUTADIENE	28	20	8	.	85,966	1,826	87,820	3,136
PROPYLENE	26	5	.	.	1	3,132,222	3,132,228	120,470
DICYCLOPENTADIENE	25	43	5,910	.	93,157	300,204	399,314	15,973
SULFURIC ACID	25	2,801	1	.	286	.	3,088	124
TOLUENE DIISOCYANATE (MIXED ISOMERS)	24	5	.	.	43,424	1,002	44,431	1,851
VINYL CHLORIDE	23	302	331	66,470	74,161	12,002	153,266	6,664
METHYL ACRYLATE	23	871	860	10,347	17,272	135,776	165,126	7,179
ACRYLAMIDE	22	161	8	.	5,047	345	5,561	253
CUMENE	22	12	62,573	.	56,310	58,344	177,239	8,056
METHYL ISOBUTYL KETONE	22	118	35	0	14,268	80,465	94,886	4,313
DICHLOROMETHANE	20	7	17,096	200,860	146,444	130,915	495,322	24,766
SEC-BUTYL ALCOHOL	20	151	182	.	1,440	25,138	26,911	1,346
TRIETHYLAMINE	16	2,356	.	.	5,764	744	8,864	554
BIPHENYL	15	269	2,140	71,034	1,392	204,113	278,948	18,597
N-METHYL-2-PYRROLIDONE	15	80,300	186,178	1,298,802	117,573	37,718	1,720,571	114,705
NITRATE COMPOUNDS	14	41,700	110,308	.	110,470	.	262,478	18,748
CHLORODIFLUOROMETHANE	14	0	.	140	5	126,140	126,285	9,020
BENZENE	13	1,323	46	94,081	67,563	186,465	349,478	26,883
ACETALDEHYDE	13	223,239	.	.	143,412	61,610	428,261	32,943
TERT-BUTYL ALCOHOL	13	94,622	515	220	102,269	143,457	341,083	26,237
N-METHYLOLACRYLAMIDE	13	2,793	13	.	1,601	294	4,701	362
BENZOYL PEROXIDE	12	5	296	.	5	5	311	26
CYCLOHEXANE	12	1,500	0	1,008	4,604	921,139	928,251	77,354
1,1-DICHLORO-1-FLUOROETHANE	12	0	.	.	32,840	900	33,740	2,812
DIETHANOLAMINE	11	5,395	5	.	9,858	360	15,618	1,420
CHROMIUM COMPOUNDS	10	0	8,668	5	4,853	0	13,526	1,353
COBALT COMPOUNDS	10	0	31	24,000	17,049	500	41,580	4,158
COPPER COMPOUNDS	9	0	87,375	668,600	72,888	.	828,863	92,096
TOLUENE-2,4-DIISOCYANATE	9	0	.	.	1,027	1,237	2,264	252
LEAD COMPOUNDS	8	0	4,748	5	1,126	.	5,879	735
FORMIC ACID	8	0	0	.	5	.	5	1

Table 13 (cont.): 1995 TRI Transfers for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
N,N-DIMETHYLFORMAMIDE	8	106,238	.	.	53,890	488,482	648,610	81,076
PROPYLENE OXIDE	8	177,100	160	.	9	4	177,273	22,159
EPICHLOROHYDRIN	8	9,888	.	.	5,563	.	15,451	1,931
NITRIC ACID	8	0	0	.	8,450	.	8,450	1,056
CHLOROMETHANE	7	250	.	.	486	.	736	105
HYDROQUINONE	7	119	74	.	377	7	577	82
DECABROMODIPHENYL OXIDE	7	5	32,360	.	4,436	.	36,801	5,257
CRESOL (MIXED ISOMERS)	7	0	.	.	2,361	42,453	44,814	6,402
TITANIUM TETRACHLORIDE	7	0	32,282	129,127	0	.	161,409	23,058
1,1,1-TRICHLOROETHANE	6	0	3,088	.	24,340	720	28,148	4,691
CHLOROETHANE	6	0	.	2,726	.	.	2,726	454
1-CHLORO-1,1-DIFLUOROETHANE	6	0	.	.	.	.	0	0
TRICHLOROETHYLENE	6	12	.	143,735	21,073	1,960	166,780	27,797
DI(2-ETHYLHEXYL) PHTHALATE	6	0	3,036	.	11,673	1,404	16,113	2,686
HYDROGEN FLUORIDE	6	0	.	210	5,400	8,840	14,450	2,408
NICKEL COMPOUNDS	5	502	576	.	27,426	.	28,504	5,701
ETHYLENE OXIDE	5	250	162	.	.	.	412	82
PHOSGENE	5	0	.	.	.	.	0	0
O-XYLENE	5	2,104	.	16,000	177,450	76,531	272,085	54,417
1,2-DICHLOROETHANE	5	1,766	.	5,876,308	2,766	3,371	5,884,211	1,176,842
1,4-DIOXANE	5	0	271	.	12,655	11,990	24,916	4,983
BARIUM COMPOUNDS	4	251	1,401	.	16	10	1,678	420
CARBON TETRACHLORIDE	4	0	4,000	355,475	72,370	10	431,855	107,964
CARBON DISULFIDE	4	13,260	1,820	0	12,130	610	27,820	6,955
VINYLIDENE CHLORIDE	4	0	250	.	33,323	.	33,573	8,393
TRICHLOROFLUOROMETHANE	4	0	250	.	5	.	255	64
CUMENE HYDROPEROXIDE	4	5	0	.	.	0	5	1
ALLYL ALCOHOL	4	191,310	.	.	79,933	430	271,673	67,918
N,N-DIMETHYLANILINE	4	5	.	.	550	517	1,072	268
PROPIONALDEHYDE	4	87,434	0	.	.	5,565	92,999	23,250
CARBONYL SULFIDE	4	0	.	.	16,000	.	16,000	4,000
BORON TRIFLUORIDE	4	0	.	.	10	.	10	3

Table 13 (cont.): 1995 TRI Transfers for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
CYANIDE COMPOUNDS	3	1,048	.	.	89,925	.	90,973	30,324
MANGANESE COMPOUNDS	3	0	259	2,000	12,028	.	14,287	4,762
ANILINE	3	8,182	5	.	3,300	44,229	55,716	18,572
CHLOROFORM	3	0	1	126,776	3,774	.	130,551	43,517
HYDROGEN CYANIDE	3	87	.	.	.	.	87	29
PROPYLENEIMINE	3	0	.	.	.	.	0	0
FREON 113	3	0	.	106,088	16,570	.	122,658	40,886
DIBUTYL PHTHALATE	3	5	5	.	505	129	644	215
TOLUENE-2,6-DIISOCYANATE	3	0	.	.	.	178	178	59
O-CRESOL	3	0	.	.	0	.	0	0
4,4'-METHYLENEDIANILINE	3	5	122	.	17,400	.	17,527	5,842
ACROLEIN	3	0	.	.	4,035	35,301	39,336	13,112
1,3-PHENYLENEDIAMINE	3	5	80	.	.	.	85	28
CHLOROBENZENE	3	0	4,205	614,904	528,000	117,000	1,264,109	421,370
2-METHOXYETHANOL	3	0	.	.	1,565	11,279	12,844	4,281
BUTYRALDEHYDE	3	440	41	.	2,200	.	2,681	894
DIMETHYL PHTHALATE	3	600	5	.	18,639	5	19,249	6,416
HYDRAZINE	3	0	.	.	274	.	274	91
ZINC (FUME OR DUST)	3	250	5,420	.	5	.	5,675	1,892
CADMIUM COMPOUNDS	2	0	9	5	.	.	14	7
DIETHYL SULFATE	2	158	.	.	.	.	158	79
DICHLORODIFLUOROMETHANE	2	0	.	.	.	.	0	0
DIMETHYL SULFATE	2	0	.	.	.	.	0	0
ISOBUTYRALDEHYDE	2	0	0	.	31	0	31	16
O-TOLUIDINE	2	1,463	.	.	.	90,221	91,684	45,842
ACETOPHENONE	2	0	1	.	.	500	501	251
4,4'-METHYLENEBIS(2-CHLOROANILINE)	2	0	.	.	.	234	234	117
ALLYL CHLORIDE	2	5	.	.	85	.	90	45
2-ETHOXYETHANOL	2	0	.	.	160	1,200	1,360	680
PYRIDINE	2	0	.	.	88,282	66,595	154,877	77,439
ANTHRACENE	2	0	.	.	1,593	40,576	42,169	21,085
TETRACHLOROETHYLENE	2	0	.	712,881	290	1,650	714,821	357,411

Table 13 (cont.): 1995 TRI Transfers for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
NICKEL	2	14	8,309	12,960	.	.	21,283	10,642
COPPER	2	142	2,104	33,192	.	.	35,438	17,719
SODIUM NITRITE	2	250	.	.	505	.	755	378
ARSENIC COMPOUNDS	1	0	.	.	5	.	5	5
SILVER COMPOUNDS	1	0	.	97,000	.	.	97,000	97,000
PIPERONYL BUTOXIDE	1	250	.	.	15,148	.	15,398	15,398
ACETAMIDE	1	0	.	.	250	.	250	250
THIOUREA	1	0	495	.	.	.	495	495
ISOPROPYL ALCOHOL (MANUFACTURING, STRONG-ACID PROCESS ONLY, NO SUPPLIE	1	0	.	.	.	500	500	500
HEXACHLOROETHANE	1	0	.	.	.	75,132	75,132	75,132
BROMOMETHANE	1	0	.	.	.	380	380	380
ACETONITRILE	1	0	.	.	1,750	.	1,750	1,750
TRICHLOROACETYL CHLORIDE	1	0	.	.	.	.	0	0
DICHLOROTETRAFLUOROETHANE (CFC-114)	1	0	.	.	.	.	0	0
1,2-DICHLOROPROPANE	1	0	404	.	.	.	404	404
1,1,2-TRICHLOROETHANE	1	0	.	4,026,507	.	.	4,026,507	4,026,507
1,1,2,2-TETRACHLOROETHANE	1	0	.	72,142	.	.	72,142	72,142
1,2-DICHLOROBENZENE	1	0	14,010	.	25,690	124,087	163,787	163,787
4,4'-DIAMINODIPHENYL ETHER	1	5	120	.	.	.	125	125
2,4-DIMETHYLPHENOL	1	0	.	.	.	2,000	2,000	2,000
P-XYLENE	1	0	.	.	.	.	0	0
P-CRESOL	1	0	.	.	.	.	0	0
1,4-DICHLOROBENZENE	1	0	.	.	498,408	48	498,456	498,456
P-PHENYLENEDIAMINE	1	0	.	.	.	.	0	0
CHLOROMETHYL METHYL ETHER	1	0	70	.	.	.	70	70
M-CRESOL	1	0	.	.	.	.	0	0
CYCLOHEXANOL	1	0	.	.	.	.	0	0
2-METHYLPYRIDINE	1	0	.	.	5	.	5	5
PROPOXUR	1	250	.	.	750	.	1,000	1,000
CHLORENDIC ACID	1	0	.	.	488	.	488	488

Table 13 (cont.): 1995 TRI Transfers for Plastic Resin Manufacturing Facilities (SIC 2821), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
DIPHENYLAMINE	1	5	.	.	.	9,417	9,422	9,422
DIMETHYLAMINE	1	0	.	.	.	.	0	0
METHACRYLONITRILE	1	0	.	.	.	.	0	0
CHLOROPRENE	1	0	.	254,406	.	.	254,406	254,406
POTASSIUM DIMETHYLDITHIOCARBAMATE	1	160,000	.	.	.	.	160,000	160,000
METHYL PARATHION	1	0	.	.	.	.	0	0
1-CHLORO-1,1,2,2-TETRAFLUOROETHANE	1	0	.	.	.	.	0	0
1,2-DICHLOROETHYLENE	1	0	.	.	.	.	0	0
LITHIUM CARBONATE	1	0	860	.	.	.	860	860
2,6-DIMETHYLPHENOL	1	0	.	.	200	.	200	200
C.I. BASIC RED 1	1	250	668	.	250	250	1,418	1,418
MOLYBDENUM TRIOXIDE	1	0	.	.	330	.	330	330
ASBESTOS (FRIABLE)	1	0	191,000	.	.	.	191,000	191,000
ALUMINUM OXIDE (FIBROUS FORMS)	1	0	.	.	.	3,424	3,424	3,424
2-CHLORO-1,1,1,2-TETRAFLUOROETHANE	1	0	.	.	.	.	0	0
CROTONALDEHYDE	1	0	.	.	.	.	0	0
LEAD	1	0	.	3,000	.	.	3,000	3,000
ANTIMONY	1	0	7,544	.	.	.	7,544	7,544
CADMIUM	1	0	.	.	5	.	5	5
CHROMIUM	1	0	.	.	0	.	0	0
COBALT	1	0	.	.	4	.	4	4
TETRAMETHRIN	1	0	.	.	750	.	750	750
PHOSPHORUS (YELLOW OR WHITE)	1	0	.	.	.	.	0	0
BROMINE	1	0	.	.	.	.	0	0
DIAMINOTOLUENE (MIXED ISOMERS)	1	250	.	.	110	990	1,350	1,350
OXYFLUORFEN	1	3,135	.	.	11,268	.	14,403	14,403
PERMETHRIN	1	0	.	.	505	.	505	505
	410	10,885,040	2,311,895	88,496,795	30,453,640	60,227,508	192,374,893	469,207

Table 14: 1995 TRI Releases for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
ETHYLENE GLYCOL	13	479,311	558,748	218,523	3,500	1,655	1,261,737	97,057
BIPHENYL	12	246,298	52,811	298	5,500	277	305,184	25,432
AMMONIA	11	78,827	107,090	284,152	230,695	26,095	726,859	66,078
CHLORINE	10	511	62,250	110	0	0	62,871	6,287
ANTIMONY COMPOUNDS	9	940	2,303	688	6	18,005	21,942	2,438
METHANOL	9	665,183	1,592,326	5,198	370,250	0	2,632,957	292,551
ACETALDEHYDE	9	400,610	799,922	3,990	120,000	0	1,324,522	147,169
PHOSPHORIC ACID	9	5	6	0	0	0	11	1
HYDROCHLORIC ACID (1995 AND AFTER "ACID AEROSOLS" ONLY)	8	240	6,034,881	0	0	0	6,035,121	754,390
1,4-DIOXANE	7	13,339	48,658	125,342	0	10	187,349	26,764
NITRATE COMPOUNDS	6	0	0	856,584	11,000,000	0	11,856,584	1,976,097
ZINC COMPOUNDS	6	250	2,653	63,900	2	533,600	600,405	100,068
TOLUENE	6	310,790	616,243	266	0	0	927,299	154,550
SULFURIC ACID	6	0	2,907	0	0	0	2,907	485
MANGANESE COMPOUNDS	5	0	2,500	2,000	340	19,000	23,840	4,768
FORMALDEHYDE	5	3,914	40,678	12,724	28,000	0	85,316	17,063
METHYL ETHYL KETONE	5	96,416	87,991	424	88,000	0	272,831	54,566
NITRIC ACID	5	2,400	4,900	0	200,000	0	207,300	41,460
CHROMIUM COMPOUNDS	4	0	533	1,510	0	8,400	10,443	2,611
CARBON DISULFIDE	4	2,697,000	56,760,000	39,110	0	265	59,496,375	14,874,094
FORMIC ACID	3	1,602	17,908	52	3,400,000	0	3,419,562	1,139,854
N-BUTYL ALCOHOL	3	35,011	3,838	18,000	830,000	0	886,849	295,616
TRICHLOROFLUOROMETHANE	3	219,927	4,400	75	0	0	224,402	74,801
ACRYLONITRILE	3	36,836	222,786	0	8,760	0	268,382	89,461
VINYL ACETATE	3	9,909	125,510	1	750	0	136,170	45,390
HYDROQUINONE	3	12,000	1,039	3,400	0	0	16,439	5,480
BUTYRALDEHYDE	3	17,330	53,300	110	84,000	0	154,740	51,580
DIMETHYLAMINE	3	18,312	261,417	20,500	0	0	300,229	100,076
NICKEL	3	0	110	341	6,100	1,340	7,891	2,630
COPPER COMPOUNDS	2	0	270	690	170	6,100	7,230	3,615
DIISOCYANATES	2	142	0	0	0	0	142	71

Table 14 (cont.): 1995 TRI Releases for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
CERTAIN GLYCOL ETHERS	2	98,400	7,100	408	0	0	105,908	52,954
BENZENE	2	0	8,100	0	0	0	8,100	4,050
1,1,1-TRICHLOROETHANE	2	6,394	227,694	0	0	0	234,088	117,044
ETHYLENE	2	3,400	110,000	0	0	0	113,400	56,700
ACETONITRILE	2	39,536	44,719	497	0	0	84,752	42,376
DICHLOROMETHANE	2	125,694	291,436	0	0	0	417,130	208,565
ETHYLENE OXIDE	2	250	23,005	0	0	0	23,255	11,628
TERT-BUTYL ALCOHOL	2	0	65	0	750	0	815	408
DICHLORODIFLUOROMETHANE	2	23,581	0	0	0	0	23,581	11,791
STYRENE	2	1,500	2,100	190	0	0	3,790	1,895
1,3-BUTADIENE	2	380	18,400	0	0	0	18,780	9,390
PHENOL	2	191	1,171	626	0	0	1,988	994
2-METHOXYETHANOL	2	24	63	2,800	0	0	2,887	1,444
N-HEXANE	2	188,179	4,672	0	0	0	192,851	96,426
CYCLOHEXANE	2	10,900	150,980	9	20,000	0	181,889	90,945
DIETHANOLAMINE	2	270	1,483	0	0	0	1,753	877
PROPIONALDEHYDE	2	14,000	100,000	7	80,000	0	194,007	97,004
DIMETHYL PHTHALATE	2	6	275	230	750	0	1,261	631
BUTYL ACRYLATE	2	36	513	5	0	0	554	277
SODIUM NITRITE	2	0	0	0	6,500	0	6,500	3,250
TOLUENE DIISOCYANATE (MIXED ISOMERS)	2	10	5	0	0	0	15	8
CADMIUM COMPOUNDS	1	0	0	0	0	0	0	0
COBALT COMPOUNDS	1	0	280	0	0	14,000	14,280	14,280
CYANIDE COMPOUNDS	1	0	0	0	0	0	0	0
LEAD COMPOUNDS	1	0	13	0	0	0	13	13
NICKEL COMPOUNDS	1	0	1	0	0	0	1	1
2,4-DINITROPHENOL	1	110	0	2,000	0	0	2,110	2,110
ANILINE	1	40	120	4,300	0	0	4,460	4,460
DIETHYL SULFATE	1	230	0	0	0	0	230	230
CHLOROFORM	1	7,000	17,000	72	0	0	24,072	24,072
N,N-DIMETHYLFORMAMIDE	1	460	4,100	410	0	0	4,970	4,970

Table 14 (cont.): 1995 TRI Releases for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
BROMOMETHANE	1	720	210,000	11	0	0	210,731	210,731
METHYL IODIDE	1	4,000	16	0	0	0	4,016	4,016
HYDROGEN CYANIDE	1	27,200	44,410	0	0	0	71,610	71,610
VINYLIDENE CHLORIDE	1	190	5,900	0	0	0	6,090	6,090
CHLORODIFLUOROMETHANE	1	5,790	0	0	0	0	5,790	5,790
FREON 113	1	167,230	30,375	0	0	0	197,605	197,605
DICHLOROTETRAFLUOROETHANE (CFC-114)	1	8,244	0	0	0	0	8,244	8,244
DIMETHYL SULFATE	1	0	0	0	0	0	0	0
ISOBUTYRALDEHYDE	1	20,000	7,300	0	0	0	27,300	27,300
SEC-BUTYL ALCOHOL	1	0	0	0	48,000	0	48,000	48,000
ACRYLIC ACID	1	3	1,087	20	0	0	1,110	1,110
1,1,2,2-TETRACHLOROETHANE	1	160	250	0	0	0	410	410
4,4'-ISOPROPYLIDENEDIPHENOL	1	0	0	0	0	0	0	0
METHYL METHACRYLATE	1	750	750	0	0	0	1,500	1,500
DIBUTYL PHTHALATE	1	7,000	190	85	0	0	7,275	7,275
PHTHALIC ANHYDRIDE	1	3,900	1,100	0	0	0	5,000	5,000
PICRIC ACID	1	0	0	0	25,000	0	25,000	25,000
O-ANISIDINE	1	460	10	0	0	0	470	470
2-PHENYLPHENOL	1	0	59	0	0	0	59	59
O-XYLENE	1	17,000	35,000	2	0	0	52,002	52,002
O-TOLUIDINE	1	460	0	0	0	0	460	460
METHYL ACRYLATE	1	3	817	0	0	0	820	820
DICHLORAN	1	0	0	0	0	0	0	0
P-NITROANILINE	1	3	0	2	0	0	5	5
BENZYL CHLORIDE	1	0	0	0	0	0	0	0
P-XYLENE	1	6,400	63,000	0	0	0	69,400	69,400
P-PHENYLENEDIAMINE	1	0	0	.	0	0	0	0
QUINONE	1	3,800	3,300	1,500	0	0	8,600	8,600
METHYL ISOBUTYL KETONE	1	44,000	100,000	4,000	0	0	148,000	148,000
MALEIC ANHYDRIDE	1	0	0	0	0	0	0	0
M-XYLENE	1	1,000	1,000	0	0	0	2,000	2,000

Table 14 (cont.): 1995 TRI Releases for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
1,3-PHENYLENEDIAMINE	1	0	0	.	0	0	0	0
CHLOROBENZENE	1	290	1,500	1	0	0	1,791	1,791
CYCLOHEXANOL	1	92	3,600	0	1,300,000	0	1,303,692	1,303,692
PYRIDINE	1	41	2	190	0	0	233	233
PROPYLENE	1	540	14,000	0	0	0	14,540	14,540
DI(2-ETHYLHEXYL) PHTHALATE	1	8,300	2	230	0	0	8,532	8,532
TRIETHYLAMINE	1	280	12,000	13	0	0	12,293	12,293
N,N-DIMETHYLANILINE	1	0	0	0	0	0	0	0
TETRACHLOROETHYLENE	1	420	3,280	.	0	0	3,700	3,700
ETHYL ACRYLATE	1	2	844	0	0	0	846	846
P-NITROSODIPHENYLAMINE	1	24	0	0	0	0	24	24
BIS(CHLOROMETHYL) ETHER	1	0	0	0	0	0	0	0
VINYL BROMIDE	1	220	8,000	0	0	0	8,220	8,220
N-METHYL-2-PYRROLIDONE	1	84	1	8,000	0	0	8,085	8,085
DECABROMODIPHENYL OXIDE	1	0	1	0	11	0	12	12
XYLENE (MIXED ISOMERS)	1	30,000	33,000	270	0	0	63,270	63,270
CROTONALDEHYDE	1	35,000	55,000	680	0	0	90,680	90,680
ANTIMONY	1	0	5	250	0	250	505	505
CADMIUM	1	0	0	71	0	71	142	142
COPPER	1	0	0	620	29,000	0	29,620	29,620
BORON TRIFLUORIDE	1	0	0	0	0	0	0	0
HYDROGEN FLUORIDE	1	0	340,000	0	0	0	340,000	340,000
CHLORINE DIOXIDE	1	0	0	0	0	0	0	0
	34	6,261,300	69,457,072	1,685,487	17,886,084	629,068	95,919,011	2,821,147

Table 15: 1995 TRI Transfers for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
ETHYLENE GLYCOL	13	81,958	333,823	40,865,058	67,979	1,186,722	42,535,540	3,271,965
BIPHENYL	12	0	19,777	46,500	5,197	5,400	76,874	6,406
AMMONIA	11	752	.	.	.	.	752	68
CHLORINE	10	0	.	.	.	.	0	0
ANTIMONY COMPOUNDS	9	194	6,843	12,799	10,922	.	30,758	3,418
METHANOL	9	15,565	580	1,180,100	12,273	241,958	1,450,476	161,164
ACETALDEHYDE	9	0	250	27,000	8,920	500	36,670	4,074
PHOSPHORIC ACID	9	1,600	.	.	.	.	1,600	178
HYDROCHLORIC ACID (1995 AND AFTER "ACID AEROSOLS" ONLY)	8	0	.	.	.	.	0	0
1,4-DIOXANE	7	140	13,557	.	1,190	1,182	16,069	2,296
NITRATE COMPOUNDS	6	0	.	.	467	.	467	78
ZINC COMPOUNDS	6	901	868,900	.	.	.	869,801	144,967
TOLUENE	6	923	3,619	1,000	12,065	58,369	75,976	12,663
SULFURIC ACID	6	0	.	.	.	.	0	0
MANGANESE COMPOUNDS	5	305	501	.	2	.	808	162
FORMALDEHYDE	5	2,060	.	.	37	.	2,097	419
METHYL ETHYL KETONE	5	0	.	.	700	79,951	80,651	16,130
NITRIC ACID	5	0	.	.	.	.	0	0
CHROMIUM COMPOUNDS	4	0	5	24,000	.	.	24,005	6,001
CARBON DISULFIDE	4	0	.	.	2,900	.	2,900	725
FORMIC ACID	3	0	.	.	208	.	208	69
N-BUTYL ALCOHOL	3	0	.	.	181	58	239	80
TRICHLOROFLUOROMETHANE	3	0	.	3,850	.	.	3,850	1,283
ACRYLONITRILE	3	200	120	.	250	.	570	190
VINYL ACETATE	3	0	.	.	557	1,290	1,847	616
HYDROQUINONE	3	150	43	.	.	.	193	64
BUTYRALDEHYDE	3	0	.	.	.	.	0	0
DIMETHYLAMINE	3	0	.	.	.	.	0	0
NICKEL	3	0	13	185,000	.	.	185,013	61,671
COPPER COMPOUNDS	2	0	1,686	30,000	.	.	31,686	15,843
DIISOCYANATES	2	0	.	.	17,258	.	17,258	8,629

Table 15 (cont.): 1995 TRI Transfers for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
CERTAIN GLYCOL ETHERS	2	430	.	43,000	240	.	43,670	21,835
BENZENE	2	0	.	.	.	.	0	0
1,1,1-TRICHLOROETHANE	2	0	.	17,443	320	.	17,763	8,882
ETHYLENE	2	0	.	.	.	.	0	0
ACETONITRILE	2	0	.	.	350,340	.	350,340	175,170
DICHLOROMETHANE	2	0	.	47,125	2,999	.	50,124	25,062
ETHYLENE OXIDE	2	0	.	.	.	.	0	0
TERT-BUTYL ALCOHOL	2	0	.	.	.	.	0	0
DICHLORODIFLUOROMETHANE	2	0	.	.	.	.	0	0
STYRENE	2	0	.	.	.	.	0	0
1,3-BUTADIENE	2	0	.	.	.	.	0	0
PHENOL	2	0	2,881	.	1	.	2,882	1,441
2-METHOXYETHANOL	2	0	.	.	.	.	0	0
N-HEXANE	2	0	.	.	508	.	508	254
CYCLOHEXANE	2	0	.	.	.	.	0	0
DIETHANOLAMINE	2	0	.	.	.	.	0	0
PROPIONALDEHYDE	2	0	.	.	.	.	0	0
DIMETHYL PHTHALATE	2	0	.	.	.	.	0	0
BUTYL ACRYLATE	2	0	15	.	337	.	352	176
SODIUM NITRITE	2	0	.	.	.	.	0	0
TOLUENE DIISOCYANATE (MIXED ISOMERS)	2	0	.	.	.	450	450	225
CADMIUM COMPOUNDS	1	0	9,000	.	.	.	9,000	9,000
COBALT COMPOUNDS	1	0	4,000	9,500	.	.	13,500	13,500
CYANIDE COMPOUNDS	1	0	.	.	.	.	0	0
LEAD COMPOUNDS	1	0	0	.	.	.	0	0
NICKEL COMPOUNDS	1	0	0	.	.	.	0	0
2,4-DINITROPHENOL	1	0	.	.	.	.	0	0
ANILINE	1	0	.	.	.	.	0	0
DIETHYL SULFATE	1	0	.	.	.	.	0	0
CHLOROFORM	1	0	.	.	.	.	0	0
N,N-DIMETHYLFORMAMIDE	1	0	.	.	1,300	.	1,300	1,300

Table 15 (cont.): 1995 TRI Transfers for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
BROMOMETHANE	1	0	.	.	.	.	0	0
METHYL IODIDE	1	0	.	.	.	.	0	0
HYDROGEN CYANIDE	1	0	.	.	.	.	0	0
VINYLIDENE CHLORIDE	1	0	.	.	.	.	0	0
CHLORODIFLUOROMETHANE	1	0	.	.	.	.	0	0
FREON 113	1	250	.	.	500	.	750	750
DICHLOROTETRAFLUOROETHANE (CFC-114)	1	0	.	.	.	.	0	0
DIMETHYL SULFATE	1	0	.	.	.	.	0	0
ISOBUTYRALDEHYDE	1	0	.	.	.	.	0	0
SEC-BUTYL ALCOHOL	1	0	.	.	.	.	0	0
ACRYLIC ACID	1	0	.	.	287	.	287	287
1,1,2,2-TETRACHLOROETHANE	1	0	.	.	.	.	0	0
4,4'-ISOPROPYLIDENEDIPHENOL	1	0	.	.	.	.	0	0
METHYL METHACRYLATE	1	0	.	.	.	.	0	0
DIBUTYL PHTHALATE	1	0	.	.	.	.	0	0
PHTHALIC ANHYDRIDE	1	0	.	.	1,000	.	1,000	1,000
PICRIC ACID	1	0	.	.	.	.	0	0
O-ANISIDINE	1	0	.	.	.	.	0	0
2-PHENYLPHENOL	1	0	.	.	.	.	0	0
O-XYLENE	1	0	.	.	.	.	0	0
O-TOLUIDINE	1	0	.	.	.	.	0	0
METHYL ACRYLATE	1	0	.	.	78	.	78	78
DICHLORAN	1	0	.	.	.	.	0	0
P-NITROANILINE	1	0	.	.	.	.	0	0
BENZYL CHLORIDE	1	0	.	.	.	.	0	0
P-XYLENE	1	0	.	.	.	.	0	0
P-PHENYLENEDIAMINE	1	0	.	.	3,200	.	3,200	3,200
QUINONE	1	0	.	.	.	.	0	0
METHYL ISOBUTYL KETONE	1	0	.	.	.	.	0	0
MALEIC ANHYDRIDE	1	0	.	.	.	.	0	0
M-XYLENE	1	0	.	.	.	.	0	0

Table 15 (cont.): 1995 TRI Transfers for Manmade Fiber Manufacturing Facilities (SIC 2823 & 2824), by Number of Facilities Reporting (in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW TRANSFERS	DISPOSAL TRANSFERS	RECYCLING TRANSFERS	TREATMENT TRANSFERS	ENERGY RECOVERY TRANSFERS	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
1,3-PHENYLENEDIAMINE	1	0	.	.	104,000	.	104,000	104,000
CHLOROBENZENE	1	0	.	.	.	.	0	0
CYCLOHEXANOL	1	0	.	.	.	.	0	0
PYRIDINE	1	0	.	.	.	.	0	0
PROPYLENE	1	0	.	.	.	.	0	0
DI(2-ETHYLHEXYL) PHTHALATE	1	0	.	.	8,500	.	8,500	8,500
TRIETHYLAMINE	1	0	.	.	600	.	600	600
N,N-DIMETHYLANILINE	1	0	.	.	.	.	0	0
TETRACHLOROETHYLENE	1	0	.	.	2,400	.	2,400	2,400
ETHYL ACRYLATE	1	0	.	.	354	.	354	354
P-NITROSODIPHENYLAMINE	1	0	.	.	.	15,000	15,000	15,000
BIS(CHLOROMETHYL) ETHER	1	0	.	.	.	.	0	0
VINYL BROMIDE	1	0	.	.	.	.	0	0
N-METHYL-2-PYRROLIDONE	1	0	.	.	398,000	.	398,000	398,000
DECABROMODIPHENYL OXIDE	1	0	3,700	.	.	.	3,700	3,700
XYLENE (MIXED ISOMERS)	1	0	370	.	800,029	13,000	813,399	813,399
CROTONALDEHYDE	1	0	.	.	.	.	0	0
ANTIMONY	1	0	500	.	12,150	.	12,650	12,650
CADMIUM	1	0	8,400	11,000	.	.	19,400	19,400
COPPER	1	0	.	.	.	.	0	0
BORON TRIFLUORIDE	1	0	.	.	.	.	0	0
HYDROGEN FLUORIDE	1	0	.	.	.	.	0	0
CHLORINE DIOXIDE	1	0	.	.	.	.	0	0
	34	105,428	1,278,583	42,503,375	1,828,249	1,603,880	47,319,515	1,391,750

Top 10 TRI Releasing Plastic Resin and Manmade Fiber Companies

The TRI database contains a detailed compilation of self-reported, facility-specific chemical releases. The top reporting facilities for the plastic resin manufacturing sector and manmade fiber manufacturing sector, based on pounds of TRI chemicals released, are listed in Tables 16 and 18, respectively. Facilities that have reported only plastic resin SIC codes (SIC 2821) appear in Table 16, and facilities that have reported only manmade fiber SIC codes (SIC 2823 or 2824) appear in Table 18. Tables 17 and 19 contain additional facilities that have reported plastic resin and manmade fiber SIC codes, and one or more that may have also reported SIC codes that are not within the scope of this notebook. Therefore, Tables 17 and 19 may include facilities that conduct multiple operations -- some that are under the scope of this notebook, and some that are not. Currently, the facility-level data do not allow pollutant releases to be broken apart by industrial process.

Table 16: Top 10 TRI Releasing Plastic Resin Manufacturing Facilities (SIC 2821)[1]

Rank	Facility	Total Releases in Pounds
1	BP Chemicals Inc. - Lima, OH	13,566,795
2	Rexene Corp. - Odessa, TX	2,558,214
3	Quantum Chemical Corp. - Clinton, IA	2,508,685
4	GE Plastics Co. - Mount Vernon, IN	2,344,168
5	Du Pont - Washington, WV	2,281,027
6	Quantum Chemical Corp. - La Porte, TX	2,225,186
7	Shell Chemical Co. - Apple Grove, WV	1,529,579
8	Carolina Eastman Div. - Columbia, SC	1,487,312
9	GE Co. - Waterford, NY	1,366,735
10	Exxon Chemical Co. - Baton Rouge, LA	1,365,101
TOTAL		**31,232,802**

Source: U.S. EPA, Toxics Release Inventory Database, 1995.

[1] Being included on this list does not mean that the releases are associated with noncompliance with environmental laws.

Note: TRI Releases shown in this table are associated with all manufacturing activities at a facility and not just those associated with plastic resin manufacturing activities.

Table 17: Top 10 TRI Releasing Facilities Reporting Plastic Resin Manufacturing SIC Codes to TRI [1]

Rank	SIC Codes Reported in TRI	Facility	Total Releases in Pounds
1	2821, 2824, 2824, 2869, 2865	Monsanto Co. - Cantonment, FL	18,058,737
2	2821, 2869	BP Chemicals Inc. - Lima, OH	13,566,795
3	2821, 2823, 2869, 2865, 2893	Tennessee Eastman Div. - Kingsport, TN	7,481,378
4	2821, 2812, 2813, 2819, 2822, 2865	Dow Chemical Co. - Freeport, TX	6,120,977
5	2821, 2911, 2869, 2865	Shell Oil Co. - Deer Park, TX	4,757,517
6	2821, 2869	Eastman Chemical Co. - Longview, TX	3,908,702
7	2821, 2865, 2824	Du Pont - Leland, NC	3,653,612
8	2821, 2611, 2631 2653	Union Camp Corp. - Savannah, GA	3,121,612
9	2821, 2869, 2819	ELF Atochem N.A. Inc. - Calvert City, KY	3,082,676
10	2821, 2869	Celanese Eng. Resins Inc. - Bishop, TX	3,049,800
TOTAL			**66,801,806**

Source: U.S. EPA, Toxics Release Inventory Database, 1995.

[1] Being included on this list does not mean that the releases are associated with noncompliance with environmental laws.

Note: TRI Releases shown in this table are associated with all manufacturing activities at a facility and not just those associated with plastic resin manufacturing activities.

Table 18: Top 10 TRI Releasing Manmade Fiber Manufacturing Facilities (SIC 2823, 2824)[1]

Rank	Facility	Total Releases in Pounds
1	Courtaulds Fibers Inc. - Axis, AL	34,018,200
2	Lenzing Fibers Corp. - Lowland, TN	23,231,860
3	Monsanto Co. - Cantonment, FL	18,058,737
4	Tennessee Eastman Div. - Kingsport, TN	7,481,378
5	North American Rayon Corp. - Elizabethton, TN	2,960,770
6	Monsanto Co. - Decatur, AL	1,580,530
7	Du Pont - Camden, SC	1,105,503
8	Du Pont - Seaford, DE	774,488
9	Hoechst Celanese Corp. - Spartanburg, SC	754,912
10	Hoechst Celanese Corp. - Rock Hill, SC	754,174
TOTAL		**90,720,552**

Source: U.S. EPA, Toxics Release Inventory Database, 1995.

[1] Being included on this list does not mean that the releases are associated with noncompliance with environmental laws.

Note: TRI Releases shown in this table are associated with all manufacturing activities at a facility and not just those associated with manmade fiber manufacturing activities.

Table 19: Top 10 TRI Releasing Facilities Reporting Manmade Fiber Manufacturing SIC Codes to TRI [1]

Rank	SIC Codes Reported in TRI	Facility	Total Releases in Pounds
1	2823, 2819	Courtaulds Fibers Inc. - Axis, AL	34,018,200
2	2823	Lenzing Fibers Corp. - Lowland, TN	23,231,860
3	2824, 2869, 2821, 2865	Monsanto Co. - Cantonment, FL	18,058,737
4	2823, 2821, 2869, 2865, 2893	Tennessee Eastman Div. - Kingsport, TN	7,481,378
5	2824, 2865, 2821	Du Pont - Leland, NC	3,653,612
6	2823	North American Rayon Corp. - Elizabethton, TN	2,960,770
7	2824, 2821, 2869	Du Pont - Washington, WV	2,281,027
8	2824, 2869	Monsanto Co. - Decatur, AL	1,580,530
9	2824, 2821	Du Pont - Camden, SC	1,105,503
10	2824, 2821	Du Pont - Seaford, DE	774,488
TOTAL			**95,146,105**

Source: U.S. EPA, Toxics Release Inventory Database, 1995.

[1] Being included on this list does not mean that the releases are associated with noncompliance with environmental laws.

Note: TRI Releases shown in this table are associated with all manufacturing activities at a facility and not just those associated with manmade fiber manufacturing activities.

IV.B. Summary of Selected Chemicals Released

The following is a synopsis of current scientific toxicity and fate information for the top chemicals (by weight) that plastic resin and manmade fiber facilities released to the environment in 1995. Ethylene glycol is mentioned also because it accounts for a large portion of the transfers for the industries. The top chemicals were selected based on TRI release data that facilities self-reported. Because this section is based on self-reported release data, it does not attempt to provide information on management practices employed by the sector to reduce the release of these chemicals. Information regarding pollutant release reductions over time may be available from EPA's TRI and 33/50 programs, or directly from the industrial trade associations that are listed in Section IX of this document. Since these descriptions are cursory, please consult the sources described in this section, and the chemicals that appear on the full list of TRI chemicals appearing in Section IV.A.

The brief descriptions provided below were taken from the *1994 Toxics Release Inventory Public Data Release* (EPA, 1995), the Hazardous Substances Data Bank (HSDB), and the Integrated Risk Information System (IRIS), both accessed via TOXNET.[1] The discussions of toxicity describe the range of possible adverse health effects that have been found to be associated with exposure to these chemicals. These adverse effects may or may not occur at the levels released to the environment. Individuals interested in a more detailed picture of the chemical concentrations associated with these adverse effects should consult a toxicologist or the toxicity literature for the chemical to obtain more information.

Acetonitrile (CAS: 75-05-8)

Sources. Acetonitrile may be generated as a byproduct of acrylonitrile manufacture and may be used as a solvent in butadiene extraction processes.

Toxicity. Toxicity may be caused through ingestion, inhalation, or dermal exposure. Exposure to acetonitrile may lead to cyanide poisoning by metabolic release of cyanide after absorption. Toxicity can be prolonged.

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[1] TOXNET is a computer system run by the National Library of Medicine that includes a number of toxicological databases managed by EPA, National Cancer Institute, and the National Institute for Occupational Safety and Health. For more information on TOXNET, contact the TOXNET help line at 800-231-3766. Databases included in TOXNET are: CCRIS (Chemical Carcinogenesis Research Information System), DART (Developmental and Reproductive Toxicity Database), DBIR (Directory of Biotechnology Information Resources), EMICBACK (Environmental Mutagen Information Center Backfile), GENE-TOX (Genetic Toxicology), HSDB (Hazardous Substances Data Bank), IRIS (Integrated Risk Information System), RTECS (Registry of Toxic Effects of Chemical Substances), and TRI (Toxic Chemical Release Inventory). HSDB contains chemical-specific information on manufacturing and use, chemical and physical properties, safety and handling, toxicity and biomedical effects, pharmacology, environmental fate and exposure potential, exposure standards and regulations, monitoring and analysis methods, and additional references.

Individuals exposed to slight concentrations may develop nausea, vomiting, headache and lassitude. Severely poisoned patients may develop extreme weakness or lassitude, respiratory depression, shock, coma, and seizures. Pulse may become rapid, weak, and sometimes irregular. Lactic acidosis is common after oral ingestion, as a result of the conversion to cyanide. Chronically exposed patients may develop headache, lack of appetite, dizziness, weakness, and dermatitis. In one study, exposures of 40 to 160 ppm for four hours resulted in no symptoms or only mild symptoms. A dose of 0.006 mg of acetonitrile per kg body weight per day is expected to result in no adverse effects if an individual is exposed to this dose for a lifetime. This dose level was determined from a study which found decreased red blood cell counts and hematocrit, and hepatic lesions in mice exposed to acetonitrile for 90 days.

Carcinogenicity. There is currently no long-term human or animal data to suggest that this chemical is carcinogenic in humans.

Environmental Fate and Potential for Human Exposure. Biodegradation is likely to occur if it is released to soil. It is also mobile in soil and may evaporate from the surface of soil. In water, the major loss process is biodegradation. Acetonitrile will persist in the troposphere for a long time and may be transported a long distance from the source of its release. Wet deposition may remove some of the atmospheric acetonitrile.

Carbon Disulfide (CAS: 75-15-0)

Sources. Carbon disulfide is used in a variety of industrial applications including the manufacture of regenerated cellulose rayon and cellophane, and in the production of rubber.

Toxicity. Short-term (acute) exposure of humans to carbon disulfide can cause headache, dizziness, fatigue, and irritation of eye, nose, and throat. Exposure to high concentrations may result in trouble breathing or respiratory failure. Contact with skin can cause severe burns.

Long-term (chronic) exposure to high levels in excess of regulatory standards may result in peripheral nerve damage (involving the nerves that control feet, legs, hands, and arms) and cardiovascular effects. A few studies contend that chronic exposure may also result in potential reproductive effects.

Carcinogenicity. There are no long-term human or animal data to suggest that this chemical is carcinogenic in humans.

Environmental Fate. If released on land, carbon disulfide will be primarily lost to volatilization and it may leach into the ground where it would be expected to biodegrade. The chemical will also volatilize if released to water and does not adsorb to sediment. In air, carbon disulfide reacts with atomic oxygen to produce hydroxyl radicals with half-lives of a few days. Carbon disulfide gas is adsorbed and degraded by soil, which demonstrates that soil may be a natural sink for this chemical. The general population may be exposed to carbon disulfide primarily from ambient air as it is released not only from industrial sources, but also from a wide variety of natural sources.

Ethylene (CAS: 74-85-1)

Sources. Ethylene is used to make polyethylene, polypropylene, polystyrene, polyester, and polyvinyl chloride resins. Ethylene is the monomer used to make high-density polyethylene, low-density polyethylene, and linear low-density polyethylene.

Toxicity. Ethylene has been used as an anaesthetic; the effects reported here are related to its properties as an anaesthetic. Asphyxia may occur from breathing ethylene in enclosed spaces and in cases where the atmospheric oxygen has been displaced to about 15 to 16 percent or less.

Carcinogenicity. According to the International Agency for Research on Cancer, there is inadequate evidence in humans and animals to suggest carcinogenicity in humans.

Environmental Fate. In the air, ozone, nitrate radicals, and hydroxyl radicals may degrade ethylene. In water and soil, ethylene may be oxidized to produce ethylene oxide, and the chemical may permeate soil and sediment. The major environmental fate process is volatilization. The most probable way humans are exposed is by inhaling ethylene from contaminated air.

Ethylene Glycol (CAS: 74-85-1)

Sources. Ethylene glycol is used to make polyethylene terephthalate (PET). It is also used in the manufacture of alkyd resins and as a solvent mixture for cellulose esters and ethers. Over 75 percent of ethylene glycol releases are by means of point and fugitive air emissions.

Toxicity. Long-term inhalation exposure to low levels of ethylene glycol may cause throat irritation, mild headache and backache. Exposure to higher concentrations may lead to unconsciousness. Liquid ethylene glycol is irritating to the eyes and skin.

Toxic effects from ingestion of ethylene glycol include damage to the central nervous system and kidneys, intoxication, conjunctivitis, nausea and vomiting, abdominal pain, weakness, low blood oxygen, tremors, convulsions, respiratory failure, and coma. Renal failure due to ethylene glycol poisoning can lead to death.

Environmental Fate. Ethylene glycol readily biodegrades in water. No data are available that report its fate in soils; however, biodegradation is probably the dominant removal mechanism. Should ethylene glycol leach into the groundwater, biodegradation may occur.

Ethylene glycol in water is not expected to bioconcentrate in aquatic organisms, adsorb to sediments or volatilize. Atmospheric ethylene glycol degrades rapidly in the presence of hydroxyl radicals.

Hydrochloric Acid (CAS: 7647-01-1)

Sources. Hydrochloric acid can be generated during plastic resin manufacture.

Toxicity. Hydrochloric acid is primarily a concern in its aerosol form. Acid aerosols have been implicated in causing and exacerbating a variety of respiratory ailments. Dermal exposure and ingestion of highly concentrated hydrochloric acid can result in corrosivity.

Ecologically, accidental releases of solution forms of hydrochloric acid may adversely affect aquatic life through a transient lowering of the pH (i.e. increasing the acidity) of surface waters.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Releases of hydrochloric acid to surface waters and soils will be neutralized to an extent due to the buffering capacities of both systems. The extent of these reactions will depend on the characteristics of the specific environment.

Physical Properties. Concentrated hydrochloric acid is highly corrosive.

Methanol (CAS: 67-56-1)

Sources. Methanol can be used as a solvent in plastic resin manufacture. Methanol is used in some processes to make polyester, although many companies have converted to newer process methods that do not use methanol (AFMA, 1997b).

Toxicity. Methanol is readily absorbed from the gastrointestinal tract and the respiratory tract, and is toxic to humans in moderate to high doses. In the body, methanol is converted into formaldehyde and formic acid. Methanol is excreted as formic acid. Observed toxic effects at high dose levels generally include central nervous system damage and blindness. Long-term exposure to high levels of methanol via inhalation cause liver and blood damage in animals.

Ecologically, methanol is expected to have low toxicity to aquatic organisms. Concentrations lethal to half the organisms of a test population are expected to exceed one mg methanol per liter water. Methanol is not likely to persist in water or to bioaccumulate in aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Liquid methanol is likely to evaporate when left exposed. Methanol reacts in air to produce formaldehyde which contributes to the formation of air pollutants. In the atmosphere it can react with other atmospheric chemicals or be washed out by rain. Methanol is readily degraded by microorganisms in soils and surface waters.

Physical Properties. Methanol is highly flammable.

IV.C. Other Data Sources

The toxic chemical release data obtained from TRI captures the vast majority of facilities in the plastic resin and manmade fiber industries. It also allows for a comparison across years and industry sectors. Reported chemicals are limited however to the 316 reported chemicals. Most of the hydrocarbon emissions from organic chemical facilities are not captured by TRI. The EPA Office of Air Quality Planning and Standards has compiled air pollutant emission factors for determining the total air emissions of priority pollutants (e.g., total hydrocarbons, SO_x, NO_x, CO, particulates, etc.) from many chemical manufacturing sources.

The EPA Office of Air's Aerometric Information Retrieval System (AIRS) contains a wide range of information related to stationary sources of air pollution, including the emissions of a number of air pollutants which may be of concern within a particular industry. With the exception of volatile organic compounds (VOCs), there is little overlap with the TRI chemicals reported above. Table 20 summarizes annual releases of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter of 10 microns or less (PM10), total particulate (PT), sulfur dioxide (SO_2), and volatile organic compounds (VOCs).

Table 20: Air Pollutant Releases by Industry Sector (tons/year)

Industry Sector	CO	NO_2	PM_{10}	PT	SO_2	VOC
Metal Mining	4,670	39,849	63,541	173,566	17,690	915
Nonmetal Mining	25,922	22,881	40,199	128,661	18,000	4,002
Lumber and Wood Production	122,061	38,042	20,456	64,650	9,401	55,983
Furniture and Fixtures	2,754	1,872	2,502	4,827	1,538	67,604
Pulp and Paper	566,883	358,675	35,030	111,210	493,313	127,809
Printing	8,755	3,542	405	1,198	1,684	103,018
Inorganic Chemicals	153,294	106,522	6,703	34,664	194,153	65,427
Organic Chemicals	112,410	187,400	14,596	16,053	176,115	180,350
Petroleum Refining	734,630	355,852	27,497	36,141	619,775	313,982
Rubber and Misc. Plastics	2,200	9,955	2,618	5,182	21,720	132,945
Stone, Clay and Concrete	105,059	340,639	192,962	662,233	308,534	34,337
Iron and Steel	1,386,461	153,607	83,938	87,939	232,347	83,882
Nonferrous Metals	214,243	31,136	10,403	24,654	253,538	11,058
Fabricated Metals	4,925	11,104	1,019	2,790	3,169	86,472
Electronics and Computers	356	1,501	224	385	741	4,866
Motor Vehicles, Bodies, Parts and Accessories	15,109	27,355	1,048	3,699	20,378	96,338
Dry Cleaning	102	184	3	27	155	7,441
Ground Transportation	128,625	550,551	2,569	5,489	8,417	104,824
Metal Casting	116,538	11,911	10,995	20,973	6,513	19,031
Pharmaceuticals	6,586	19,088	1,576	4,425	21,311	37,214
Plastic Resins and Manmade Fibers	**16,388**	**41,771**	**2,218**	**7,546**	**67,546**	**74,138**
Textiles	8,177	34,523	2,028	9,479	43,050	27,768
Power Generation	366,208	5,986,757	140,760	464,542	13,827,511	57,384
Shipbuilding and Repair	105	862	638	943	3,051	3,967

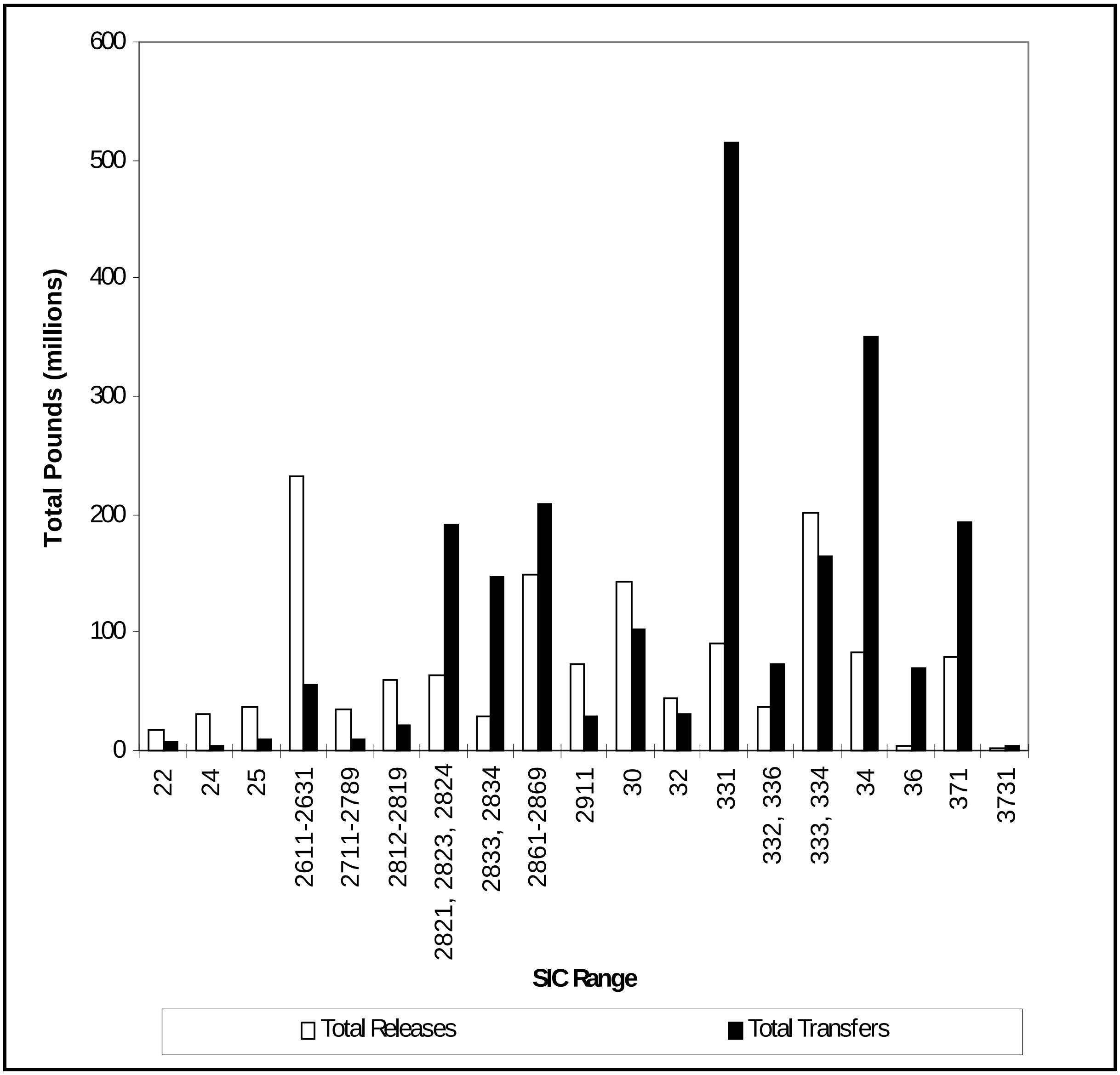
Source: U.S. EPA Office of Air and Radiation, AIRS Database, 1997.

IV.D. Comparison of Toxic Release Inventory Between Selected Industries

The following information is presented as a comparison of pollutant release and transfer data across industrial categories. It is provided to give a general sense as to the relative scale of releases and transfers within each sector profiled under this project. Please note that the following figure and table do not contain releases and transfers for industrial categories that are not included in this project, and thus cannot be used to draw conclusions regarding the total release and transfer amounts that are reported to TRI. Similar information is available within the annual TRI Public Data Release Book.

Figure 18 is a graphical representation of a summary of the 1995 TRI data for the plastic resin and manmade fibers industries and the other sectors profiled in separate notebooks. The bar graph presents the total TRI releases and total transfers on the vertical axis. The graph is based on the data shown in Table 21 and is meant to facilitate comparisons between the relative amounts of releases, transfers, and releases per facility both within and between these sectors. The reader should note, however, that differences in the proportion of facilities captured by TRI exist between industry sectors. This can be a factor of poor SIC matching and relative differences in the number of facilities reporting to TRI from the various sectors. In the case of the plastic resin and manmade fiber industries, the 1995 TRI data presented here covers 469 facilities. Only those facilities listing SIC Codes falling within SIC 2821, 2823, and 2824 were used.

Figure 18: Summary of TRI Releases and Transfers by Industry



Source: US EPA 1995 Toxics Release Inventory Database.

SIC Range	Industry Sector	SIC Range	Industry Sector	SIC Range	Industry Sector
22	Textiles	2833, 2834	Pharmaceuticals	333, 334	Nonferrous Metals
24	Lumber and Wood Products	2861-2869	Organic Chem. Mfg.	34	Fabricated Metals
25	Furniture and Fixtures	2911	Petroleum Refining	36	Electronic Equip. and Comp.
2611-2631	Pulp and Paper	30	Rubber and Misc. Plastics	371	Motor Vehicles, Bodies, Parts, and Accessories
2711-2789	Printing	32	Stone, Clay, and Concrete	3731	Shipbuilding
2812-2819	Inorganic Chemical Manufacturing	331	Iron and Steel		
2821, 2823, 2824	**Plastic Resins and Manmade Fibers**	332, 336	Metal Casting		

Table 21: Toxics Release Inventory Data for Selected Industries

Industry Sector	SIC Range	# TRI Facilities	TRI Releases		TRI Transfers		Total Releases +Transfers (million lbs.)	Average Releases + Transfers per Facility (pounds)
			Total Releases (million lbs.)	Ave. Releases per Facility (pounds)	Total Transfers (million lbs.)	Ave. Trans. per Facility (pounds)		
Textiles	22	339	17.8	53,000	7.0	21,000	24.8	74,000
Lumber and Wood Products	24	397	30.0	76,000	4.1	10,000	34.1	86,000
Furniture and Fixtures	25	336	37.6	112,000	9.9	29,000	47.5	141,000
Pulp and Paper	2611-2631	305	232.6	763,000	56.5	185,000	289.1	948,000
Printing	2711-2789	262	33.9	129,000	10.4	40,000	44.3	169,000
Inorganic Chem. Mfg.	2812-2819	413	60.7	468,000	21.7	191,000	438.5	659,000
Plastic Resins and Manmade Fibers	**2821,2823, 2824**	**410**	**64.1**	**156,000**	**192.4**	**469,000**	**256.5**	**625,000**
Pharmaceuticals	2833, 2834	200	29.9	150,000	147.2	736,000	177.1	886,000
Organic Chemical Mfg.	2861-2869	402	148.3	598,000	208.6	631,000	946.8	1,229,000
Petroleum Refining	2911	180	73.8	410,000	29.2	162,000	103.0	572,000
Rubber and Misc. Plastics	30	1,947	143.1	73,000	102.6	53,000	245.7	126,000
Stone, Clay, and Concrete	32	623	43.9	70,000	31.8	51,000	75.7	121,000
Iron and Steel	331	423	90.7	214,000	513.9	1,215,000	604.6	1,429,000
Metal Casting	332, 336	654	36.0	55,000	73.9	113,000	109.9	168,000
Nonferrous Metals	333, 334	282	201.7	715,000	164	582,000	365.7	1,297,000
Fabricated Metals	34	2,676	83.5	31,000	350.5	131,000	434.0	162,000
Electronic Equip. and Comp.	36	407	4.3	11,000	68.8	169,000	73.1	180,000
Motor Vehicles, Bodies, Parts, and Accessories	371	754	79.3	105,000	194	257,000	273.3	362,000
Shipbuilding	3731	43	2.4	56,000	4.1	95,000	6.5	151,000

Source: *US EPA Toxics Release Inventory Database, 1995.*

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V. POLLUTION PREVENTION OPPORTUNITIES

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and substituting benign chemicals for toxic ones. Some smaller facilities are able to get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies.

The Pollution Prevention Act of 1990 established a national policy of managing waste through source reduction, which means preventing the generation of waste. The Pollution Prevention Act also established as national policy a hierarchy of waste management options for situations in which source reduction cannot be implemented feasibly. In the waste management hierarchy, if source reduction is not feasible the next alternative is recycling of wastes, followed by energy recovery, and waste treatment as a last alternative.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the plastic resin and manmade fiber industries and the chemical industry as a whole. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in starting their own pollution prevention projects. This section provides information from real activities that can, or are being implemented by this sector -- including a discussion of associated costs, time frames, and expected rates of return.

This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land and water pollutant releases.

✔ **Substitute raw materials.** The substitution or elimination of some of the raw materials used in the manufacturing of plastic resins and manmade fibers can result in substantial waste reductions and cost savings. Raw materials can be substituted with less water soluble materials to reduce water contamination and less volatile materials to reduce fugitive emissions. Sometimes certain raw materials can be eliminated all together. The need for raw materials that end up as wastes should be reexamined to determine if raw materials can be eliminated by modifying the process and improving process control.

- *A specialty batch polymer plant* in the Northeast avoids highly toxic and hazardous substances in the facility's proprietary products and formulations. The company also minimizes waste by using water-based chemistry in place of organic-based chemistry wherever possible (SOCMA, 1993).

- *Du Pont* substituted coal with butadiene in the production of nylon and substituted terephthalic acid for dimethyl terephthalate in the production of polyester. The substitutions eliminated generation of by-products, such as liquid methanol (North Carolina Department of Environment, Health, and Natural Resources, 1995).

- *A manmade fibers and organic chemicals manufacturer* eliminated benzene from its manufacturing processes. As a result, the facility simplified its compliance and recordkeeping procedures since it is no longer subject to the benzene NESHAP (EPA, 1993).

✔ **Improve catalyst.** The catalyst plays a critical role in the effectiveness of chemical conversion in the reactor. Alternative catalyst chemical makeups and physical characteristics can lead to substantial improvements in the effectiveness and life of a catalyst. Different catalysts can also eliminate byproduct formation. Using a more active catalyst and purchasing catalysts in the active form can reduce catalyst consumption and decrease emissions generated during catalyst activation. Catalyst activity can also be optimized by limiting catalyst residence time in the charge lines (Smith, 1964).

✔ **Optimize processes.** Process changes that optimize reactions and raw materials use can reduce chemical releases. Developing more reliable reactor operations with fewer upsets can reduce air emissions and pollution from unreacted reactants. Modifications may include improved process control systems, optimized use of chemicals, or equipment modifications. Many larger facilities are using computer controlled systems which analyze the process continuously and respond more quickly and accurately than manual control systems. These systems are often capable of automatic startups, shutdowns and product changeover which can bring the process to stable conditions quickly, minimizing the generation of off-spec wastes. Textile fiber manufacturers can optimize use of chemicals and minimize hazardous waste from fiber finishes by improving control of finish add-on and selection of finish components (EPA, 1995).

Processes can also be optimized through equipment retrofits and replacements. For instance, dedicated piping can isolate certain types of solvents from others, avoiding offgrade product and waste production. Equipment and process changes can also minimize byproduct waste and improve product yield by lowering polymer conversion rate in the reactors.

Rationalizing the equipment used for high pressure pumping and installing interlocking raw material valves to gain better recipe control can minimize offgrade product (Clements and Thompson, 1993).

- *BP Chemicals* switched from a series of programmable controllers and analog controllers to a distributed control system. The new control system has greater ability to report what is occurring in the reaction tank and provides operators with more opportunity to improve reaction consistency or correct small problems before they become big ones. This results in less reactor downtime and off-spec product (Elley, 1991).

- *Du Pont's* Wilmington, North Carolina polyester plant reduced its releases and transfers of 33/50 chemicals by 55 percent, or more than 1 million lb/yr between 1988 and 1993. By simplifying manufacturing processes, Du Pont eliminated use of *ortho*-xylene and generation of methanol and ethylene glycol by-products. This change resulted in savings of over $1 million /yr. The plant also made innovative process modifications which reduced process temperatures and VOC emissions (North Carolina Department of Environment, Health, and Natural Resources, 1995).

- While increasing production in 1990 and 1991, *Monsanto's* Pensacola, Florida plant implemented process modifications and operational changes in its nylon operations that reduced TRI releases by 74 percent and cyclohexane releases by 96 percent. The plant changed processes and reduced the amount of ammonia required to neutralize nitric acid, a by-product of nylon production. This reduced the amount of ammonium nitrate the company disposed of in deep wells by 18 million pounds. The facility also made process modifications and operational changes from 1989 to 1991 which cut cyclohexane releases by 96 percent and installed a new ammonia storage tank which increased safety and reduced air emissions (CMA, 1992).

- *Reichhold Chemicals* made equipment improvements to reduce waste from product sampling. Special canisters were permanently fixed to production tanks which enabled smaller samples to be taken and later returned to the tanks.

- *A manmade fibers and hydrocarbon resins facility* implemented four process modifications to reduce waste. The plant changed to closed purge systems to eliminate emissions in sampling operations, flushed pumps through equipment to process vessels to avoid discharging wastewater, optimized the wetting agent amount needed for fibers to reduce oxygen demand in upstream effluent, and modified procedures to require flushing of the system between product grades to minimize off-grade product. These steps reduced waste generated due to off-spec quality by 40 percent (Kikta, 1994).

✔ **Adopt good operating practices.** Companies can improve production efficiency and maintain low operating costs by incorporating pollution prevention codes into their management procedures. These codes can include a written commitment by senior management to ongoing waste reduction at each of the company's facilities, inclusion of pollution prevention objectives in research and new facility design, or implementation of employee training and incentive programs. In addition, establishing training programs and improving recordkeeping are other ways that companies can prevent pollution without changing industrial processes. Employee involvement groups can also be used to identify and implement waste minimization projects within their operational areas, and wastes from lab, maintenance and off-spec materials can be minimized through better housekeeping practices and personnel training (Smith, 1987), (http://es.inel.gov/techinfo/facts/cma/cma-fs3.html, 7/96).

- *A specialty batch polymer facility* established a facility-wide monetary bonus program aimed at reducing waste on a monthly basis. The company also gave the reactor operator the ability to alter production schedule and recipe parameters to ensure product quality and prevent offgrade production (SOCMA, 1993).

- *Du Pont* targeted, tracked and reported tabulated wastes. *Du Pont* defined its "tabulated waste" as RCRA-defined waste, solid waste treated or disposed of on-site or off-site, waste-derived fuels, some recycled materials, deep well injection wastes, and wastewater effluents. The company also chose an environmental coordinator for each waste-generating site, established training programs, and reduced waste through use of belt filters. Du Pont also saved over $12.5 million by implementing a company wide energy efficiency program. Improvements included shutdown of spare or unneeded equipment, tune-up and optimization of systems and processes, renegotiation of fuel, electricity and service contracts, waste heat and condensate return, electrical peak management, fuels inventory reduction, HVAC system management improvements, improved steam trap maintenance program, and system or process improvements (Cleenger and Hassell,1994).

- At the *Du Pont* Kinston, North Carolina plant, lube oil waste was significantly reduced through preventative maintenance programs and installation of longer-life oils in certain equipment (North Carolina Department of Environment, Health, and Natural Resources, 1995).

✔ **Modify product.** Product modification can eliminate the use of hazardous chemicals, reduce emissions from manufacturing processes, and also decrease emissions from final products. Improvements in product packaging systems and materials can be used to cut back disposal of contaminated product.

- *A batch specialty polymer facility* has encouraged its customers to eliminate the use of hazardous chemicals wherever possible in their batch specifications (SOCMA, 1993).

- A *manmade fiber and hydrocarbon resin plant* reduced product waste from the mechanical failure of its sheet-forming dewatering machine. The company achieved this by rectifying the inadequate design and writing better operating procedures for the machine (Kikta, 1994).

- *PPG Industries* introduced resins for industrial paints with lower VOC emissions and reduced solvent waste by modifying plant equipment and processes. Processes were modified to reformulate resins and eliminate extraneous solvents. These changes made recovery and recycle of solvent easier.

✔ **Prevent leaks and spills.** The elimination of sources of leaks and spills can be a very cost effective pollution prevention opportunity. Leaks and spills can be prevented by adopting a preventative maintenance program, maintaining a leak detection program, and installing seamless pumps and other "leakless" equipment. Vapor recovery lines can also be used to reduce monomer vapors generated during polymerization and VOCs emitted during unloading of bulk raw materials from tank trucks. Additionally, process water can be used to clean out unloading vehicles and be recycled back into the processes (CMA, 1993).

- *Novacor Chemicals* replaced three 100,000 gallon monomer storage tanks at its Springfield, MA site and reduced VOC emissions by 8,800 lbs/ year. The new tanks are equipped with vapor recovery systems and use a nitrogen gas blanket in the tank head space to prevent volatilization of monomer. Additionally, the tanks are better equipped for fire protection and spill containment (in person interview, M. Garvey, Novacor, 11/96).

- At *Texas Eastman's Longview plant,* employees monitored thousands of leaking valves and reduced air emissions from those valves by 99 percent, through the development of new valve packing materials (http://es.inel.gov/studies/eastx-d.html, 7/96).

- *A specialty batch polymer plant* initiated an intensive maintenance program to improve wetting agent pump seals and installed curbs around pumps to contain leaks. Refrigerant releases were also lowered by pumping equipment down to very low pressure prior to maintenance (Kikta, 1994).

✔ **Optimize cleaning practices.** Modifying equipment cleaning practices can reduce wastewater discharges and reduce solvent use. Substituting cleaning solvents with less toxic solvents can reduce hazardous waste generation and can simplify treatment of wastewater. Many facilities have switched from using ozone-depleting chemicals to non-ozone-depleting ones. Wastes can also be minimized by either washing out piping and transfer hoses after use or by purchasing dedicated hoses for each product loaded into tankers. Techniques used to minimize fouling on the reactor walls include maintaining a high polish on reactors, using less water-soluble and more active catalysts, and using reflux condensers and water-cooled baffles.

- *Monsanto's* Pensacola, Florida plant eliminated CFC and methyl chloroform releases by substituting solvents used in its degreasing and cleaning operations (CMA, 1992). In addition, both *Du Pont* and *Monsanto* switched from solvents to high-pressure water washing to clean vessels of polymer buildup. This eliminated 180,000 lbs of TRI waste discharged annually to publicly owned treatment works by *Monsanto's* Indian Orchard plant in Massachusetts.

- *Du Pont's* Chambers Works plant in New Jersey reduced cleaning waste by 98%. The company turned to experts in waterjet engineering, used in the mining industry, to design a special water lance and nozzle. This change cut turnaround time and saved money (http://es.inel.gov/techinfo/facts/cma/cma-fs3.html, 7/96).

✔ **Improve inventory management and storage.** Good inventory management can reduce waste by preventing materials from exceeding their shelf life, preventing materials from being left over or not needed, and reducing the likelihood of accidental releases of stored material. Designating a materials storage area, limiting traffic through the area, and giving one person the responsibility to maintain and distribute materials can reduce materials use and contamination and dispersal of materials.

- At its polyethylene facility in Victoria, Australia, *Commercial Polymers* adopted a comprehensive water conservation program. Workers read over 20 water meters on a daily basis and adopted water intake minimization strategies based on usage. Water usage has been reduced by 30 percent to about 500 m^3 per day (Clements and Thompson, 1993).

Recycling, Recovery and Reuse

Although not pollution prevention as defined by the Pollution Prevention Act of 1990, recovery, recycling and reuse can be effective tools for minimizing pollutant releases to the environment. By recovering solvents and raw materials, plastic resin and manmade fiber manufacturers can reduce pollution without modifying existing processes and can reduce raw materials costs. Solvents are widely used in the industries for activities ranging from polymerization and fiber spinning to degreasing and cleaning. Raw materials can also be recycled, such as unreacted monomer, catalyst and additives.

✔ **Recover Solvents.** Capturing, purifying and recycling solvents can be an effective method of reducing pollution. Facilities can reduce TRI chemical releases and save money by recycling solvents used in polymerization, fiber manufacture and supporting operations. Common methods used in solvent recovery are evaporation, distillation and carbon adsorption.

- *Hoechst* installed carbon adsorption solvent recovery units to recover and recycle acetone back to the acetate fiber spinning process. Using carbon adsorption, overall plant acetone recovery efficiency reaches nearly 99 percent. Hoechst plans to achieve additional reductions by revamping air handling and ventilation systems to improve acetone capture.

- *A phenol formaldehyde resin manufacturer* used distillation and reuse of alcohol wash liquid to reduce waste generation and off-site disposal by 67%. The plant had generated 6,000 gal/yr of reactor wash solution containing 50% alcohol, phenol formaldehyde resin and water. By recycling the alcohol wash solution, the plant saves $15,000 annually in material and treatment costs (http://es.inel.gov/studies/cs435.html, 7/96).

- *A specialty batch polymer plant* switched to a cryogenic vapor recovery system to minimize the amount of residual solvent trapped by fibers and released with downstream processing (Kikta, 1994).

✔ **Recover Raw Materials.** By capturing, purifying and recycling raw materials, companies can reduce pollution and raw materials costs. Many companies recycle unreacted monomer back to reactor vessels. This saves money by reducing monomer costs and treatment and disposal costs. Some companies save money by recycling catalyst components.

- *Allied Signal's* high-density polyethylene plant (Baton Rouge, Louisiana) implemented a chromium recovery process, which uses an ion exchange resin, to reduce the plant's hazardous catalyst waste. The company installed a chromium recovery unit at a cost of $265,000 and saved $500,000 that year in hazardous waste disposal costs.

- *Hoechst Celanese* recovers Freon, used in the quality control laboratories, for reuse via a glassware batch distillation system. The recovery and reuse of Freon in the laboratory has saved Celanese's Greenville plant over $1,800 a year in disposal and raw material costs. Contaminated heat transfer fluid (Dowtherm) is sent to an off-site distillation facility for recovery and returned for reuse in production. Recycling of heat recovery fluid saves the plant about $164,000 per year in disposal and raw material costs.

- *Du Pont* recycled pump out solution wastes (polymer and acid) from polyarymide fiber production, saving the company disposal, treatment and handling costs.

- *Borden Chemical Company* recycled phenolic resins and modified its reactor rinse procedures to reduce waste volume and toxicity. *Borden* switched from a one-rinse system to a two-rinse system. Previously, the plant used 20,000 gallons of water to rinse the reactors. Now, the reactors are first rinsed with 500-1000 gallons of water and then rinsed again. The wastewater from the first rinse has a high concentration of resins, which are filtered, rinsed, and recycled back into the process as raw materials. The filtered wastewater is reused for rinsing (http://es.inel.gov/studies/cs20.html, 7/96).

- *American Enka* used an alternative two-stage precipitation process to recover zinc, which is used in the acid spinning bath process. Zinc is precipitated, treated and returned to the spinning bath. Zinc recycling can be an economical solution that conserves limited resources and reduces waste disposal (http://es.inel.gov/studies/hml10053.html, 7/96).

CMA's Responsible Care® Program

The leaders in the plastics and manmade fibers industries, similar to those in the chemical industry as a whole, have been promoting pollution prevention through various means. The most visible of these efforts is the Responsible Care® initiative of the Chemical Manufacturers Association (CMA). Responsible Care® is mandatory for CMA members who must commit to act as stewards for products through use and ultimate reuse or disposal. One of the guiding principles of this initiative is the inclusion of waste and release prevention objectives in research and in design of new or modified facilities, processes and products.

The following tables, Table 22 and Table 23, are adapted from the CMA "Designing Pollution Prevention into the Process" manual. These tables cover, in greater detail, those activities which afford the greatest opportunity to utilize source reduction and/or recycle versus treatment as a way to manage waste. The first table covers pollution prevention methods that require process or product modification. The second table describes pollution prevention options that involve changes in equipment design and operation.

Table 22: Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
By-products **Co-products**		
Quantity and Quality	▪ Process inefficiencies result in the generation of undesired by-products and co-products. Inefficiencies will require larger volumes of raw materials and result in additional secondary products. Inefficiencies can also increase fugitive emissions and wastes generated through material handling.	▪ Increase product yield to reduce by-product and co-product generation and raw material requirements.
Uses and Outlets	▪ By-products and co-products are not fully utilized, generating material or waste that must be managed.	▪ Identify uses and develop a sales outlet. Collect information necessary to firm up a purchase commitment such as minimum quality criteria, maximum impurity levels that can be tolerated, and performance criteria.
Catalysts		
Composition	▪ The presence of heavy metals in catalysts can result in contaminated process wastewater from catalyst handling and separation. These wastes may require special treatment and disposal procedures or facilities. Heavy metals can be inhibitory or toxic to biological wastewater treatment units. Sludge from wastewater treatment units may be classified as hazardous due to heavy metals content. Heavy metals generally exhibit low toxicity thresholds in aquatic environments and may bioaccumulate.	▪ Catalysts comprised of noble metals, because of their cost, are generally recycled by both onsite and offsite reclaimers.
Preparation and Handling	▪ Emissions or effluents are generated with catalyst activation or regeneration.	▪ Obtain catalyst in the active form. ▪ Provide insitu activation with appropriate processing/activation facilities.
	▪ Catalyst attrition and carryover into product requires de-ashing facilities which are a likely source of wastewater and solid waste.	▪ Develop a more robust catalyst or support.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Catalysts (cont.)		
Preparation and Handling (cont.)	■ Catalyst is spent and needs to be replaced.	■ In situ regeneration eliminates unloading/loading emissions and effluents versus offsite regeneration or disposal.
	■ Pyrophoric catalyst needs to be kept wet, resulting in liquid contaminated with metals.	■ Use a nonpryrophoric catalyst. Minimize amount of water required to handle and store safely.
	■ Short catalyst life.	■ Study and identify catalyst deactivation mechanisms. Avoid conditions which promote thermal or chemical deactivation. By extending catalyst life, emissions and effluents associated with catalyst handling and regeneration can be reduced.
Effectiveness	■ Catalyzed reaction has by-product formation, incomplete conversion and less-than-perfect yield.	■ Reduce catalyst consumption with a more active form. A higher concentration of active ingredient or increased surface area can reduce catalyst loadings.
		■ Use a more selective catalyst which will reduce the yield of undesired by-products.
		■ Improve reactor mixing/contacting to increase catalyst effectiveness.
	■ Catalyzed reaction has by-product formation, incomplete conversion and less-than perfect yield.	■ Develop a thorough understanding of reaction to allow optimization of reactor design. Include in the optimization, catalyst consumption and by-product yield.
Intermediate Products		
Quantity and Quality	■ Intermediate reaction products or chemical species, including trace levels of toxic constituents, may contribute to process waste under both normal and upset conditions.	■ Modify reaction sequence to reduce amount or change composition of intermediates.
	■ Intermediates may contain toxic constituents or have characteristics that are harmful to the environment.	■ Modify reaction sequence to change intermediate properties.
		■ Use equipment design and process control to reduce releases.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration		
Temperature	■ High heat exchange tube temperatures cause thermal cracking/decomposition of many chemicals. These lower molecular weight by-products are a source of “light ends” and fugitive emissions. High localized temperature gives rise to polymerization of reactive monomers, resulting in “heavies” or “tars.” such materials can foul heat exchange equipment or plug fixed-bed reactors, thereby requiring costly equipment cleaning and production outage.	■ Select operating temperatures at or near ambient temperature whenever possible. ■ Use lower pressure steam to lower temperatures. ■ Use intermediate exchangers to avoid contact with furnace tubes and walls. ■ Use staged heating to minimize product degradation and unwanted side reactions. ■ Use superheat of high-pressure steam in place of furnace. ■ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers. ■ Use online tube cleaning technologies to keep tube surfaces clean to increase heat transfer. ■ Use scraped wall exchangers in viscous service. ■ Use falling film reboiler, pumped recirculation reboiler or high-flux tubes.
	■ Higher operating temperatures imply “heat input” usually via combustion which generates emissions. ■ Heat sources such as furnaces and boilers are a source of combustion emissions. ■ Vapor pressure increases with increasing temperature. Loading/ unloading, tankage and fugitive emissions generally increase with increasing vapor pressure.	■ Explore heat integration opportunities (e.g., use waste heat to preheat materials and reduce the amount of combustion required.) ■ Use thermocompressor to upgrade low-pressure steam to avoid the need for additional boilers and furnaces. ■ If possible, cool materials before sending to storage. ■ Use hot process streams to reheat feeds.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.)		
Temperature (cont.)		▪ Add vent condensers to recover vapors in storage tanks or process. ▪ Add closed dome loading with vapor recovery condensers.
	▪ Water solubility of most chemicals increases with increasing temperature.	▪ Use lower temperature (vacuum processing).
Pressure	▪ Fugitive emissions from equipment.	▪ Equipment operating in vacuum service is not a source of fugitives; however, leaks into the process require control when system is degassed.
	▪ Seal leakage potential due to pressure differential.	▪ Minimize operating pressure.
	▪ Gas solubility increases with higher pressures.	▪ Determine whether gases can be recovered, compressed, and reused or require controls.
Corrosive Environment	▪ Material contamination occurs from corrosion products. Equipment failures result in spills, leaks and increased maintenance costs.	▪ Improve metallurgy or provide coating or lining. ▪ Neutralize corrosivity of materials contacting equipment. ▪ Use corrosion inhibitors.
	▪ Increased waste generation due to addition of corrosion inhibitors or neutralization.	▪ Improve metallurgy or provide coating or lining or operate in a less corrosive environment.
Batch vs. Continuous Operations	▪ Vent gas lost during batch fill.	▪Equalize reactor and storage tank vent lines. ▪Recover vapors through condenser, adsorber, etc.
	▪ Waste generated by cleaning/purging of process equipment between production batches.	▪ Use materials with low viscosity. Minimize equipment roughness.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.) *Batch vs. Continuous Operations (cont.)*		■ Optimize product manufacturing sequence to minimize washing operations and cross-contamination of subsequent batches.
	■ Process inefficiencies lower yield and increase emissions.	■ Sequence addition of reactants and reagents to optimize yields and lower emissions.
	■ Continuous process fugitive emissions and waste increase over time due to equipment failure through a lack of maintenance between turnarounds.	■Design facility to readily allow maintenance so as to avoid unexpected equipment failure and resultant release.
Process Operation/Design	■ Numerous processing steps create wastes and opportunities for errors.	■ Keep it simple. Make sure all operations are necessary. More operations and complexity only tend to increase potential emission and waste sources.
	■ Nonreactant materials (solvents, absorbants, etc.) create wastes. Each chemical (including water) employed within the process introduces additional potential waste sources; the composition of generated wastes also tends to become more complex.	■ Evaluate unit operation or technologies (e.g., separation) that do not require the addition of solvents or other nonreactant chemicals.
	■ High conversion with low yield results in wastes.	■ Recycle operations generally improve overall use of raw materials and chemicals, thereby both increasing the yield of desired products while at the same time reducing the generation of wastes. A case-in-point is to operate at a lower conversion per reaction cycle by reducing catalyst consumption, temperature, or residence time. Many times, this can result in a higher selectivity to desired products. The net effect upon recycle of unreacted reagents is an increase in product yield, while at the same time reducing the quantities of spent catalyst and less desirable by-products.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.)		
Process Operation/Design	■ Non-regenerative treatment systems result in increased waste versus regenerative systems.	■ Regenerative fixed bed treating or desiccant operation (e.g., aluminum oxide, silica, activated carbon, molecular sieves, etc.) will generate less quantities of solid or liquid waste than nonregenerative units (e.g., calcium chloride or activated clay). With regenerative units though, emissions during bed activation and regeneration can be significant. Further, side reactions during activation/regeneration can give rise to problematic pollutants.
Product		
Process Chemistry	■ Insufficient R&D into alternative reaction pathways may miss pollution opportunities such as waste reduction or eliminating a hazardous constituent.	■ R&D during process conception and laboratory studies should thoroughly investigate alternatives in process chemistry that affect pollution prevention.
Product Formulation	■ Product based on end-use performance may have undesirable environmental impacts or use raw materials or components that generate excessive or hazardous wastes.	■ Reformulate products by substituting different material or using a mixture of individual chemicals that meet end-use performance specifications.
Raw Materials		
Purity	■ Impurities may produce unwanted by-products and waste. Toxic impurities, even in trace amounts, can make a waste hazardous and therefore subject to strict and costly regulation.	■ Use higher purity materials. ■ Purify materials before use and reuse if practical. ■ Use inhibitors to prevent side reactions.
	■ Excessive impurities may require more processing and equipment to meet product specifications, increasing costs and potential for fugitive emissions, leaks, and spills.	■ Achieve balance between feed purity, processing steps, product quality and waste generation.
	■ Specifying a purity greater than needed by the process increases costs and can result in more waste generation by the supplier.	■ Specify a purity no greater than what the process needs.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Raw Materials (cont.) *Purity (cont.)*	■ Impurities in clean air can increase inert purges.	■Use pure oxygen.
	■ Impurities may poison catalyst prematurely resulting in increased wastes due to yield loss and more frequent catalyst replacement.	■Install guard beds to protect catalysts.
Vapor Pressure	■ Higher vapor pressures increase fugitive emissions in material handling and storage.	■ Use material with lower vapor pressure.
	■ High vapor pressure with low odor threshold materials can cause nuisance odors.	■ Use materials with lower vapor pressure and higher odor threshold.
Water Solubility	■ Toxic or nonbiodegradable materials that are water soluble may affect wastewater treatment operation, efficiency, and cost.	■ Use less toxic or more biodegradable materials.
	■ Higher solubility may increase potential for surface and groundwater contamination and may require more careful spill prevention, containment, and cleanup (SPCC) plans.	■ Use less soluble materials.
	■ Higher solubility may increase potential for storm water contamination in open areas.	■ Use less soluble materials. ■ Prevent direct contact with storm water by diking or covering areas.
	■ Process wastewater associated with water washing or hydrocarbon/water phase separation will be impacted by containment solubility in water. Appropriate wastewater treatment will be impacted.	■ Minimize water usage. ■ Reuse wash water. ■ Determine optimum process conditions for phase separation. ■ Evaluate alternative separation technologies (coalescers, membranes, distillation, etc.)

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Raw Materials (cont.)		
Toxicity	▪ Community and worker safety and health concerns result from routine and nonroutine emissions. Emissions sources include vents, equipment leaks, wastewater emissions, emergency pressure relief, etc.	▪ Use less toxic materials. ▪ Reduce exposure through equipment design and process control. Use systems which are passive for emergency containment of toxic releases.
	▪ Surges or higher than normal continuous levels of toxic materials can shock or miss wastewater biological treatment systems resulting in possible fines and possible toxicity in the receiving water.	▪ Use less toxic material. ▪ Reduce spills, leaks, and upset conditions through equipment and process control. ▪ Consider effect of chemicals on biological treatment; provide unit pretreatment or diversion capacity to remove toxicity. ▪ Install surge capacity for flow and concentration equalization.
Regulatory	▪ Hazardous or toxic materials are stringently regulated. They may require enhanced control and monitoring; increased compliance issues and paperwork for permits and record keeping; stricter control for handling, shipping, and disposal; higher sampling and analytical costs; and increased health and safety costs.	▪ Use materials which are less toxic or hazardous. ▪ Use better equipment and process design to minimize or control releases; in some cases, meeting certain regulatory criteria will exempt a system from permitting or other regulatory requirements.
Form of Supply	▪ Small containers increase shipping frequency which increases chances of material releases and waste residues from shipping containers (including wash waters).	▪ Use bulk supply, ship by pipeline, or use "jumbo" drums or sacks. ▪ In some cases, product may be shipped out in the same containers the material supply was shipped in without washing.
	▪ Nonreturnable containers may increase waste.	▪ Use returnable shipping containers or drums.
Handling and Storage	▪ Physical state (solid, liquid, gaseous) may raise unique environmental, safety, and health issues with unloading operations and transfer to process equipment.	▪ Use equipment and controls appropriate to the type of materials to control releases.

Table 22 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Raw Materials (cont.) *Handling and Storage (cont.)*	■ Large inventories can lead to spills, inherent safety issues and material expiration.	■ Minimize inventory by utilizing just-in-time delivery.
Waste Streams		
Quantity and Quality	■ Characteristics and sources of waste streams are unknown.	■ Document sources and quantities of waste streams prior to pollution prevention assessment.
	■ Wastes are generated as part of the process.	■ Determine what changes in process conditions would lower waste generation of toxicity.
		■ Determine if wastes can be recycled back into the process.
Composition	■ Hazardous or toxic constituents are found in waste streams. Examples are: sulfides, heavy metals, halogenated hydrocarbons, and polynuclear aromatics.	■ Evaluate whether different process conditions, routes, or reagent chemicals (e.g., solvent catalysts) can be substituted or changed to reduce or eliminate hazardous or toxic compounds.
Properties	■ Environmental fate and waste properties are not known or understood.	■ Evaluate waste characteristics using the following type properties: corrosivity, ignitability, reactivity, BTU content (energy recovery), biodegradability, aquatic toxicity, and bioaccumulation potential of the waste and of its degradable products, and whether it is a solid, liquid, or gas.
Disposal	■ Ability to treat and manage hazardous and toxic waste unknown or limited.	■ Consider and evaluate all onsite and offsite recycle, reuse, treatment, and disposal options available. Determine availability of facilities to treat or manage wastes generated.

Source: Chemical Manufacturers Association, *Designing Pollution Prevention into the Process, Research, Development and Engineering*, Washington, DC, 1993.

Table 23: Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach	
		Design Related	**Operational Related**
Compressors, blowers, fans	■ Shaft seal leaks, piston rod seal leaks, and vent streams	■ Seal-less designs (diaphragmatic, hermetic or magnetic) ■ Design for low emissions (internal balancing, double inlet, gland eductors) ■ Shaft seal designs (carbon rings, double mechanical seals, buffered seals) ■ Double seal with barrier fluid vented to control device	■ Preventive maintenance program
Concrete pads, floors, sumps	■ Leaks to groundwater	■ Water stops ■ Embedded metal plates ■ Epoxy sealing ■ Other impervious sealing	■ Reduce unnecessary purges, transfers, and sampling ■ Use drip pans where necessary
Controls	■ Shutdowns and start-ups generate waste and releases	■ Improve on-line controls ■ On-line instrumentation ■ Automatic start-up and shutdown ■ On-line vibration analysis ■ Use “consensus” systems (e.g., shutdown trip requires 2 out of 3 affirmative responses)	■ Continuous versus batch ■ Optimize on-line run time ■ Optimize shutdown interlock inspection frequency ■ Identify safety and environment critical instruments and equipment
Distillation	■ Impurities remain in process streams	■ Increase reflux ratio ■ Add section to column ■ Column intervals ■ Change feed tray	■ Change column operating conditions - reflux ratio - feed tray - temperature - pressure - etc.

Table 23 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Distillation (cont.)	▪ Impurities remain in process streams (cont.)	▪ Insulate to prevent heat loss ▪ Preheat column feed ▪ Increase vapor line size to lower pressure drop	▪ Clean column to reduce fouling
	▪ Large amounts of contaminated water condensate from stream stripping	▪ Use reboilers or inert gas stripping agents	▪ Use higher temperature steam
General manufacturing equipment areas	▪ Contaminated rainwater	▪ Provide roof over process facilities ▪ Segregate process sewer from storm sewer (diking) ▪ Hard-pipe process streams to process sewer	▪ Return samples to process ▪ Monitor stormwater discharge
	▪ Contaminated sprinkler and fire water	▪ Seal floors ▪ Drain to sump ▪ Route to waste treatment	
	▪ Leaks and emissions during cleaning	▪ Design for cleaning ▪ Design for minimum rinsing ▪ Design for minimum sludge ▪ Provide vapor enclosure ▪ Drain to process	▪ Use drip pans for maintenance activities ▪ Rinse to sump ▪ Reuse cleaning solutions
Heat exchangers	▪ Increased waste due to high localized temperatures	▪ Use intermediate exchangers to avoid contact with furnace tubes and walls ▪ Use staged heating to minimize product degradation and unwanted side reactions. (waste heat >>low pressure steam >>high pressure steam)	▪ Select operating temperatures at or near ambient temperature when-ever possible. These are generally most desirable from a pollution prevention standpoint ▪ Use lower pressure steam to lower temperatures

Table 23 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Heat exchangers (cont.)	▪ Increased waste due to high localized temperatures (cont.)	▪ Use scraped wall exchangers in viscous service ▪ Using falling film reboiler, piped recirculation reboiler or high-flux tubes ▪ Use lowest pressure steam possible	▪ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers ▪ Use on-line tube cleaning techniques to keep tube surfaces clean
	▪ Contaminated materials due to tubes leaking at tube sheets	▪ Use welded tubes or double tube sheets with inert purge. Mount vertically	▪ Monitor for leaks
	▪ Furnace emissions	▪ Use superheat of high-pressure steam in place of a furnace	
Piping	▪ Leaks to groundwater; fugitive emissions	▪ Design equipment layout so as to minimize pipe run length ▪ Eliminate underground piping or design for cathodic protection if necessary to install piping underground ▪ Welded fittings ▪ Reduce number of flanges and valves ▪ All welded pipe ▪ Secondary containment ▪ Spiral-wound gaskets ▪ Use plugs and double valves for open end lines ▪ Change metallurgy ▪ Use lined pipe	▪ Monitor for corrosion and erosion ▪ Paint to prevent external corrosion

Table 23 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	**Potential Environment Problem**	**Possible Approach**	
		Design Related	**Operational Related**
Piping (cont.)	■ Releases when cleaning or purging lines	■ Use “pigs” for cleaning ■ Slope to low point drain ■ Use heat tracing and insulation to prevent freezing ■ Install equalizer lines	■ Flush to product storage tank
Pumps	■ Fugitive emissions from shaft seal leaks	■ Mechanical seal in lieu of packing ■ Double mechanical seal with inert barrier fluid ■ Double machined seal with barrier fluid vented to control device ■ Seal-less pump (canned motor magnetic drive) ■ Vertical pump	■ Seal installation practices ■ Monitor for leaks
	■ Fugitive emissions from shaft seal leaks	■ Use pressure transfer to eliminate pump	
	■ Residual “heel” of liquid during pump maintenance	■ Low point drain on pump casing	■ Flush casing to process sewer for treatment ■ Increase the mean time between pump failures by: - selecting proper seal material; - good alignment; - reduce pipe-induced stress - Maintaining seal lubrication
	■ Injection of seal flush fluid into process stream	■ Use double mechanical seal with inert barrier fluid where practical	
Reactors	■ Poor conversion or performance due to inadequate mixing	■ Static mixing ■ Add baffles ■ Change impellers	■ Add ingredients with optimum sequence

Table 23 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Reactors (cont.)	■ Poor conversion (cont.)	■ Add horsepower ■ Add distributor	■ Allow proper head space in reactor to enhance vortex effect
	■ Waste by-product formation	■ Provide separate reactor for converting recycle streams to usable products	■ Optimize reaction conditions (temperature, pressure, etc.)
Relief Valve	■ Leaks	■ Provide upstream rupture disc	
	■ Fugitive emissions	■ Vent to control or recovery device	■ Monitor for leaks and for control efficiency
	■ Discharge to environment from over pressure	■ Pump discharges to suction of pump ■ Thermal relief to tanks ■ Avoid discharge to roof areas to prevent contamination of rainwater	■ Monitor for leaks
	■ Frequent relief	■ Use pilot operated relief valve ■ Increase margin between design and operating pressure	■ Reduce operating pressure ■ Review system performance
Sampling	■ Waste generation due to sampling (disposal, containers, leaks, fugitives, etc.)	■ In-line insitu analyzers ■ System for return to process ■ Closed loop ■ Drain to sump	■ Reduce number and size of samples required ■ Sample at the lowest possible temperature ■ Cool before sampling
Tanks	■ Tank breathing and working losses	■ Cool materials before storage ■ Insulate tanks ■ Vent to control device (flare, condenser, etc.) ■ Vapor balancing ■ Floating roof	■ Optimize storage conditions to reduce losses

Table 23 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach	
		Design Related	**Operational Related**
Tanks (cont.)	■ Tank breathing and working losses (cont.) ■ Leak to groundwater ■ Large waste heel	■ Higher design pressure ■ All aboveground (situated so bottom can routinely be checked for leaks) ■ Secondary containment ■ Improve corrosion resistance ■ Design for 100% de-inventory	■ Monitor for leaks and corrosion ■ Recycle to process if practical
Vacuum Systems	■ Waste discharge from jets	■ Substitute mechanical vacuum pump ■ Evaluate using process fluid for powering jet	■ Monitor for air leaks ■ Recycle condensate to process
Valves	■ Fugitive emissions from leaks	■ Bellow seals ■ Reduce number where practical ■ Special packing sets	■ Stringent adherence to packing procedures
Vents	■ Release to environment	■ Route to control or recovery device	■ Monitor performance

Source: Chemical Manufacturers Association, *Designing Pollution Prevention into the Process, Research, Development and Engineering*, Washington, DC, 1993.

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VI. SUMMARY OF APPLICABLE FEDERAL STATUTES AND REGULATIONS

This section discusses the Federal regulations that may apply to this sector. The purpose of this section is to highlight and briefly describe the applicable Federal requirements, and to provide citations for more detailed information. The three following sections are included:

- Section VI.A contains a general overview of major statutes
- Section VI.B contains a list of regulations specific to this industry
- Section VI.C contains a list of pending and proposed regulations

The descriptions within Section VI are intended solely for general information. Depending upon the nature or scope of the activities at a particular facility, these summaries may or may not necessarily describe all applicable environmental requirements. Moreover, they do not constitute formal interpretations or clarifications of the statutes and regulations. For further information readers should consult the Code of Federal Regulations and other state or local regulatory agencies. EPA Hotline contacts are also provided for each major statute.

VI.A. General Description of Major Statutes

Resource Conservation and Recovery Act

The Resource Conservation And Recovery Act (RCRA) of 1976 which amended the Solid Waste Disposal Act, addresses solid (Subtitle D) and hazardous (Subtitle C) waste management activities. The Hazardous and Solid Waste Amendments (HSWA) of 1984 strengthened RCRA's waste management provisions and added Subtitle I, which governs underground storage tanks (USTs).

Regulations promulgated pursuant to Subtitle C of RCRA (40 CFR Parts 260-299) establish a "cradle-to-grave" system governing hazardous waste from the point of generation to disposal. RCRA hazardous wastes include the specific materials listed in the regulations (commercial chemical products, designated with the code "P" or "U"; hazardous wastes from specific industries/sources, designated with the code "K"; or hazardous wastes from non-specific sources, designated with the code "F") or materials which exhibit a hazardous waste characteristic (ignitability, corrosivity, reactivity, or toxicity and designated with the code "D").

Regulated entities that generate hazardous waste are subject to waste accumulation, manifesting, and record keeping standards. Facilities must obtain a permit either from EPA or from a State agency which EPA has authorized to implement the permitting program if they store hazardous wastes for more than 90 days before treatment or disposal. Facilities may treat hazardous wastes stored in less-than-ninety-day tanks or containers without a permit. Subtitle C permits contain general facility standards such as contingency plans, emergency procedures, record keeping and reporting requirements, financial assurance mechanisms, and unit-specific standards. RCRA also contains provisions (40 CFR Part 264 Subpart S and §264.10) for conducting corrective actions which govern the cleanup of releases of hazardous waste or constituents from solid waste management units at RCRA-regulated facilities.

Although RCRA is a Federal statute, many States implement the RCRA program. Currently, EPA has delegated its authority to implement various provisions of RCRA to 47 of the 50 States and two U.S. territories. Delegation has not been given to Alaska, Hawaii, or Iowa.

Most RCRA requirements are not industry specific but apply to any company that generates, transports, treats, stores, or disposes of hazardous waste. Here are some important RCRA regulatory requirements:

- **Identification of Solid and Hazardous Wastes** (40 CFR Part 261) lays out the procedure every generator must follow to determine whether the material in question is considered a hazardous waste, solid waste, or is exempted from regulation.

- **Standards for Generators of Hazardous Waste** (40 CFR Part 262) establishes the responsibilities of hazardous waste generators including obtaining an EPA ID number, preparing a manifest, ensuring proper packaging and labeling, meeting standards for waste accumulation units, and recordkeeping and reporting requirements. Generators can accumulate hazardous waste for up to 90 days (or 180 days depending on the amount of waste generated) without obtaining a permit.

- **Land Disposal Restrictions** (LDRs) (40 CFR Part 268) are regulations prohibiting the disposal of hazardous waste on land without prior treatment. Under the LDRs program, materials must meet LDR treatment standards prior to placement in a RCRA land disposal unit (landfill, land treatment unit, waste pile, or surface impoundment). Generators of waste subject to the LDRs must provide notification of such to the designated TSD facility to ensure proper treatment prior to disposal.

- **Used Oil Management Standards** (40 CFR Part 279) impose management requirements affecting the storage, transportation, burning, processing, and re-refining of the used oil. For parties that merely generate used oil, regulations establish storage standards. For a party considered a used oil processor, re-refiner, burner, or marketer (one who generates and sells off-specification used oil), additional tracking and paperwork requirements must be satisfied.

- RCRA contains unit-specific standards for all units used to store, treat, or dispose of hazardous waste, including **Tanks and Containers**. Tanks and containers used to store hazardous waste with a high volatile organic concentration must meet emission standards under RCRA. Regulations (40 CFR Part 264-265, Subpart CC) require generators to test the waste to determine the concentration of the waste, to satisfy tank and container emissions standards, and to inspect and monitor regulated units. These regulations apply to all facilities that store such waste, including large quantity generators accumulating waste prior to shipment off-site.

- **Underground Storage Tanks** (USTs) containing petroleum and hazardous substances are regulated under Subtitle I of RCRA. Subtitle I regulations (40 CFR Part 280) contain tank design and release detection requirements, as well as financial responsibility and corrective action standards for USTs. The UST program also includes upgrade requirements for existing tanks that must be met by December 22, 1998.

- **Boilers and Industrial Furnaces** (BIFs) that use or burn fuel containing hazardous waste must comply with design and operating standards. BIF regulations (40 CFR Part 266, Subpart H) address unit design, provide performance standards, require emissions monitoring, and restrict the type of waste that may be burned.

EPA's RCRA, Superfund and EPCRA Hotline, *at (800) 424-9346, responds to questions and distributes guidance regarding all RCRA regulations. The RCRA Hotline operates weekdays from 9:00 a.m. to 6:00 p.m., ET, excluding Federal holidays.*

Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a 1980 law known commonly as Superfund, authorizes EPA to respond to releases, or threatened releases, of hazardous substances that may endanger public health, welfare, or the environment. CERCLA also enables EPA to force parties responsible for environmental contamination to clean it up or to reimburse the Superfund for response costs incurred by EPA. The Superfund Amendments and Reauthorization Act (SARA) of 1986 revised various sections of CERCLA, extended the taxing authority for the Superfund, and created a free-standing law, SARA Title III, also known as the Emergency Planning and Community Right-to-Know Act (EPCRA).

The CERCLA hazardous substance release reporting regulations (40 CFR Part 302) direct the person in charge of a facility to report to the National Response Center (NRC) any environmental release of a hazardous substance which equals or exceeds a reportable quantity. Reportable quantities are listed in 40 CFR §302.4. A release report may trigger a response by EPA, or by one or more Federal or State emergency response authorities.

EPA implements hazardous substance responses according to procedures outlined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR Part 300). The NCP includes provisions for permanent cleanups, known as remedial actions, and other cleanups referred to as removals. EPA generally takes remedial actions only at sites on the National Priorities List (NPL), which currently includes approximately 1300 sites. Both EPA and states can act at sites; however, EPA provides responsible parties the opportunity to conduct removal and remedial actions and encourages community involvement throughout the Superfund response process.

EPA's RCRA, Superfund and EPCRA Hotline, at (800) 424-9346, answers questions and references guidance pertaining to the Superfund program. The CERCLA Hotline operates weekdays from 9:00 a.m. to 6:00 p.m., ET, excluding Federal holidays.

Emergency Planning And Community Right-To-Know Act

The Superfund Amendments and Reauthorization Act (SARA) of 1986 created the Emergency Planning and Community Right-to-Know Act (EPCRA, also known as SARA Title III), a statute designed to improve community access to information about chemical hazards and to facilitate the development of chemical emergency response plans by State and local governments. EPCRA required the establishment of State emergency response commissions (SERCs), responsible for coordinating certain emergency response activities and for appointing local emergency planning committees (LEPCs).

EPCRA and the EPCRA regulations (40 CFR Parts 350-372) establish four types of reporting obligations for facilities which store or manage specified chemicals:

- **EPCRA §302** requires facilities to notify the SERC and LEPC of the presence of any extremely hazardous substance (the list of such substances is in 40 CFR Part 355, Appendices A and B) if it has such substance in excess of the substance's threshold planning quantity, and directs the facility to appoint an emergency response coordinator.

- **EPCRA §304** requires the facility to notify the SERC and the LEPC in the event of a release equaling or exceeding the reportable quantity of a CERCLA hazardous substance or an EPCRA extremely hazardous substance.

- **EPCRA §311 and §312** require a facility at which a hazardous chemical, as defined by the Occupational Safety and Health Act, is present in an amount exceeding a specified threshold to submit to the SERC, LEPC and local fire department material safety data sheets (MSDSs) or lists of MSDS's and hazardous chemical inventory forms (also known as Tier I and II forms). This information helps the local government respond in the event of a spill or release of the chemical.

- **EPCRA §313** requires manufacturing facilities included in SIC codes 20 through 39, which have ten or more employees, and which manufacture, process, or use specified chemicals in amounts greater than threshold quantities, to submit an annual toxic chemical release report. This report, known commonly as the Form R, covers releases and transfers of toxic chemicals to various facilities and environmental media, and allows EPA to compile the national Toxic Release Inventory (TRI) database.

All information submitted pursuant to EPCRA regulations is publicly accessible, unless protected by a trade secret claim.

EPA's RCRA, Superfund and EPCRA Hotline, at (800) 424-9346, answers questions and distributes guidance regarding the emergency planning and community right-to-know regulations. The EPCRA Hotline operates weekdays from 9:00 a.m. to 6:00 p.m., ET, excluding Federal holidays.

Clean Water Act

The primary objective of the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA), is to restore and maintain the chemical, physical, and biological integrity of the nation's surface waters. Pollutants regulated under the CWA include "priority" pollutants, including various toxic pollutants; "conventional" pollutants, such as biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform, oil and grease, and pH; and "non-conventional" pollutants, including any pollutant not identified as either conventional or priority.

The CWA regulates both direct and indirect discharges. The National Pollutant Discharge Elimination System (NPDES) program (CWA §502) controls direct discharges into navigable waters. Direct discharges or "point source" discharges are from sources such as pipes and sewers. NPDES permits, issued by either EPA or an authorized State (EPA has authorized 42

States to administer the NPDES program), contain industry-specific, technology-based and/or water quality-based limits, and establish pollutant monitoring requirements. A facility that intends to discharge into the nation's waters must obtain a permit prior to initiating its discharge. A permit applicant must provide quantitative analytical data identifying the types of pollutants present in the facility's effluent. The permit will then set the conditions and effluent limitations on the facility discharges.

A NPDES permit may also include discharge limits based on Federal or State water quality criteria or standards, that were designed to protect designated uses of surface waters, such as supporting aquatic life or recreation. These standards, unlike the technological standards, generally do not take into account technological feasibility or costs. Water quality criteria and standards vary from State to State, and site to site, depending on the use classification of the receiving body of water. Most States follow EPA guidelines which propose aquatic life and human health criteria for many of the 126 priority pollutants.

Storm Water Discharges

In 1987 the CWA was amended to require EPA to establish a program to address storm water discharges. In response, EPA promulgated the NPDES storm water permit application regulations. These regulations require that facilities with the following storm water discharges apply for an NPDES permit: (1) a discharge associated with industrial activity; (2) a discharge from a large or medium municipal storm sewer system; or (3) a discharge which EPA or the State determines to contribute to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States.

The term "storm water discharge associated with industrial activity" means a storm water discharge from one of 11 categories of industrial activity defined at 40 CFR 122.26. Six of the categories are defined by SIC codes while the other five are identified through narrative descriptions of the regulated industrial activity. If the primary SIC code of the facility is one of those identified in the regulations, the facility is subject to the storm water permit application requirements. If any activity at a facility is covered by one of the five narrative categories, storm water discharges from those areas where the activities occur are subject to storm water discharge permit application requirements.

Those facilities/activities that are subject to storm water discharge permit application requirements are identified below. To determine whether a particular facility falls within one of these categories, consult the regulation.

Category i: Facilities subject to storm water effluent guidelines, new source performance standards, or toxic pollutant effluent standards.

Category ii: Facilities classified as SIC 24-lumber and wood products (except wood kitchen cabinets); SIC 26-paper and allied products (except paperboard containers and products); SIC 28-chemicals and allied products (except drugs and paints); SIC 291-petroleum refining; and SIC 311-leather tanning and finishing, 32 (except 323)-stone, clay, glass, and concrete, 33-primary metals, 3441-fabricated structural metal, and 373-ship and boat building and repairing.

Category iii: Facilities classified as SIC 10-metal mining; SIC 12-coal mining; SIC 13-oil and gas extraction; and SIC 14-nonmetallic mineral mining.

Category iv: Hazardous waste treatment, storage, or disposal facilities.

Category v: Landfills, land application sites, and open dumps that receive or have received industrial wastes.

Category vi: Facilities classified as SIC 5015-used motor vehicle parts; and SIC 5093-automotive scrap and waste material recycling facilities.

Category vii: Steam electric power generating facilities.

Category viii: Facilities classified as SIC 40-railroad transportation; SIC 41-local passenger transportation; SIC 42-trucking and warehousing (except public warehousing and storage); SIC 43-U.S. Postal Service; SIC 44-water transportation; SIC 45-transportation by air; and SIC 5171-petroleum bulk storage stations and terminals.

Category ix: Sewage treatment works.

Category x: Construction activities except operations that result in the disturbance of less than five acres of total land area.

Category xi: Facilities classified as SIC 20-food and kindred products; SIC 21-tobacco products; SIC 22-textile mill products; SIC 23-apparel related products; SIC 2434-wood kitchen cabinets manufacturing; SIC 25-furniture and fixtures; SIC 265-paperboard containers and boxes; SIC 267-converted paper and paperboard products; SIC 27-printing, publishing, and allied industries; SIC 283-drugs; SIC 285-paints, varnishes, lacquer, enamels, and allied products; SIC 30-rubber and plastics; SIC 31-leather and leather products (except leather and tanning and finishing); SIC 323-glass products; SIC 34-fabricated metal products (except fabricated structural metal); SIC 35-industrial and commercial machinery and computer equipment; SIC 36-electronic and other electrical equipment and components; SIC 37-

transportation equipment (except ship and boat building and repairing); SIC 38-measuring, analyzing, and controlling instruments; SIC 39-miscellaneous manufacturing industries; and SIC 4221-4225-public warehousing and storage.

Pretreatment Program

Another type of discharge that is regulated by the CWA is one that goes to a publicly-owned treatment works (POTWs). The national pretreatment program (CWA §307(b)) controls the indirect discharge of pollutants to POTWs by "industrial users." Facilities regulated under §307(b) must meet certain pretreatment standards. The goal of the pretreatment program is to protect municipal wastewater treatment plants from damage that may occur when hazardous, toxic, or other wastes are discharged into a sewer system and to protect the quality of sludge generated by these plants. Discharges to a POTW are regulated primarily by the POTW itself, rather than the State or EPA.

EPA has developed technology-based standards for industrial users of POTWs. Different standards apply to existing and new sources within each category. "Categorical" pretreatment standards applicable to an industry on a nationwide basis are developed by EPA. In addition, another kind of pretreatment standard, "local limits," are developed by the POTW in order to assist the POTW in achieving the effluent limitations in its NPDES permit.

Regardless of whether a State is authorized to implement either the NPDES or the pretreatment program, if it develops its own program, it may enforce requirements more stringent than Federal standards.

Spill Prevention, Control and Countermeasure Plans

The 1990 Oil Pollution Act requires that facilities that could reasonably be expected to discharge oil in harmful quantities prepare and implement more rigorous Spill Prevention Control and Countermeasure (SPCC) Plan required under the CWA (40 CFR §112.7). There are also criminal and civil penalties for deliberate or negligent spills of oil. Regulations covering response to oil discharges and contingency plans (40 CFR Part 300), and Facility Response Plans to oil discharges (40 CFR §112.20) and for PCB transformers and PCB-containing items were revised and finalized in 1995.

EPA's Office of Water, at (202) 260-5700, will direct callers with questions about the CWA to the appropriate EPA office. EPA also maintains a bibliographic database of Office of Water publications which can be accessed through the Ground Water and Drinking Water resource center, at (202) 260-7786.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) mandates that EPA establish regulations to protect human health from contaminants in drinking water. The law authorizes EPA to develop national drinking water standards and to create a joint Federal-State system to ensure compliance with these standards. The SDWA also directs EPA to protect underground sources of drinking water through the control of underground injection of liquid wastes.

EPA has developed primary and secondary drinking water standards under its SDWA authority. EPA and authorized States enforce the primary drinking water standards, which are, contaminant-specific concentration limits that apply to certain public drinking water supplies. Primary drinking water standards consist of maximum contaminant level goals (MCLGs), which are non-enforceable health-based goals, and maximum contaminant levels (MCLs), which are enforceable limits set as close to MCLGs as possible, considering cost and feasibility of attainment.

The SDWA Underground Injection Control (UIC) program (40 CFR Parts 144-148) is a permit program which protects underground sources of drinking water by regulating five classes of injection wells. UIC permits include design, operating, inspection, and monitoring requirements. Wells used to inject hazardous wastes must also comply with RCRA corrective action standards in order to be granted a RCRA permit, and must meet applicable RCRA land disposal restrictions standards. The UIC permit program is primarily State-enforced, since EPA has authorized all but a few States to administer the program.

The SDWA also provides for a Federally-implemented Sole Source Aquifer program, which prohibits Federal funds from being expended on projects that may contaminate the sole or principal source of drinking water for a given area, and for a State-implemented Wellhead Protection program, designed to protect drinking water wells and drinking water recharge areas.

EPA's Safe Drinking Water Hotline, at (800) 426-4791, answers questions and distributes guidance pertaining to SDWA standards. The Hotline operates from 9:00 a.m. through 5:30 p.m., ET, excluding Federal holidays.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) granted EPA authority to create a regulatory framework to collect data on chemicals in order to evaluate, assess, mitigate, and control risks which may be posed by their manufacture, processing, and use. TSCA provides a variety of control methods to prevent chemicals from posing unreasonable risk.

TSCA standards may apply at any point during a chemical's life cycle. Under TSCA §5, EPA has established an inventory of chemical substances. If a chemical is not already on the inventory, and has not been excluded by TSCA, a premanufacture notice (PMN) must be submitted to EPA prior to manufacture or import. The PMN must identify the chemical and provide available information on health and environmental effects. If available data are not sufficient to evaluate the chemicals effects, EPA can impose restrictions pending the development of information on its health and environmental effects. EPA can also restrict significant new uses of chemicals based upon factors such as the projected volume and use of the chemical.

Under TSCA §6, EPA can ban the manufacture or distribution in commerce, limit the use, require labeling, or place other restrictions on chemicals that pose unreasonable risks. Among the chemicals EPA regulates under §6 authority are asbestos, chlorofluorocarbons (CFCs), and polychlorinated biphenyls (PCBs).

EPA's TSCA Assistance Information Service, at (202) 554-1404, answers questions and distributes guidance pertaining to Toxic Substances Control Act standards. The Service operates from 8:30 a.m. through 4:30 p.m., ET, excluding Federal holidays.

Clean Air Act

The Clean Air Act (CAA) and its amendments, including the Clean Air Act Amendments (CAAA) of 1990, are designed to "protect and enhance the nation's air resources so as to promote the public health and welfare and the productive capacity of the population." The CAA consists of six sections, known as Titles, which direct EPA to establish national standards for ambient air quality and for EPA and the States to implement, maintain, and enforce these standards through a variety of mechanisms. Under the CAAA, many facilities will be required to obtain permits for the first time. State and local governments oversee, manage, and enforce many of the requirements of the CAAA. CAA regulations appear at 40 CFR Parts 50-99.

Pursuant to Title I of the CAA, EPA has established national ambient air quality standards (NAAQSs) to limit levels of "criteria pollutants," including carbon monoxide, lead, nitrogen dioxide, particulate matter, volatile organic compounds (VOCs), ozone, and sulfur dioxide. Geographic areas that meet NAAQSs for a given pollutant are classified as attainment areas; those that do not meet NAAQSs are classified as non-attainment areas. Under section 110 of the CAA, each State must develop a State Implementation Plan (SIP) to identify sources of air pollution and to determine what reductions are required to meet Federal air quality standards. Revised NAAQSs for particulates and ozone were proposed in 1996 and may go into effect as early as late 1997.

Title I also authorizes EPA to establish New Source Performance Standards (NSPSs), which are nationally uniform emission standards for new stationary sources falling within particular industrial categories. NSPSs are based on the pollution control technology available to that category of industrial source.

Under Title I, EPA establishes and enforces National Emission Standards for Hazardous Air Pollutants (NESHAPs), nationally uniform standards oriented towards controlling particular hazardous air pollutants (HAPs). Title I, section 112(c) of the CAA further directed EPA to develop a list of sources that emit any of 189 HAPs, and to develop regulations for these categories of sources. To date EPA has listed 174 categories and developed a schedule for the establishment of emission standards. The emission standards will be developed for both new and existing sources based on "maximum achievable control technology" (MACT). The MACT is defined as the control technology achieving the maximum degree of reduction in the emission of the HAPs, taking into account cost and other factors.

Title II of the CAA pertains to mobile sources, such as cars, trucks, buses, and planes. Reformulated gasoline, automobile pollution control devices, and vapor recovery nozzles on gas pumps are a few of the mechanisms EPA uses to regulate mobile air emission sources.

Title IV of the CAA establishes a sulfur dioxide nitrous oxide emissions program designed to reduce the formation of acid rain. Reduction of sulfur dioxide releases will be obtained by granting to certain sources limited emissions allowances, which, beginning in 1995, will be set below previous levels of sulfur dioxide releases.

Title V of the CAA of 1990 created a permit program for all "major sources" (and certain other sources) regulated under the CAA. One purpose of the operating permit is to include in a single document all air emissions requirements that apply to a given facility. States are developing the permit programs in accordance with guidance and regulations from EPA. Once a State program is approved by EPA, permits will be issued and monitored by that State.

Title VI of the CAA is intended to protect stratospheric ozone by phasing out the manufacture of ozone-depleting chemicals and restrict their use and distribution. Production of Class I substances, including 15 kinds of chlorofluorocarbons (CFCs) and chloroform, were phased out (except for essential uses) in 1996.

EPA's Clean Air Technology Center, at (919) 541-0800, provides general assistance and information on CAA standards. The Stratospheric Ozone Information Hotline, at (800) 296-1996, provides general information about regulations promulgated under Title VI of the CAA, and EPA's EPCRA

Hotline, at (800) 535-0202, answers questions about accidental release prevention under CAA §112(r). In addition, the Clean Air Technology Center's website includes recent CAA rules, EPA guidance documents, and updates of EPA activities (www.epa.gov/ttn then select Directory and then CATC).

VI.B. Industry Specific Requirements

The plastic resin and manmade fiber industries are affected by nearly all federal environmental statutes. In addition, the industries are subject to numerous laws and regulations from state and local governments designed to protect and improve the nation's health, safety, and environment. A summary of the major federal regulations affecting the plastic resin and manmade fiber industry follows.

Clean Air Act

The original CAA authorized EPA to set limits on plastic resin and manmade fiber plant emissions. In its new source performance standards (NSPS) for polymer manufacturing facilities (40 CFR Part 60 Subpart DDD), EPA set minimum standards for the lowest achievable emissions rates (LAER) and best available control technologies (BACT). The NSPS for Polymers requires air emission controls on new and existing facilities that manufacture polypropylene, polyethylene, polystyrene and poly(ethylene terephthalate). Included are standards on controlling intermittent and continuous sources of emissions from processes. EPA also published an NSPS for synthetic fiber production facilities (40 CFR Part 60 Subpart HHH). The NSPS for Synthetic Fibers regulates VOC emissions from facilities that use solvents in manufacturing fibers. There are additional NSPS that apply to plastic resin and synthetic fiber manufacturers including those for flares (40 CFR Part 60 Subpart A), storage vessels (40 CFR Part 60 Subpart K), equipment leaks (40 CFR Part 60 Subpart VV), air oxidation processes (40 CFR Part 60 Subpart III), distillation operations (40 CFR Part 60 Subpart NNN), and reactor processes (40 CFR Part 60 Subpart RRR).

The Clean Air Act Amendments of 1990 set National Emission Standards for Hazardous Air Pollutants (NESHAP) from industrial sources for 41 pollutants to be met by 1995 and for 148 other pollutants to be reached by 2003. Several provisions affect the plastic resin and manmade fiber industries. In April 1994, the EPA published Hazardous Organic National Emissions Standards for Hazardous Air Pollutants, also known as HON, in a rule aimed at reducing air toxics emissions from chemical and allied product plants. This rule, which consists of four subparts, affects hundreds of plastic resin and manmade fiber plants and thousands of chemical process units since potential organic hazardous air pollutants are widely used as reactants. Processes covered include heat exchange systems and maintenance operations (40 CFR Part 63 Subpart F); process vents, storage vessels, transfer operations, and wastewater (40 CFR Part 63 Subpart G); equipment leaks (40 CFR Part 63 Subpart H); and equipment leaks for polycarbonate plants (40 CFR Part 63 Subpart I). Another NESHAP that may affect plastic resin and manmade fiber manufacturers is that for treatment, storage, and disposal facilities (40 Part CFR 63 Subpart AA). The HON also includes innovative provisions such as emissions trading, that offer industry flexibility in complying with the rule's emissions goals.

Subsets of the plastic resin and manmade fiber industries are regulated under other NESHAPs. EPA published a final rule for epoxy resins and non-nylon polyamide resins in March 1995. The rule was expected to reduce epichlorohydrin emissions from process vents and storage tank emissions. In September 1996, EPA published a final rule for Group I Polymers and Resins (61 FR 46906) under 40 CFR part 63, Subpart U. This rule focused on reducing emissions from facilities that make certain elastomers used in the manufacture of synthetic rubber products. The rule was expected to reduce emissions of styrene, hexane, toluene, and other toxics. Provisions on pollution prevention, as well as a market-based provision on emissions averaging, were also included in the rule.

In September 1996, EPA also published a final rule for Designated Group IV Polymers and Resins (61 FR 48208) under 40 CFR part 63, Subpart JJJ. This rule was expected to reduce emissions of air toxics from poly(ethylene terephlate), nitrile, and styrene-based resins facilities. The rule was expected to reduce styrene, butadiene, and methanol emissions from storage vessels, process vents, equipment leaks, and wastewater operations. A direct final notice (62 FR 1869) was published on January 14, 1997, which extended the heat exchange system compliance date for the Group I rule and the equipment leak compliance dates for both the Group I and Group IV rules. Other NESHAPs that apply to the industry cover vinyl chloride manufacturers (40 CFR Part 61 Subpart F), benzene equipment leaks (40 CFR Part 61 Subpart J), fugitive emissions (40 CFR Part 61 Subpart V), benzene emissions from benzene storage vessels (40 CFR Part 61 Subpart Y), benzene emissions from benzene transfer operations (40 CFR Part 61 Subpart BB), and benzene waste operations (40 CFR Part 61 Subpart FF).

Clean Water Act

The Clean Water Act, first passed in 1972 and amended in 1977 and 1987, gives EPA the authority to regulate effluents from sewage treatment works, chemical plants, and other industrial sources into waters. The act sets “best available” technology standards for treatment of wastes for both direct and indirect (discharged to a Publicly Owned Treatment Work (POTW)) discharges. EPA originally promulgated effluent limitations guidelines and standards for the plastic resin and manmade fiber industries in two phases. Phase I, covering 13 products and processes, was promulgated on April 5, 1974 (39 FR 12502), and Phase II, covering eight additional products and processes, was promulgated on January 23, 1975 (40 FR 3716). In 1976, these regulations were challenged and eventually remanded by the federal circuit court in FMC Corp. versus Train, 539F.2d 973 (4th Cir. 1976). As a result, EPA withdrew both the Phase I and II plastic resin and manmade fiber regulations on August 4, 1976 (41 FR 32587) (EPA, 1987).

On November 5, 1987, EPA proposed final effluent guidelines (52FR42522) for the organic chemical, plastics, and synthetic fiber industries (OCPSF) (40 CFR Part 414). The effluent guidelines include limits for biological oxygen demand (BOD), total suspended solids (TSS), and acidity (pH). In this rule, limits are specified for facilities that manufacture rayon fibers, other synthetic fibers, thermoplastic resins, and thermoset resins.

The majority of this rule was upheld by the federal courts in 1989 when the Chemical Manufacturers Association sued the EPA. The Court left the rule in effect pending further rulemaking but remanded three aspects of the OCPSF guidelines. The Court remanded the New Source Performance Standards (NSPS) and the Pretreatment Standards for New Sources (PSNS) for consideration of whether zero discharge limits were appropriate for the industries; the subcategorization of the industries into two subcategories imposing differing limitations based on Best Available Technology Economically Achievable (BAT); and limitations for BAT Subpart J pollutants that were based upon in-plant biological treatment technology.

The EPA decided not to revise the NSPS and PSNS standards or the BAT subcategorization scheme and promulgated two sets of amendments to the rule in 1992 and 1993. On September 11, 1992, EPA promulgated a first set of amendments (57 FR 41836) to the OCPSF rule. These amendments allowed regulatory authorities to establish alternative cyanide limitations and standards for cyanide resulting from complexing of cyanide at the process source and establish alternative metals limitations and standards to accommodate low background levels of metals in non-“metal-bearing waste streams.” These amendments also allowed regulatory authorities to specify the method for determining five-day biochemical oxygen demand and total suspended solids effluent limitations for direct discharge plants (FR, September 11, 1992).

On July 9, 1993, EPA promulgated the remaining portions of the OCPSF rule in second set of amendments (58 FR 36872) which added Subpart J limitations based on BAT and NSPS for 19 additional pollutants. These amendments also established Pretreatment Standards for Existing Sources (PSES) and PSNS for 11 of these 19 pollutants. EPA also corrected the criteria for designating “metal-” and “cyanide-bearing” waste streams. In this rulemaking, phenol and 2,4-dimethylphenol pretreatment standards were not promulgated since EPA concluded that they did not pass through POTWs. The implementation of the guidelines is left to the states who issue NPDES permits for each facility. The compliance date for PSES was no later than July 23, 1996 (FR, July 9, 1993).

The Storm Water Rule (40 CFR §122.26(b)(14) Subparts (i, ii)) requires the capture and treatment of stormwater at facilities producing chemicals and allied products, including plastic resin and synthetic fiber manufacture. Required treatment will remove from stormwater flows a large fraction of both conventional pollutants, such as suspended solids and biological oxygen demand (BOD), as well as toxic pollutants, such as certain metals and organic compounds.

Resource Conservation and Recovery Act

Products, intermediates, and off-specification products generated at plastic resin and synthetic fiber facilities that are considered hazardous wastes are listed in 40 CFR Part 261.33(f). Some of the handling and treatment requirements for RCRA hazardous waste generators are covered under 40 CFR Part 262 and include the following: determining what constitutes a RCRA hazardous waste (Subpart A); manifesting (Subpart B); packaging, labeling, and accumulation time limits (Subpart C); and recordkeeping and reporting (Subpart D).

Many plastic resin and synthetic fiber facilities store some hazardous wastes at the facility for more than 90 days, and therefore, are a storage facility under RCRA. Storage facilities are required to have a RCRA treatment, storage, and disposal facility (TSDF) permit (40 CFR Part 262.34). Some plastic resin and synthetic fiber facilities are considered TSDF facilities and are subject to the following regulations covered under 40 CFR Part 264: contingency plans and emergency procedures (40 CFR Part 264 Subpart D); manifesting, recordkeeping, and reporting (40 CFR Part 264 Subpart E); use and management of containers (40 CFR Part 264 Subpart I); tank systems (40 CFR Part 264 Subpart J); surface impoundments (40 CFR Part 264 Subpart K); land treatment (40 CFR Part 264 Subpart M); corrective action of hazardous waste releases (40 CFR Part 264 Subpart S); air emissions standards for process vents of processes that process or generate hazardous wastes (40 CFR Part 264 Subpart AA); emissions standards for leaks in hazardous waste handling equipment (40 CFR Part 264 Subpart BB); and emissions standards for containers, tanks, and surface impoundments that contain hazardous wastes (40 CFR Part 264 Subpart CC).

A number of RCRA wastes have been prohibited from land disposal unless treated to meet specific standards under the RCRA Land Disposal Restriction (LDR) program. The wastes covered by the RCRA LDRs are listed in 40 CFR Part 268 Subpart C and include a number of wastes commonly generated at plastic resin and synthetic fiber facilities. Standards for the treatment and storage of restricted wastes are described in Subparts D and E, respectively.

Many plastic resin and synthetic fiber facilities are also subject to the underground storage tank (UST) program (40 CFR Part 280). The UST regulations apply to facilities that store either petroleum products or hazardous substances (except hazardous waste) identified under the Comprehensive Environmental Response, Compensation, and Liability Act. UST regulations address design standards, leak detection, operating practices, response to releases, financial responsibility for releases, and closure standards.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA), passed in 1976, gives the Environmental Protection Agency comprehensive authority to regulate any chemical substance whose manufacture, processing, distribution in commerce, use or disposal may present an unreasonable risk of injury to human health or the environment. Four sections are of primary importance to the plastic resin and manmade fiber industries. TSCA §5 (new chemicals) mandates that plastic resin and manmade fiber companies submit pre-manufacture notices that provide information on health and environmental effects for each new product and test existing products for these effects (40 CFR Part 720). TSCA §4 (existing chemicals) authorizes the EPA to require testing of certain substances (40 CFR Part 790). TSCA §6 gives the EPA authority to prohibit, limit or ban the manufacture, process and use of chemicals (40 CFR Part 750). For certain chemicals, TSCA §8 also imposes record-keeping and reporting requirements including substantial risk notification; record-keeping for data relative to adverse reactions; and periodic updates to the TSCA Chemical Inventory.

Under §5(h)(4), which grants EPA authority to promulgate rules granting exemptions to some or all of the premanufacture requirements for new chemicals, EPA published an exemption rule in 1984 and an amendment to the rule in 1995. The amendment, entitled Premanufacture Notification Exemptions (PMN) rule, contained a section on polymers (40 CFR Part 723.250) that allowed polymers that met certain restrictions to be exempt from some of the reporting requirements for new chemicals. Two exemptions {40 CFR Part 723.250(e)(1) and (e)(2)} exempt polymers based on molecular weight and oligomer content. The third exemption (40 CFR Part 723.250(e)(3)) exempts certain polyester polymers which use particular monomers and reactants.

In addition to meeting the specific criteria of one of the three exemption types, the new polymer must also not fall into one of the prohibited categories. This section (40 CFR Part 723.250(d)) excludes certain polymers from reduced reporting requirements, namely: certain cationic polymers; polymers that do not meet elemental restrictions; polymers that are reasonably predicted to decompose, degrade, or depolymerize; and polymers which are produced from monomers and/or other reactants which are not on the TSCA inventory or otherwise exempted from reporting under a §5 exemption.

VI.C. Pending and Proposed Regulatory Requirements

Clean Air Act

NESHAP for Formaldehyde-based Resin Manufacturers

Presumptive MACT standards were published for amino, phenolic, and acetal resins in July 1996. These resins use formaldehyde as their primary building block. A NESHAP for amino and phenolic resins is expected to be proposed in 1997 and will reduce emissions, primarily, of formaldehyde and methanol. Over 100 facilities are expected to be affected by this rule. EPA is also expecting to propose a NESHAP for acetal resins which will affect 3 facilities. For more information, please contact John Schaefer at 919-541-0296.

NESHAP for Polyether Polyols

A proposed rule for polyether polyols is expected to be published in 1997. Roughly 50 major sources in the United States are expected to be affected by this regulation. For more information, please contact David Svendsgaard at 919-541-2380.

NESHAP for Polycarbonate Resin Manufacturers

This rule, scheduled to be proposed in 1997, will reduce emissions from polycarbonate resin facilities. It is anticipated that only two major sources in the United States will be affected by this regulation. For more information, please contact Mark Morris at 919-541-5416.

NESHAP for Acrylic and Modacrylic Fiber Manufacturers

EPA is working on a rule to reduce emissions from acrylic and modacrylic fiber manufacturers. This rule is scheduled to be proposed in 1997 and is expected to primarily reduce emissions of acrylonitrile and vinyl acetate. Only two major sources in the United States will be affected by this regulation. For more information, contact Leonardo Ceron at 404-562-9129.

VII. COMPLIANCE AND ENFORCEMENT PROFILE

Background

Until recently, EPA has focused much of its attention on measuring compliance with specific environmental statutes. This approach allows the Agency to track compliance with the Clean Air Act, the Resource Conservation and Recovery Act, the Clean Water Act, and other environmental statutes. Within the last several years, the Agency has begun to supplement single-media compliance indicators with facility-specific, multimedia indicators of compliance. In doing so, EPA is in a better position to track compliance with all statutes at the facility level, and within specific industrial sectors.

A major step in building the capacity to compile multimedia data for industrial sectors was the creation of EPA's Integrated Data for Enforcement Analysis (IDEA) system. IDEA has the capacity to "read into" the Agency's single-media databases, extract compliance records, and match the records to individual facilities. The IDEA system can match Air, Water, Waste, Toxics/Pesticides/EPCRA, TRI, and Enforcement Docket records for a given facility, and generate a list of historical permit, inspection, and enforcement activity. IDEA also has the capability to analyze data by geographic area and corporate holder. As the capacity to generate multimedia compliance data improves, EPA will make available more in-depth compliance and enforcement information. Additionally, sector-specific measures of success for compliance assistance efforts are under development.

Compliance and Enforcement Profile Description

Using inspection, violation and enforcement data from the IDEA system, this section provides information regarding the historical compliance and enforcement activity of this sector. In order to mirror the facility universe reported in the Toxic Chemical Profile, the data reported within this section consists of records only from the TRI reporting universe. With this decision, the selection criteria are consistent across sectors with certain exceptions. For the sectors that do not normally report to the TRI program, data have been provided from EPA's Facility Indexing System (FINDS) which tracks facilities in all media databases. Please note, in this section, EPA does not attempt to define the actual number of facilities that fall within each sector. Instead, the section portrays the records of a subset of facilities within the sector that are well defined within EPA databases.

As a check on the relative size of the full sector universe, most notebooks contain an estimated number of facilities within the sector according to the Bureau of Census (See Section II). With sectors dominated by small businesses, such as metal finishers and printers, the reporting universe within the EPA databases may be small in comparison to Census data. However, the group selected for inclusion in this data analysis section should be consistent with this sector's general make-up.

Following this introduction is a list defining each data column presented within this section. These values represent a retrospective summary of inspections and enforcement actions, and reflect solely EPA, State, and local compliance assurance activities that have been entered into EPA databases. To identify any changes in trends, the EPA ran two data queries, one for the past five calendar years (April 1, 1992 to March 31, 1997) and the other for the most recent twelve-month period (April 1, 1996 to March 31, 1997). The five-year analysis gives an average level of activity for that period for comparison to the more recent activity.

Because most inspections focus on single-media requirements, the data queries presented in this section are taken from single media databases. These databases do not provide data on whether inspections are state/local or EPA-led. However, the table breaking down the universe of violations does give the reader a crude measurement of the EPA's and states' efforts within each media program. The presented data illustrate the variations across EPA Regions for certain sectors.[2] This variation may be attributable to state/local data entry variations, specific geographic concentrations, proximity to population centers, sensitive ecosystems, highly toxic chemicals used in production, or historical noncompliance. Hence, the exhibited data do not rank regional performance or necessarily reflect which regions may have the most compliance problems.

Compliance and Enforcement Data Definitions

General Definitions

Facility Indexing System (FINDS) -- this system assigns a common facility number to EPA single-media permit records. The FINDS identification number allows EPA to compile and review all permit, compliance, enforcement and pollutant release data for any given regulated facility.

Integrated Data for Enforcement Analysis (IDEA) -- is a data integration system that can retrieve information from the major EPA program office databases. IDEA uses the FINDS identification number to link separate data records from EPA's databases. This allows retrieval of records from across media or statutes for any given facility, thus creating a "master list" of

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[2] EPA Regions include the following states: I (CT, MA, ME, RI, NH, VT); II (NJ, NY, PR, VI); III (DC, DE, MD, PA, VA, WV); IV (AL, FL, GA, KY, MS, NC, SC, TN); V (IL, IN, MI, MN, OH, WI); VI (AR, LA, NM, OK, TX); VII (IA, KS, MO, NE); VIII (CO, MT, ND, SD, UT, WY); IX (AZ, CA, HI, NV, Pacific Trust Territories); X (AK, ID, OR, WA).

records for that facility. Some of the data systems accessible through IDEA are: AIRS (Air Facility Indexing and Retrieval System, Office of Air and Radiation), PCS (Permit Compliance System, Office of Water), RCRIS (Resource Conservation and Recovery Information System, Office of Solid Waste), NCDB (National Compliance Data Base, Office of Prevention, Pesticides, and Toxic Substances), CERCLIS (Comprehensive Environmental and Liability Information System, Superfund), and TRIS (Toxic Release Inventory System). IDEA also contains information from outside sources such as Dun and Bradstreet and the Occupational Safety and Health Administration (OSHA). Most data queries displayed in notebook sections IV and VII were conducted using IDEA.

Data Table Column Heading Definitions

Facilities in Search -- are based on the universe of TRI reporters within the listed SIC code range. For industries not covered under TRI reporting requirements (metal mining, nonmetallic mineral mining, electric power generation, ground transportation, water transportation, and dry cleaning), or industries in which only a very small fraction of facilities report to TRI (e.g., printing), the notebook uses the FINDS universe for executing data queries. The SIC code range selected for each search is defined by each notebook's selected SIC code coverage described in Section II.

Facilities Inspected --- indicates the level of EPA and state agency inspections for the facilities in this data search. These values show what percentage of the facility universe is inspected in a one-year or five-year period.

Number of Inspections -- measures the total number of inspections conducted in this sector. An inspection event is counted each time it is entered into a single media database.

Average Time Between Inspections -- provides an average length of time, expressed in months, between compliance inspections at a facility within the defined universe.

Facilities with One or More Enforcement Actions -- expresses the number of facilities that were the subject of at least one enforcement action within the defined time period. This category is broken down further into federal and state actions. Data are obtained for administrative, civil/judicial, and criminal enforcement actions. Administrative actions include Notices of Violation (NOVs). A facility with multiple enforcement actions is only counted once in this column, e.g., a facility with 3 enforcement actions counts as 1 facility.

Total Enforcement Actions -- describes the total number of enforcement actions identified for an industrial sector across all environmental statutes. A facility with multiple enforcement actions is counted multiple times, e.g., a facility with 3 enforcement actions counts as 3.

State Lead Actions -- shows what percentage of the total enforcement actions are taken by state and local environmental agencies. Varying levels of use by states of EPA data systems may limit the volume of actions recorded as state enforcement activity. Some states extensively report enforcement activities into EPA data systems, while other states may use their own data systems.

Federal Lead Actions -- shows what percentage of the total enforcement actions are taken by the United States Environmental Protection Agency. This value includes referrals from state agencies. Many of these actions result from coordinated or joint state/federal efforts.

Enforcement to Inspection Rate -- is a ratio of enforcement actions to inspections, and is presented for comparative purposes only. This ratio is a rough indicator of the relationship between inspections and enforcement. It relates the number of enforcement actions and the number of inspections that occurred within the one-year or five-year period. This ratio includes the inspections and enforcement actions reported under the Clean Water Act (CWA), the Clean Air Act (CAA) and the Resource Conservation and Recovery Act (RCRA). Inspections and actions from the TSCA/FIFRA/ EPCRA database are not factored into this ratio because most of the actions taken under these programs are not the result of facility inspections. Also, this ratio does not account for enforcement actions arising from non-inspection compliance monitoring activities (e.g., self-reported water discharges) that can result in enforcement action within the CAA, CWA, and RCRA.

Facilities with One or More Violations Identified -- indicates the percentage of inspected facilities having a violation identified in one of the following data categories: In Violation or Significant Violation Status (CAA); Reportable Noncompliance, Current Year Noncompliance, Significant Noncompliance (CWA); Noncompliance and Significant Noncompliance (FIFRA, TSCA, and EPCRA); Unresolved Violation and Unresolved High Priority Violation (RCRA). The values presented for this column reflect the extent of noncompliance within the measured time frame, but do not distinguish between the severity of the noncompliance. Violation status may be a precursor to an enforcement action, but does not necessarily indicate that an enforcement action will occur.

Media Breakdown of Enforcement Actions and Inspections -- four columns identify the proportion of total inspections and enforcement actions within EPA Air, Water, Waste, and TSCA/FIFRA/EPCRA databases. Each column is a percentage of either the "Total Inspections," or the "Total Actions" column.

VII.A. Plastic Resin and Manmade Fiber Industries Compliance History

Table 24 provides an overview of the reported compliance and enforcement data for the plastic resin and manmade fiber industries over the past five years (April 1992 to April 1997). These data are also broken out by EPA Region thereby permitting geographical comparisons. A few points evident from the data are listed below.

- The majority of plastic resin and manmade fiber facilities (about 60%) and inspections over the past five years were in Regions IV, V, and VI.

- Regions III and II had the second and third largest number of inspections, respectively, although they ranked fourth and fifth in terms of number of facilities, respectively.

- Region VI had a high ratio of enforcement actions to inspections (0.25) compared to other Regions. Region VI also had the highest number of enforcement actions and facilities with enforcement actions.

- Region II had the second largest number of enforcement actions (52), but ranks fifth in number of facilities.

Table 24: Five-Year Enforcement and Compliance Summary for the Plastic Resin and Manmade Fiber Industries

A	B	C	D	E	F	G	H	I	J
Region	**Facilities in Search**	**Facilities Inspected**	**Number of Inspections**	**Average Months Between Inspections**	**Facilities with 1 or More Enforcement Actions**	**Total Enforcement Actions**	**Percent State Lead Actions**	**Percent Federal Lead Actions**	**Enforcement to Inspection Rate**
I	24	16	73	20	4	8	50%	50%	0.11
II	31	30	366	5	17	52	81%	19%	0.14
III	38	36	418	5	10	21	90%	10%	0.05
IV	90	78	864	6	22	46	78%	22%	0.05
V	55	40	311	11	5	9	67%	33%	0.03
VI	51	43	309	10	28	76	71%	29%	0.25
VII	6	5	20	18	1	1	0%	100%	0.05
VIII	4	1	11	22	1	1	100%	0%	0.09
IX	25	10	41	37	4	3	100%	0%	0.07
X	5	4	17	18	1	2	100%	0%	0.12
TOTAL	329	263	2,430	8	93	219	76%	24%	0.09

VII.B. Comparison of Enforcement Activity Between Selected Industries

Tables 25 and 26 allow the compliance history of the plastic resin and manmade fiber industries to be compared with the other industries covered by the industry sector notebooks. Comparisons between Tables 25 and 26 permit the identification of trends in compliance and enforcement records of the industries by comparing data covering the last five years (April 1992 to April 1997) to that of the past year (April 1996 to April 1997). Some points evident from the data are listed below.

- The ratio of enforcement actions to inspections for plastic resin and manmade fiber manufacturing facilities over the past five years (0.09) was very close to the average across the industries shown (0.08).
- Over the past five years, the average number of months between inspections was relatively low (8 months) for plastic resin and manmade fiber facilities. The average across the industries shown was 22 months indicating that, on average, facilities in the plastic resin and manmade fiber industry are inspected more frequently than facilities in many other industries.
- While the average enforcement to inspection rate across industries fell from 0.08 over the past five years to 0.06 over the past year, the enforcement to inspection rate for plastic resin and manmade fiber facilities remained at 0.09.
- Only three of the industries shown (petroleum refining, lumber and wood, and water transportation) had a higher percent of facilities inspected with enforcement actions over the past year.

Tables 27 and 28 provide a more in-depth comparison between the plastic resin and manmade fiber industries and other sectors by breaking out the compliance and enforcement data by environmental statute. As in Tables 25 and 26, the data cover the last five years (Table 27) and the last one year (Table 28) to facilitate the identification of recent trends. A few points evident from the data are listed below.

- While the percentage of RCRA inspections remained the same between the past five years and past year, the percent of enforcement actions taken under RCRA dropped from 23 percent to 5 percent.
- The Clean Air Act accounted for the largest share of enforcement actions over the past five years (43 percent) and the past year (51 percent).

Table 25: Five-Year Enforcement and Compliance Summary for Selected Industries

A	B	C	D	E	F	G	H	I	J
Industry Sector	**Facilities in Search**	**Facilities Inspected**	**Number of Inspections**	**Average Months Between Inspections**	**Facilities with 1 or More Enforcement Actions**	**Total Enforcement Actions**	**Percent State Lead Actions**	**Percent Federal Lead Actions**	**Enforcement to Inspection Rate**
Metal Mining	1,232	378	1,600	46	63	111	53%	47%	0.07
Coal Mining	3,256	741	3,748	52	88	132	89%	11%	0.04
Oil and Gas Extraction	4,676	1,902	6,071	46	149	309	79%	21%	0.05
Non-Metallic Mineral Mining	5,256	2,803	12,826	25	385	622	77%	23%	0.05
Textiles	355	267	1,465	15	53	83	90%	10%	0.06
Lumber and Wood	712	473	2,767	15	134	265	70%	30%	0.10
Furniture	499	386	2,379	13	65	91	81%	19%	0.04
Pulp and Paper	484	430	4,630	6	150	478	80%	20%	0.10
Printing	5,862	2,092	7,691	46	238	428	88%	12%	0.06
Inorganic Chemicals	441	286	3,087	9	89	235	74%	26%	0.08
Resins and Manmade Fibers	**329**	**263**	**2,430**	**8**	**93**	**219**	**76%**	**24%**	**0.09**
Pharmaceuticals	164	129	1,201	8	35	122	80%	20%	0.10
Organic Chemicals	425	355	4,294	6	153	468	65%	35%	0.11
Agricultural Chemicals	263	164	1,293	12	47	102	74%	26%	0.08
Petroleum Refining	156	148	3,081	3	124	763	68%	32%	0.25
Rubber and Plastic	1,818	981	4,383	25	178	276	82%	18%	0.06
Stone, Clay, Glass and Concrete	615	388	3,474	11	97	277	75%	25%	0.08
Iron and Steel	349	275	4,476	5	121	305	71%	29%	0.07
Metal Castings	669	424	2,535	16	113	191	71%	29%	0.08
Nonferrous Metals	203	161	1,640	7	68	174	78%	22%	0.11
Fabricated Metal Products	2,906	1,858	7,914	22	365	600	75%	25%	0.08
Electronics	1,250	863	4,500	17	150	251	80%	20%	0.06
Automobile Assembly	1,260	927	5,912	13	253	413	82%	18%	0.07
Shipbuilding and Repair	44	37	243	9	20	32	84%	16%	0.13
Ground Transportation	7,786	3,263	12,904	36	375	774	84%	16%	0.06
Water Transportation	514	192	816	38	36	70	61%	39%	0.09
Air Transportation	444	231	973	27	48	97	88%	12%	0.10
Fossil Fuel Electric Power	3,270	2,166	14,210	14	403	789	76%	24%	0.06
Dry Cleaning	6,063	2,360	3,813	95	55	66	95%	5%	0.02

Table 26: One-Year Enforcement and Compliance Summary for Selected Industries

A	B	C	D	E		F		G	H
				Facilities with 1 or More Violations		Facilities with 1 or more Enforcement Actions			
Industry Sector	**Facilities in Search**	**Facilities Inspected**	**Number of Inspections**	**Number**	**Percent***	**Number**	**Percent***	**Total Enforcement Actions**	**Enforcement to Inspection Rate**
Metal Mining	1,232	142	211	102	72%	9	6%	10	0.05
Coal Mining	3,256	362	765	90	25%	20	6%	22	0.03
Oil and Gas Extraction	4,676	874	1,173	127	15%	26	3%	34	0.03
Non-Metallic Mineral Mining	5,256	1,481	2,451	384	26%	73	5%	91	0.04
Textiles	355	172	295	96	56%	10	6%	12	0.04
Lumber and Wood	712	279	507	192	69%	44	16%	52	0.10
Furniture	499	254	459	136	54%	9	4%	11	0.02
Pulp and Paper	484	317	788	248	78%	43	14%	74	0.09
Printing	5,862	892	1,363	577	65%	28	3%	53	0.04
Inorganic Chemicals	441	200	548	155	78%	19	10%	31	0.06
Resins and Manmade Fibers	**329**	**173**	**419**	**152**	**88%**	**26**	**15%**	**36**	**0.09**
Pharmaceuticals	164	80	209	84	105%	8	10%	14	0.07
Organic Chemicals	425	259	837	243	94%	42	16%	56	0.07
Agricultural Chemicals	263	105	206	102	97%	5	5%	11	0.05
Petroleum Refining	156	132	565	129	98%	58	44%	132	0.23
Rubber and Plastic	1,818	466	791	389	83%	33	7%	41	0.05
Stone, Clay, Glass and Concrete	615	255	678	151	59%	19	7%	27	0.04
Iron and Steel	349	197	866	174	88%	22	11%	34	0.04
Metal Castings	669	234	433	240	103%	24	10%	26	0.06
Nonferrous Metals	203	108	310	98	91%	17	16%	28	0.09
Fabricated Metal	2,906	849	1,377	796	94%	63	7%	83	0.06
Electronics	1,250	420	780	402	96%	27	6%	43	0.06
Automobile Assembly	1,260	507	1,058	431	85%	35	7%	47	0.04
Shipbuilding and Repair	44	22	51	19	86%	3	14%	4	0.08
Ground Transportation	7,786	1,585	2,499	681	43%	85	5%	103	0.04
Water Transportation	514	84	141	53	63%	10	12%	11	0.08
Air Transportation	444	96	151	69	72%	8	8%	12	0.08
Fossil Fuel Electric Power	3,270	1,318	2,430	804	61%	100	8%	135	0.06
Dry Cleaning	6,063	1,234	1,436	314	25%	12	1%	16	0.01

**Percentages in Columns E and F are based on the number of facilities inspected (Column C). Percentages can exceed 100% because violations and actions can occur without a facility inspection.*

Table 27: Five-Year Inspection and Enforcement Summary by Statute for Selected Industries

Industry Sector	Facilities Inspected	Total Inspections	Total Enforcement Actions	Clean Air Act		Clean Water Act		RCRA		FIFRA/TSCA/ EPCRA/Other	
				% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions
Metal Mining	378	1,600	111	39%	19%	52%	52%	8%	12%	1%	17%
Coal Mining	741	3,748	132	57%	64%	38%	28%	4%	8%	1%	1%
Oil and Gas Extraction	1,902	6,071	309	75%	65%	16%	14%	8%	18%	0%	3%
Non-Metallic Mineral Mining	2,803	12,826	622	83%	81%	14%	13%	3%	4%	0%	3%
Textiles	267	1,465	83	58%	54%	22%	25%	18%	14%	2%	6%
Lumber and Wood	473	2,767	265	49%	47%	6%	6%	44%	31%	1%	16%
Furniture	386	2,379	91	62%	42%	3%	0%	34%	43%	1%	14%
Pulp and Paper	430	4,630	478	51%	59%	32%	28%	15%	10%	2%	4%
Printing	2,092	7,691	428	60%	64%	5%	3%	35%	29%	1%	4%
Inorganic Chemicals	286	3,087	235	38%	44%	27%	21%	34%	30%	1%	5%
Resins and Manmade Fibers	**263**	**2,430**	**219**	**35%**	**43%**	**23%**	**28%**	**38%**	**23%**	**4%**	**6%**
Pharmaceuticals	129	1,201	122	35%	49%	15%	25%	45%	20%	5%	5%
Organic Chemicals	355	4,294	468	37%	42%	16%	25%	44%	28%	4%	6%
Agricultural Chemicals	164	1,293	102	43%	39%	24%	20%	28%	30%	5%	11%
Petroleum Refining	148	3,081	763	42%	59%	20%	13%	36%	21%	2%	7%
Rubber and Plastic	981	4,383	276	51%	44%	12%	11%	35%	34%	2%	11%
Stone, Clay, Glass and Concrete	388	3,474	277	56%	57%	13%	9%	31%	30%	1%	4%
Iron and Steel	275	4,476	305	45%	35%	26%	26%	28%	31%	1%	8%
Metal Castings	424	2,535	191	55%	44%	11%	10%	32%	31%	2%	14%
Nonferrous Metals	161	1,640	174	48%	43%	18%	17%	33%	31%	1%	10%
Fabricated Metal	1,858	7,914	600	40%	33%	12%	11%	45%	43%	2%	13%
Electronics	863	4,500	251	38%	32%	13%	11%	47%	50%	2%	7%
Automobile Assembly	927	5,912	413	47%	39%	8%	9%	43%	43%	2%	9%
Shipbuilding and Repair	37	243	32	39%	25%	14%	25%	42%	47%	5%	3%
Ground Transportation	3,263	12,904	774	59%	41%	12%	11%	29%	45%	1%	3%
Water Transportation	192	816	70	39%	29%	23%	34%	37%	33%	1%	4%
Air Transportation	231	973	97	25%	32%	27%	20%	48%	48%	0%	0%
Fossil Fuel Electric Power	2,166	14,210	789	57%	59%	32%	26%	11%	10%	1%	5%
Dry Cleaning	2,360	3,813	66	56%	23%	3%	6%	41%	71%	0%	0%

Table 28: One-Year Inspection and Enforcement Summary by Statute for Selected Industries

Industry Sector	Facilities Inspected	Total Inspections	Total Enforcement Actions	Clean Air Act		Clean Water Act		RCRA		FIFRA/TSCA/ EPCRA/Other	
				% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions
Metal Mining	142	211	10	52%	0%	40%	40%	8%	30%	0%	30%
Coal Mining	362	765	22	56%	82%	40%	14%	4%	5%	0%	0%
Oil and Gas Extraction	874	1,173	34	82%	68%	10%	9%	9%	24%	0%	0%
Non-Metallic Mineral Mining	1,481	2,451	91	87%	89%	10%	9%	3%	2%	0%	0%
Textiles	172	295	12	66%	75%	17%	17%	17%	8%	0%	0%
Lumber and Wood	279	507	52	51%	30%	6%	5%	44%	25%	0%	40%
Furniture	254	459	11	66%	45%	2%	0%	32%	45%	0%	9%
Pulp and Paper	317	788	74	54%	73%	32%	19%	14%	7%	0%	1%
Printing	892	1,363	53	63%	77%	4%	0%	33%	23%	0%	0%
Inorganic Chemicals	200	548	31	35%	59%	26%	9%	39%	25%	0%	6%
Resins and Manmade Fibers	**173**	**419**	**36**	**38%**	**51%**	**24%**	**38%**	**38%**	**5%**	**0%**	**5%**
Pharmaceuticals	80	209	14	43%	71%	11%	14%	45%	14%	0%	0%
Organic Chemicals	259	837	56	40%	54%	13%	13%	47%	34%	0%	0%
Agricultural Chemicals	105	206	11	48%	55%	22%	0%	30%	36%	0%	9%
Petroleum Refining	132	565	132	49%	67%	17%	8%	34%	15%	0%	10%
Rubber and Plastic	466	791	41	55%	64%	10%	13%	35%	23%	0%	0%
Stone, Clay, Glass and Concrete	255	678	27	62%	63%	10%	7%	28%	30%	0%	0%
Iron and Steel	197	866	34	52%	47%	23%	29%	26%	24%	0%	0%
Metal Castings	234	433	26	60%	58%	10%	8%	30%	35%	0%	0%
Nonferrous Metals	108	310	28	44%	43%	15%	20%	41%	30%	0%	7%
Fabricated Metal	849	1,377	83	46%	41%	11%	2%	43%	57%	0%	0%
Electronics	420	780	43	44%	37%	14%	5%	43%	53%	0%	5%
Automobile Assembly	507	1,058	47	53%	47%	7%	6%	41%	47%	0%	0%
Shipbuilding and Repair	22	51	4	54%	0%	11%	50%	35%	50%	0%	0%
Ground Transportation	1,585	2,499	103	64%	46%	11%	10%	26%	44%	0%	1%
Water Transportation	84	141	11	38%	9%	24%	36%	38%	45%	0%	9%
Air Transportation	96	151	12	28%	33%	15%	42%	57%	25%	0%	0%
Fossil Fuel Electric Power	1,318	2,430	135	59%	73%	32%	21%	9%	5%	0%	0%
Dry Cleaning	1,234	1,436	16	69%	56%	1%	6%	30%	38%	0%	0%

VII.C. Review of Major Legal Actions

Major Cases/Supplemental Environmental Projects

This section provides summary information about major cases that have affected this sector, and a list of Supplemental Environmental Projects (SEPs).

VII.C.1. Review of Major Cases

As indicated in EPA's *Enforcement Accomplishments Report, FY1995 and FY1996* publications, four significant enforcement actions were resolved between 1995 and 1996 for the metal casting industry.

Teknor Apex Company: A September 30, 1996 consent agreement and order resolved TSCA violations by Teknor Apex of Pawtucket, RI. Teknor Apex had failed to report the identities and volumes of several chemicals manufactured in 1989, as required by EPA's Inventory Update rule. Teknor Apex manufactures organic plasticizers, vinyl resins, garden hose, plastic sheeting, and color pigments. The violations, which occurred at facilities in Attleboro, MA, and in Brownsville, TN, hampered EPA's efforts to assess the health and environmental risks of chemical manufacture and distribution. The settlement provides for a penalty of $52,950 and implementation of SEPs costing $300,000. Four SEPs at the Attleboro facility will reduce toxic emissions, reduce and improve the quality of wastewater discharges, and reduce the volume of industrial wastewater processed at Teknor's on-site wastewater treatment plant.

Union Carbide Chemicals and Plastics (South Charleston, WV): On May 16, 1995, the Regional Administrator signed a consent order resolving a RCRA administrative penalty action against Union Carbide Chemicals and Plastics Company, Inc. (UCC), for violations of the BIF Rule (Boiler and Industrial Furnace Rule) at UCC's South Charleston, West Virginia, plant. The complaint alleged failure to: continuously monitor and record operating parameters; accurately analyze the hazardous waste fed into the boiler; and properly mark equipment. Under the settlement terms UCC is required to pay a $195,000 civil penalty and comply with the requirements of the BIF Rule.

Formosa Plastics Co.: On May 31, 1995, a Class I CERCLA 103(a) and EPCRA 304(a) consent agreement and consent order (CACO) was entered with Formosa Plastics for numerous releases of vinyl chloride from its Point Comfort, Texas, facility between February 1989 and August 1992 that were not reported to the National Response Center (NRC) in a timely manner following the release. Additionally, the respondent experienced a release of ethylene dichloride in September 1990, and a release of hydrochloric acid in July 1991. Formosa did not report these releases to the NRC, State

Emergency Response Commission (SERC), and Local Emergency Planning Committee (LEPC) in a timely manner. Formosa agreed to pay a civil penalty of $50,000 and agreed to construct and maintain a secondary containment system which will prevent large pressure releases of vinyl chloride from the facility. The system cost is estimated to be $1.68 million with an anticipated start-up date of January 1996. Additionally, as part of a SEP, Formosa agreed to complete the following actions: (1) implement a chemical safety project for the citizens of Point Comfort, Texas at a cost of $10,000; (2) permit a chemical safety audit to be performed by a team led by EPA personnel to review facility emergency response procedures and plans; (3) develop and implement a risk management program; and (4) provide funding ($35,000) to support a Region-wide LEPC conference.

VII.C.2. Supplementary Environmental Projects (SEPs)

Supplemental environmental projects (SEPs) are enforcement options that require the non-compliant facility to complete specific projects. Information on SEP cases can be accessed via the Internet at EPA's Enviroene website: http://es.inel.gov/sep.

VIII. COMPLIANCE ACTIVITIES AND INITIATIVES

This section highlights the activities undertaken by this industry sector and public agencies to voluntarily improve the sector's environmental performance. These activities include those independently initiated by industrial trade associations. In this section, the notebook also contains a listing and description of national and regional trade associations.

VIII.A. Sector-Related Environmental Programs and Activities

Chemical Manufacturer’s Association and EPA have developed training modules, self-audit manuals, and compliance guides for Section 608 of the Clean Air Act, which covers leak detection and repair. They are discussing developing plant level compliance guides, auditing protocols, and training materials for RCRA Subpart CC and other areas.

VIII.B. EPA Voluntary Programs

33/50 Program

The 33/50 Program is a ground breaking program that has focused on reducing pollution from seventeen high-priority chemicals through voluntary partnerships with industry. The program's name stems from its goals: a 33% reduction in toxic releases by 1992, and a 50% reduction by 1995, against a baseline of 1.5 billion pounds of releases and transfers in 1988. The results have been impressive: 1,300 companies have joined the 33/50 Program (representing over 6,000 facilities) and have reached the national targets a year ahead of schedule. The 33% goal was reached in 1991, and the 50% goal -- a reduction of 745 million pounds of toxic wastes -- was reached in 1994. The 33/50 Program can provide case studies on many of the corporate accomplishments in reducing waste (Contact 33/50 Program Director David Sarokin -- 260-6396).

Table 29 lists those companies participating in the 33/50 program that reported the SIC codes 2821, 2823, or 2824 to TRI. Many of the companies shown listed multiple SIC codes and, therefore, are likely to carry out operations in addition to plastic resin and manmade fiber manufacturing. In addition, the number of facilities within each company that are participating in the 33/50 program and that report SIC 2821, 2823, or 2824 to TRI are shown. Finally, where available and quantifiable against 1988 releases and transfers, each company’s 33/50 goals for 1995 and the actual total releases, transfers and percent reduction between 1988 and 1994 are presented.

Table 29: Plastic Resin and Manmade Fiber Industries Participation in the 33/50 Program

Parent Company (Headquarters Location)	Company-Owned Facilities Reporting 33/50 Chemicals	Company-Wide % Reduction Goal[1] (1988 to 1995)	1988 TRI Releases and Transfers of 33/50 Chemicals (pounds)	1994 TRI Releases and Transfers of 33/50 Chemicals (pounds)	Actual % Reduction for Facilities (1988-1994)
AIR PRODUCTS AND CHEMICALS ALLENTOWN, PA	1	50	0	411	---
AKZO NOBEL INC CHICAGO, IL	1	13	158,650	87,268	45
ALBEMARLE CORPORATION RICHMOND, VA	6	51	960,620	1,181,712	-23
ALLIED-SIGNAL INC MORRISTOWN, NJ	1	50	0	10	---
AMERICAN PLASTIC TECHNOLOGIES MIDDLEFIELD, OH	1	50	750	0	100
AMOCO CORPORATION CHICAGO, IL	1	50	0	30	---
ARISTECH CHEMICAL CORPORATION PITTSBURGH, PA	7	18	1,648,348	159,614	90
ASHLAND OIL INC RUSSELL, KY	2	50	207,440	4,632	98
ATLANTIC RICHFIELD COMPANY LOS ANGELES, CA	1	2	47,543	3,158	93
B F GOODRICH COMPANY AKRON, OH	6	50	31,478	864	97
BASF CORPORATION MOUNT OLIVE, NJ	3	50	241,760	45,195	81
BORDEN CHEM & PLAS LTD PARTNR COLUMBUS, OH	1	***	11,781	26,393	-124
BORDEN INC NEW YORK, NY	2	*	105	161	-53
BULK MOLDING COMPOUNDS INC SAINT CHARLES, IL	1	40	48,555	0	100
CAPITAL RESIN CORPORATION COLUMBUS, OH	1	50	42,480	14,077	67
CARGILL DETROIT CORPORATION CLAWSON, MI	5	40	165,288	23,836	86
CHEVRON CORPORATION SAN FRANCISCO, CA	1	50	56,216	72,044	-28
COURTAULDS FIBERS AXIS, AL	1	***	0	3,250	---
CYTEC INDUSTRIES WEST PATERSON, NJ	3	50	226,059	56,230	75

Parent Company (Headquarters Location)	Company-Owned Facilities Reporting 33/50 Chemicals	Company-Wide % Reduction Goal[1] (1988 to 1995)	1988 TRI Releases and Transfers of 33/50 Chemicals (pounds)	1994 TRI Releases and Transfers of 33/50 Chemicals (pounds)	Actual % Reduction for Facilities (1988-1994)
DOCK RESINS CORPORATION LINDEN, NJ	1	***	10,100	2,370	77
DOW CHEMICAL COMPANY MIDLAND, MI	20	50	6,202,765	1,761,522	72
E. I. DU PONT DE NEMOURS & CO WILMINGTON, DE	2	50	599,530	176,040	71
ETHYL CORPORATION RICHMOND, VA	1	46	29,174	0	100
EXXON CORPORATION IRVING, TX	3	50	10,548	11,696	-11
FINA INC DALLAS, TX	1	40	0	294	----
GENERAL ELECTRIC COMPANY FAIRFIELD, CT	6	50	7,710,278	1,798,408	77
GEORGIA-PACIFIC CORPORATION ATLANTA, GA	1	50	0	35	---
GLASGO PLASTICS INC SPRINGFIELD, OH	1	50	12,630	0	100
GLOBE MANUFACTURING CO FALL RIVER, MA	1	45	957,417	161,523	83
GRIFFITH POLYMERS HILLSBORO, OR	1	**	29,491	0	100
H & N CHEMICAL CO INC TOTOWA, NJ	1	***	10,700	2,807	74
HERCULES INCORPORATED WILMINGTON, DE	3	50	551,064	137,808	75
HERESITE PROTECTIVE COATINGS MANITOWOC, WI	1	50	2,100	0	100
HOECHST CELANESE CORPORATION CORPUS CHRISTY, TX	21	50	4,836,469	1,463,490	70
ILLINOIS TOOL WORKS INC GLENVIEW, IL	1	***	0	500	---
INTERNATIONAL PAPER COMPANY PURCHASE, NY	3	50	138,072	531,258	-285
JAMES RIVER CORP VIRGINIA RICHMOND, VA	1	53	0	0	---
LIBERTY POLYGLAS INC WEST MIFFLIN, PA	1	*	48,401	20,295	58
LYONDELL PETROCHEMICAL CO HOUSTON, TX	1	57	6,901	0	100

Parent Company (Headquarters Location)	Company-Owned Facilities Reporting 33/50 Chemicals	Company-Wide % Reduction Goal[1] (1988 to 1995)	1988 TRI Releases and Transfers of 33/50 Chemicals (pounds)	1994 TRI Releases and Transfers of 33/50 Chemicals (pounds)	Actual % Reduction for Facilities (1988-1994)
MILES INC PITTSBURGH, PA	20	37	2,069,780	1,410,749	32
MOBIL CORPORATION FAIRFAX, VA	1	50	11,922	800	93
MONSANTO COMPANY SAINT LOUIS, MO	19	25	5,554,821	1,977,399	64
MORTON INTERNATIONAL INC CHICAGO, IL	1	20	0	0	---
NEWPORT ADHESIVES & COMPOSITES FOUNTAIN VALLEY, CA	1	50	139,000	0	100
NORTH AMERICAN PLASTICS INC. PRAIRIE, MS	2	*	4	12	-200
OCCIDENTAL PETROLEUM CORP LOS ANGELES, CA	6	19	1,670,197	702,818	58
PHILLIPS PETROLEUM COMPANY BARTLESVILLE, OK	1	50	0	168	---
PLASTICS ENGINEERING COMPANY SHEBOYGAN, WI	1	*	3,685	0	100
PPG INDUSTRIES INC PITTSBURGH, PA	2	50	580,992	161,719	72
PREMIX INC N KINGSVILLE, OH	2	23	41,200	750	98
QUANTUM CHEMICAL CORPORATION ISELIN, NJ	7	50	391,086	177,588	55
RANBAR TECHNOLOGY INC GLENSHAW, PA	1	52	26,900	5,693	79
REVLIS CORPORATION AKRON, OH	1	50	1,500	1,870	-25
REXENE CORPORATION DALLAS, TX	1	50	347,520	103,401	70
ROGERS CORPORATION ROGERS, CT	5	***	243,173	82,483	66
ROHM AND HAAS COMPANY PHILADELPHIA, PA	3	50	319,380	37,660	88
SARTORIUS NORTH AMERICA INC BRENTWOOD, NY	1	50	377,320	77,750	79
SOLVAY AMERICA INC HOUSTON, TX	2	*	9,800	21,000	-114
TEXTILE RUBBER & CHEMICAL CO DALTON, GA	1	*	7,150	0	100

Parent Company (Headquarters Location)	Company-Owned Facilities Reporting 33/50 Chemicals	Company-Wide % Reduction Goal[1] (1988 to 1995)	1988 TRI Releases and Transfers of 33/50 Chemicals (pounds)	1994 TRI Releases and Transfers of 33/50 Chemicals (pounds)	Actual % Reduction for Facilities (1988-1994)
UNION CAMP CORPORATION WAYNE, NJ	1	50	136,301	1,434	99
UNION CARBIDE CORPORATION DANBURY, CT	2	54	810,702	1,337	100
UNOCAL CORPORATION LOS ANGELES, CA	1	50	44,750	0	100
VALSPAR CORPORATION MINNEAPOLIS, MN	4	50	111,244	71,238	36
VISTA CHEMICAL COMPANY HOUSTON, TX	5	50	553,331	61,068	89
W R GRACE & CO INC BOCA RATON, FL	1	50	10,980	43,300	-294
ZENECA HOLDINGS INC WILMINGTON, DE	1	*	2,639	1,774	33
TOTAL	**209**		**38,468,090**	**12,688,942**	**39**

Source: U.S. EPA 33/50 Program Office, 1996.

[1] Company-Wide Reduction Goals aggregate all company-owned facilities which may include facilities not manufacturing plastic resins or manmade fibers.
* = Reduction goal not quantifiable against 1988 TRI data.
** = Use reduction goal only.
***= No numeric reduction goal.
--- = Actual reduction not quantifiable against 1988 TRI data.

Environmental Leadership Program

The Environmental Leadership Program (ELP) is a national initiative developed by EPA that focuses on improving environmental performance, encouraging voluntary compliance, and building working relationships with stakeholders. EPA initiated a one year pilot program in 1995 by selecting 12 projects at industrial facilities and federal installations that demonstrate the principles of the ELP program. These principles include: environmental management systems, multimedia compliance assurance, third-party verification of compliance, public measures of accountability, community involvement, and mentor programs. In return for participating, pilot participants receive public recognition and are given a period of time to correct any violations discovered during these experimental projects.

EPA is making plans to launch its full-scale Environmental Leadership Program in 1997. The full-scale program will be facility-based with a 6-year participation cycle. Facilities that meet certain requirements will be eligible to participate, such as having a community outreach/employee involvement programs and an environmental management system (EMS) in place for 2 years. (Contact: http://es.inel.gov/elp or Debby Thomas, ELP Deputy Director, at 202-564-5041)

Project XL

Project XL was initiated in March 1995 as a part of President Clinton's *Reinventing Environmental Regulation* initiative. The projects seek to achieve cost effective environmental benefits by providing participants regulatory flexibility on the condition that they produce greater environmental benefits. EPA and program participants will negotiate and sign a Final Project Agreement, detailing specific environmental objectives that the regulated entity shall satisfy. EPA will provide regulatory flexibility as an incentive for the participants' superior environmental performance. Participants are encouraged to seek stakeholder support from local governments, businesses, and environmental groups. EPA hopes to implement fifty pilot projects in four categories, including industrial facilities, communities, and government facilities regulated by EPA. Applications will be accepted on a rolling basis. For additional information regarding XL projects, including application procedures and criteria, see the May 23, 1995 Federal Register Notice. (Contact: Fax-on-Demand Hotline 202-260-8590, Web: http://www.epa.gov/ProjectXL, or Christopher Knopes at EPA's Office of Policy, Planning and Evaluation 202-260-9298)

Climate Wise Program

Climate Wise is helping US industries turn energy efficiency and pollution prevention into a corporate asset. Supported by the technical assistance, financing information and public recognition that Climate Wise offers, participating companies are developing and launching comprehensive industrial energy efficiency and pollution prevention action plans that save money and protect the environment. The nearly 300 Climate Wise companies expect to save more than $300 million and reduce greenhouse gas emissions by 18 million metric tons of carbon dioxide equivalent by the year 2000. Some of the actions companies are undertaking to achieve these results include: process improvements, boiler and steam system optimization, air compressor system improvements, fuel switching, and waste heat recovery measures including cogeneration. Created as part of the President's Climate Change Action Plan, Climate Wise is jointly operated by the Department of Energy and EPA. Under the Plan many other programs were also launched or upgraded including Green Lights, WasteWi$e and DoE's Motor Challenge Program. Climate Wise provides an umbrella for these programs which encourage company participation by providing information on the range of partnership opportunities available. (Contact: Pamela Herman, EPA, 202-260-4407 or Jan Vernet, DoE, 202-586-4755)

Energy Star Buildings Program

EPA's ENERGY STAR Buildings Program is a voluntary, profit-based program designed to improve the energy-efficiency in commercial and industrial buildings. Expanding the successful Green Lights Program, ENERGY STAR Buildings was launched in 1995. This program relies on a 5-stage strategy designed to maximize energy savings thereby lowering energy bills, improving occupant comfort, and preventing pollution -- all at the same time. If implemented in every commercial and industrial building in the United States, ENERGY STAR Buildings could cut the nation's energy bill by up to $25 billion and prevent up to 35% of carbon dioxide emissions. (This is equivalent to taking 60 million cars of the road). ENERGY STAR Buildings participants include corporations; small and medium sized businesses; local, federal and state governments; non-profit groups; schools; universities; and health care facilities. EPA provides technical and non-technical support including software, workshops, manuals, communication tools, and an information hotline. EPA's Office of Air and Radiation manages the operation of the ENERGY STAR Buildings Program. (Contact: Green Light/Energy Star Hotline at 1-888-STAR-YES or Maria Tikoff Vargas, EPA Program Director at 202-233-9178 or visit the ENERGY STAR Buildings Program website at http://www.epa.gov/appdstar/buildings/)

Green Lights Program

EPA's Green Lights program was initiated in 1991 and has the goal of preventing pollution by encouraging U.S. institutions to use energy-efficient lighting technologies. The program saves money for businesses and organizations and creates a cleaner environment by reducing pollutants released into the atmosphere. The program has over 2,345 participants which include major corporations, small and medium sized businesses, federal, state and local governments, non-profit groups, schools, universities, and health care facilities. Each participant is required to survey their facilities and upgrade lighting wherever it is profitable. As of March 1997, participants had lowered their electric bills by $289 million annually. EPA provides technical assistance to the participants through a decision support software package, workshops and manuals, and an information hotline. EPA's Office of Air and Radiation is responsible for operating the Green Lights Program. (Contact: Green Light/Energy Star Hotline at 1-888-STARYES or Maria Tikoff Vargar, EPA Program Director, at 202-233-9178 the)

WasteWi$e Program

The WasteWi$e Program was started in 1994 by EPA's Office of Solid Waste and Emergency Response. The program is aimed at reducing municipal solid wastes by promoting waste prevention, recycling collection and the manufacturing and purchase of recycled products. As of 1997, the program had about 500 companies as members, one third of whom are Fortune 1000 corporations. Members agree to identify and implement actions to reduce their solid wastes setting waste reduction goals and providing EPA with yearly progress reports. To member companies, EPA, in turn, provides technical assistance, publications, networking opportunities, and national and regional recognition. (Contact: WasteWi$e Hotline at 1-800-372-9473 or Joanne Oxley, EPA Program Manager, 703-308-0199)

NICE³

The U.S. Department of Energy is administering a grant program called The National Industrial Competitiveness through Energy, Environment, and Economics (NICE³). By providing grants of up to 45 percent of the total project cost, the program encourages industry to reduce industrial waste at its source and become more energy-efficient and cost-competitive through waste minimization efforts. Grants are used by industry to design, test, and demonstrate new processes and/or equipment with the potential to reduce pollution and increase energy efficiency. The program is open to all industries; however, priority is given to proposals from participants in the forest products, chemicals, petroleum refining, steel, aluminum, metal casting and glass manufacturing sectors. (Contact: http//www.oit.doe.gov/access/nice3, Chris Sifri, DOE, 303-275-4723 or Eric Hass, DOE, 303-275-4728)

Design for the Environment (DfE)

DfE is working with several industries to identify cost-effective pollution prevention strategies that reduce risks to workers and the environment. DfE helps businesses compare and evaluate the performance, cost, pollution prevention benefits, and human health and environmental risks associated with existing and alternative technologies. The goal of these projects is to encourage businesses to consider and use cleaner products, processes, and technologies. For more information about the DfE Program, call (202) 260-1678. To obtain copies of DfE materials or for general information about DfE, contact EPA's Pollution Prevention Information Clearinghouse at (202) 260-1023 or visit the DfE Website at http://es.inel.gov/dfe.

VIII.C. Trade Association/Industry Sponsored Activity

VIII.C.1. Environmental Programs

The Global Environmental Management Initiative (GEMI) is made up of a group of leading companies dedicated to fostering environmental excellence by business. GEMI promotes a worldwide business ethic for environmental management and sustainable development, to improve the environmental performance of business through example and leadership. In 1994, GEMI's membership consisted of about 30 major corporations including Union Carbide Corporation and Dow Chemical.

Center for Waste Reduction Technologies under the aegis of the American Institute of Chemical Engineers sponsored research on innovative technologies to reduce waste in the chemical processing industries. The primary mechanism is through funding of academic research.

The **American Plastics Council** is working on a life-cycle study to examine the emissions released from plastics and resins manufacturing facilities. The study will compare emissions from plastics and resins manufacturing with manufacturing of other materials, such as wood products.

The **National Science Foundation** and the **Environmental Protection Agency's** Office of Pollution Prevention and Toxics signed an agreement in January of 1994 to coordinate the two agencies' programs of **basic research related to pollution prevention**. The collaboration will stress research in the use of less toxic chemical and synthetic feedstocks, use of photochemical processes instead of traditional ones that employ toxic reagents, use of recyclable catalysts to reduce metal contamination, and use of natural feedstocks when synthesizing chemicals in large quantities.

The **Chemical Manufacturer's Association** funds research on issues of interest to their members particularly in support of their positions on proposed or possible legislation. They recently funded a study to characterize the environmental fate of organochlorine compounds.

The **Responsible Care® Initiative** of the Chemical Manufacturer's Association requires all members and partners to continuously improve their health, safety, and environmental performance in a manner that is responsive to the public. Launched in 1988, the Responsible Care® concepts are now being applied in 36 countries around the world. Responsible Care® is a comprehensive, performance-oriented initiative composed of ten progressive Guiding Principles and six board Codes of Management Practices. These Management Practices cover all aspects of the chemical industry's operations, from research to manufacturing, distribution, transportation, sales and marketing, and to downstream users of chemical products. Through

Responsible Care®, CMA members and partners gain insight from the public through, among other means, a national Public Advisory Panel and over 250 local Community Advisory Panels. This, coupled with the fact that participation in Responsible Care® is an obligation of membership with the Chemical Manufacturer's Association, make this performance improvement initiative unique. The Synthetic Organic Chemical Manufacturer's Association whose membership consists of smaller batch and custom chemical manufacturers with typically fewer than 50 employees and less than $50 million in annual sales, encourages its members to achieve continuous performance improvement in their health, safety, and environmental programs through implementation of the chemical industry's Responsible Care® initiative. SOCMA is a partner in Responsible Care®.

The Society of the Plastics Industry has implemented two programs aimed at reducing plastic pellet loss. In 1991, SPI's Polymeric Materials Producers Division developed and endorsed a "Pellet Retention Environmental Code." Companies that sign the code commit themselves to the total containment of plastic pellets throughout the pellets' lifespan and to operating in full compliance with environmental laws and regulations pertaining to pellet containment (SPI, 1994). In 1992, SPI expanded the program to include a processor's pledge to uphold six principles to prevent the loss of resin pellets into the environment.

ISO 9000 is a series of international total quality management guidelines. After a successful independent audit of their management plans, firms are qualified to be ISO 9000 registered. In June of 1993, the International Standards Organization created a technical committee to work on new standards for environmental management systems.

VIII.C.2. Summary of Trade Associations

American Chemical Society
1155 16th Street, NW
Washington, D.C. 20036
Phone: 202-872-4600
Fax: 202-872-4615

Members: 150,000 individuals
Staff: 1950
Budget: $192,000,000

The American Chemical Society (ACS) has an educational and research focus. The ACS produces approximately thirty different industry periodicals and research journals, including *Environmental Science and Technology* and *Chemical Research in Toxicology*. In addition to publishing, the ACS presently conducts studies and surveys; legislation monitoring, analysis, and reporting; and operates a variety of educational programs. The ACS library and on-line information services are extensive. Some available on-line services are *Chemical Journals Online*, containing the full text of 18 ACS journals, 10 Royal Society of Chemistry journals, five polymer journals and the Chemical Abstracts Service, *CAS*, which provides a variety of information on chemical compounds. Founded in 1876, the ACS is presently comprised of 184 local groups and 843 student groups nationwide.

American Fiber Manufacturers Association, Inc.
1150- 17th Street, NW, Suite 310
Washington, DC 22036
Phone: 202-296-6508
Fax: 202-296-3052
E-mail: afma@aol.com

Members: 18 companies
Staff: 6
Budget: $2,000,000

Previously known as the Man-Made Fiber Producers Association up until 1988, the American Fiber Manufacturers Association, Inc. (AFMA) is a domestic trade organization representing U.S. producers of more than 90 percent of domestic production of manufactured fibers, filaments, and yarns. AFMA manages programs on government relations, international trade policy, the environment, technical issues, and educational services. Committees of experts from member companies work on each of these subjects. The group publishes fact books and economic profiles, *Fiber Organon*, and recently published an environmental life cycle study.

Chemical Manufacturers Association
1300 Wilson Boulevard
Arlington, VA 22209
Phone: 703-741-5224
Fax: 703-741-6224

Members: 185 companies
Staff: 246
Budget: $36,000,000

A principal focus of the Chemical Manufacturer’s Association (CMA) is on regulatory issues facing chemical manufacturers at the local, state, and federal levels. At its inception in 1872, the focus of CMA was on serving chemical manufacturers through research. Research is still ongoing at CMA. Member committees, task groups, and work groups routinely sponsor research and technical data collection that is then provided to the public in support of CMA’s advocacy. Much additional research takes place through the CHEMSTAR® program. CHEMSTAR® consists of a variety of self-funded panels working on single-chemical research agendas. This research fits within the overall regulatory focus of CMA; CHEMSTAR® study results are provided to both CMA membership and regulatory agencies. Other initiatives include the Responsible Care® program, which includes six codes of management practices designed to go beyond simple regulatory compliance. CMA is currently developing measurement and appropriate verification systems for these codes. CMA also conducts workshops and technical symposia, promotes in-plant safety, operates a chemical emergency center (CHEMTREC®) which offers guidance in chemical emergency situations, and operates the Chemical Referral Center which provides chemical health and safety information to the public. Publications include the annual *U.S. Chemical Industry Statistical Handbook*, containing detailed data on the industry; *Responsible Care in Action*, the 1993-94 progress report on implementing Responsible Care®; and *Preventing Pollution in the Chemical Industry: A Progress Report (1988-1993)*, summarizing waste generation and reduction data for the years 1988-93. CMA holds an annual meeting for its membership in White Sulphur Springs, WV.

Polyurethane Manufacturers Association	
800 Roosevelt Road, Bldg.C, Ste. 20	Members: 116 companies
Glen Ellyn, IL 60137-5833	Staff: 4
Phone: 708-858-2670	Budget: $500,000
Fax: 708-790-3095	

This group includes manufacturers, suppliers, distributors and sales agents of raw materials, additives, or processing equipment; processors of solid cast, microcellular, RIM and thermoplastic urethane elastomers; and individuals or companies providing publishing, education, research, or consulting services to the industry. The association publishes the bimonthly *Polytopics.*

Society of Plastics Engineers	
14 Fairfield Drive	
Brookfield, CT 06804-0403	Members: 37,000 individuals
Phone: 203-775-0471	Staff: 38
Fax: 203-775-8490	Budget: $6,100,000

Society of Plastics Engineers (SPE) is a group dedicated to promoting the knowledge and education of plastics and polymers worldwide and strives to be the leading technology society for the plastics industry. SPE is made up of over 37,500 members around the world involved in engineering, design, production and processing, research and development, consulting, marketing and sales, purchasing, education, and all levels of management. SPE publishes journals, including *Plastics Engineering* and *Polymer Engineering and Science,* and sponsors a large range of technical conferences on polymer and plastics processing.

Society of the Plastics Industry, Inc.	
1801 K Street, NW, Suite 600K	Web: www.socplas.org
Washington, DC 20006-1301	Members: 1900 companies
Phone: 202-974-5200	Staff: 130
Fax: 202-296-7005	Budget: $30,000,000

SPI is a principal trade association for the U.S. plastics industry. Comprised of 2,000 members, SPI has representatives from all segments of the plastics industry, including materials suppliers, processors, machinery manufacturers, moldmakers, distributors, and other industry-related groups and individuals. SPI publishes an annual report on market trends called *Facts and Figures of the U.S. Plastics Industry*. In addition to its general services -- Government and Technical Affairs, Communications, Trade Shows, Membership, and Finance Administration -- SPI has 28 business units as well as numerous key services offering programs specifically geared to the interests of particular industry segments. These special purpose groups include the Degradable Polymers Council, which acts as a clearinghouse for research in the degradable plastics industry, and the Polymeric Materials Producers Division, which includes manufacturers of basic polymers or prepolymers for the plastics industry. Other industry segment groups which focus on particular plastic resins include the Fluoropolymers Division, Naphthalate Polymers Council, the Phenolic Division, the Polyurethane Division, the Styrene Information and Research Center, and the Vinyl Institute. SPI also has an affiliation with the American Plastics Council which includes U.S. resin and monomer producers, plastics processers, and suppliers. Contact information for these groups is listed below.

American Plastics Council, Red Cavaney, President, 202-974-5400
Composites Institute, Catherine Randazzo, Executive Director, 212-351-5410
Degradable Polymers Council, John Malloy, Director of Packaging Services, 202-974-5245,dpc@socplas.org
Fluoropolymers Division, Allen Weidman, Director, 202-974-5233
Naphthalate Polymers Council, John Malloy, Director of Packaging Services, 202-974-5245
Phenolic Division, Allen Weidman, Director, 202-974-5233
Polymeric Materials Producers Division, Betsy Shirley, Executive Director, 202-974-5319, pmd@socplas.org
Polyurethane Division, Fran Lichtenberg, Executive Director, 212-351-5242, polyu@socplas.org
Styrene Information and Research Center, Betsy Shirley, Executive Director, 202-974-5319 sirc@socplas.org
The Vinyl Institute, Robert Burnett, Executive Director, 201-898-6633, vi@socplas.org

Synthetic Organic Chemicals Manufacturer's Association	
1100 New York Avenue, NW	
Washington, D.C. 20005	Members: 250
Phone: 202-414-4100	Staff: 50
Fax: 202-289-8584	Budget: $12,000,000

Synthetic Organic Chemicals Manufacturer's Association (SOCMA) is the national trade association representing the legislative, regulatory, and commercial interests of some 250 companies that manufacture, distribute, or market organic chemicals. Most of SOCMA's members are batch and custom chemical manufacturers who are the highly innovative, entrepreneurial and customer-driven sector of the U.S. chemical industry. The majority of SOCMA's members are small businesses with annual sales of less than $50 million and fewer than 50 employees. SOCMA assists its members in improving their environmental, safety, and health performance through various programs focusing on continuous improvement. A bi-monthly newsletter provides information on legislative and regulatory developments, as well as on education and training opportunities. SOCMA holds an annual meeting in May and also sponsors INFORMEX, the largest custom chemical trade show in the U.S. In addition, SOCMA's Association Management Center includes two dozen self-funded groups that focus on single chemical issues.

IX. CONTACTS/ACKNOWLEDGMENTS/REFERENCES

For further information on selected topics within the plastic resin and manmade fiber industries, a list of publications and contacts are provided below.

Contacts[3]

Name	Organization	Telephone	Subject
Sally Sasnett	EPA, Office of Compliance	202-564-7074	Compliance assistance
Bob Rosensteel	EPA, OAQPS	919-541-5608	Industrial processes and regulatory requirements (CAA)
George Jett	EPA, Office of Water	202-260-7151	Industrial processes and effluent guidelines
Bob Barker	AFMA	202-296-6508	Industrial processes
Lucinda Schofer	CMA	703-741-5231	Industrial resources and regulatory requirements
David Gustafson	Dow Chemical	517-636-2953	Regulatory requirements and polyethylene manufacture
John Dege	Du Pont	302-773-0900	Regulatory requirements and synthetic fiber manufacture
Bob Lambour	Exxon	713-870-6017	Regulatory requirements, polyethylene and polypropylene manufacture
Brent Smith	NC State	919-515-6548	Manmade fibers processes and pollution prevention methods
Jim Kachtick	Occidental Chemical	713-215-7602	Regulatory requirements and PVC manufacture
Lynne Harris	SPI	202-974-5217	Industrial resources and regulatory requirements

AFMA: American Fiber Manufacturers Association
CMA: Chemical Manufacturers Association
CAA: Clean Air Act
OAQPS: Office of Air Quality Planning and Standards
SPI: Society of the Plastics Industry

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[3] Many of the contacts listed below have provided valuable background information and comments during development of this document. EPA appreciates this support and acknowledges that the individuals listed do not necessarily endorse all statements made within this notebook.

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