

4. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

4.1 PRODUCTION

Because of its low cost and high purity, formaldehyde has become one of the most important industrial and research chemicals in the world. Between 1958 and 1968, the annual growth rate for formaldehyde production averaged 11.7% (Gerberich et al. 1980). During the late 1960s, production averaged 71% of capacity. The recession of the mid-1970s, however, caused production to drop as low as 54% of capacity (Gerberich et al. 1980). From 1988 to 1997, formaldehyde production averaged an annual growth rate of 2.7% per year (Anonymous 1998). In 1992, formaldehyde ranked 22nd (8.28 billion pounds produced) among the top 50 chemicals produced in the United States (Anonymous 1994). Total annual capacities for the 15–17 U.S. companies listed as the top formaldehyde manufacturers or processors for 1988, 1990, and 1992 were 8.94, 9.70, and 10.08 billion pounds, respectively (SRI 1988, 1990, 1992). The estimated total annual formaldehyde capacity in 1998 was 11.3 billion pounds (Anonymous 1998). With production volumes varying between 6.43 billion pounds and 8.11 billion pounds for 1990, 1991, and the period 1993–1995, formaldehyde ranked either 24th or 25th among the top 50 chemicals produced (Anonymous 1992, 1994, 1995a; Kirschner 1996).

As of 1998, three manufacturers of formaldehyde were responsible for 50% of the annual capacity for the United States: Georgia-Pacific Resins, Inc. (Albany, Oregon; Columbus, Ohio; Conway, North Carolina; Crossett, Arkansas; Grayling, Michigan; Hampton, South Carolina; Healing Springs, North Carolina; Houston, Texas; Lufkin, Texas; Russellville, South Carolina; Taylorsville, Mississippi; Vienna, Georgia; White City, Oregon), Hoechst Celanese Corporation (Bishop, Texas; Rock Hill, South Carolina), and Borden, Inc. (Baytown, Texas; Demopolis, Alabama; Diboll, Texas; Fayetteville, North Carolina; Fremont, California; Hope, Arkansas; Kent, Washington; La Grande, Oregon; Missoula, Montana; Sheboygan, Wisconsin; Springfield, Oregon; Vicksburg, Mississippi) (Anonymous 1998; SRI 1997). In addition to the above facilities, the following companies also contributed to the overall U.S. capacity: Capital Resin (Columbus, Ohio); D.B. Western (Las Vegas, New Mexico; Virginia, Minnesota); Degussa (Theodore, Alabama); DuPont (LaPorte, Texas; Parkersburg, West Virginia); Hercules-Aqualon (Louisiana, Montana); ISP (Calvert City, Kentucky; Texas City, Texas); Monsanto (Alvin, Texas); Neste Resins (five sites); Perstorp (Toledo, Ohio); Praxair (Geismar, Louisiana); Solutia (Alvin, Texas); Spurlock (Malvern, Arkansas; Waverly, Virginia); Trimet Technical Products (Mallinckrodt);

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(Allentown, Pennsylvania); and Wright Chemical (Acme, North Carolina) (Anonymous 1998; SRI 1997). Formaldehyde production is predicted to increase 2–3% per year through 2002 (Anonymous 1998).

Table 4-1 lists the facilities in each state that manufacture or process formaldehyde, the intended use, and the range of maximum amounts of formaldehyde that are stored on site. The data listed in Table 4-1 are derived from the Toxics Release Inventory (TRI96 1998). Only certain types of facilities were required to report. Therefore, this is not an exhaustive list. Table 4-2 shows capacity and production volumes for selected years between 1960 and 1978.

Formaldehyde has been manufactured primarily from methanol since the beginning of the century (Gerberich et al. 1980). Because methanol is manufactured from synthesis gas, usually produced from methane, there have been extensive efforts to develop a one-step process that partially oxidizes methane to formaldehyde. Although a successful commercial process has not been developed, a wide range of catalysts and oxidation conditions have been studied (Gerberich et al. 1980). During the decades following World War II, approximately 20% of the production volume in the United States was manufactured by vapor phase, non-catalytic oxidation of propane and butane (Gerberich et al. 1980).

Two primary methods of manufacturing formaldehyde from methanol are used today. The first uses silver as a metal catalyst in its reactions. In earlier years, facilities used a copper catalyst in this process. The simultaneous reactions involved in the metal catalyst process occur at essentially atmospheric pressure and 600–650 EC (Gerberich et al. 1980). Approximately 50–60% of the formaldehyde produced using the metal catalyst process is formed during an exothermic reaction; the remainder is formed from an endothermic reaction. The overall yield for this process is 86–90% formaldehyde. The domestic licensors for this process include Borden Chemical Company and Davy Powergas, Inc. (Gerberich et al. 1980).

The second method uses a metal oxide catalyst. All of the formaldehyde is produced from an exothermic reaction occurring at atmospheric pressure and 300–400 EC. The patent for formaldehyde production using a vanadium pentoxide catalyst was issued in 1921. Although the patent for an iron oxide-molybdenum oxide catalyst was issued in 1933, the first commercial facility did not begin operating until 1952 (Gerberich et al. 1980).

Gaseous formaldehyde can be regenerated from paraformaldehyde by heating (Gerberich et al. 1980).

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Table 4-1. Facilities That Manufacture or Process Formaldehyde

| State ^a | Number of facilities | Range of maximum amounts on site in pounds ^b | Activities and uses ^c |
|--------------------|----------------------|---|--|
| AK | 1 | 100,000 - 999,999 | 8 |
| AL | 30 | 0 - 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, |
| AR | 15 | 0 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 12 |
| AZ | 3 | 100 - 9,999 | 1, 5, 7, 9, 12, 13 |
| CA | 26 | 100 - 9,999,999 | 1, 3, 4, 5, 7, 8, 9, 11, 12 |
| CO | 2 | 0 - 9,999 | 12 |
| CT | 8 | 100 - 9,999,999 | 2, 3, 7, 8, 12 |
| DE | 1 | 10,000 - 99,999 | 8 |
| FL | 6 | 0 - 99,999 | 1, 6, 7, 9, 11, 13 |
| GA | 35 | 0 - 999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 |
| IA | 5 | 1,000 - 999,999 | 7, 8, 9, 10 |
| IL | 27 | 0 - 999,999 | 1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13 |
| IN | 15 | 100 - 999,999 | 1, 5, 7, 8, 9, 11, 12, 13 |
| KS | 8 | 100 - 999,999 | 1, 2, 5, 7, 8, 11, 13 |
| KY | 8 | 1,000 - 9,999,999 | 1, 3, 4, 7, 8, 10, 11, 12, 13 |
| LA | 31 | 0 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 13 |
| MA | 10 | 1,000 - 9,999,999 | 1, 3, 4, 7, 8, 9, 11, 13 |
| MD | 2 | 1,000 - 9,999 | 7, 8, 9 |
| ME | 3 | 1,000 - 999,999 | 1, 5, 6, 7, 12 |
| MI | 33 | 0 - 9,999,999 | 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13 |
| MN | 15 | 0 - 999,999 | 1, 5, 6, 7, 8, 9, 10, 11, 12 |
| MO | 12 | 0 - 9,999,999 | 1, 3, 4, 6, 7, 8, 11, 12, 13 |
| MS | 16 | 0 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9 |
| MT | 4 | 0 - 9,999,999 | 1, 3, 4, 6, 7, 8, 9 |
| NC | 39 | 0 - 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13 |
| NH | 4 | 100 - 999,999 | 7, 11, 12 |
| NJ | 18 | 100 - 999,999 | 1, 3, 5, 7, 8, 9, 10, 12, 13 |
| NM | 1 | 100 - 999 | 9 |
| NV | 1 | 1,000 - 9,999 | 7 |
| NY | 25 | 100 - 999,999 | 1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13 |
| OH | 50 | 0 - 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 |
| OK | 4 | 100 - 999,999 | 1, 6, 7, 8 |
| OR | 25 | 100 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 11, 13 |
| PA | 21 | 0 - 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13 |
| PR | 4 | 1,000 - 99,999 | 2, 3, 7, 11, 12, 13 |
| RI | 4 | 100 - 99,999 | 1, 3, 5, 7, 8, 9, 10, 11 |
| SC | 40 | 0 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13 |
| SD | 1 | 100 - 999 | 8 |
| TN | 8 | 0 - 9,999,999 | 1, 5, 7, 8, 11, 12, 13 |
| TX | 55 | 0 - 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13 |
| UT | 4 | 1,000 - 9,999 | 1, 5, 7, 11 |

Table 4-1. Facilities That Manufacture or Process Formaldehyde (continued)

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| State ^a | Number of facilities | Range of maximum amounts on site in pounds ^b | Activities and uses ^c |
|--------------------|----------------------|---|---------------------------------------|
| VA | 26 | 0 - 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 |
| VT | 1 | 100 - 999 | 2, 3, 9, 11 |
| WA | 8 | 0 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 11 |
| WI | 24 | 0 - 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 11, 13 |
| WV | 10 | 100 - 9,999,999 | 1, 3, 5, 7, 8, 10, 11 |

Source: TRI96 1998

^a Post office state abbreviations used

^b Range represents maximum amounts on site reported by facilities in each state

^c Activities/uses:

- | | |
|--------------------------|-----------------------------|
| 1. Produce | 8. Formulation component |
| 2. Import | 9. Article component |
| 3. Onsite use/processing | 10. Repackaging |
| 4. Sale/distribution | 11. Chemical processing aid |
| 5. Byproduct | 12. Manufacturing aid |
| 6. Impurity | 13. Ancillary/other uses |
| 7. Reactant | |

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Table 4-2. U.S. Formaldehyde Capacity and Production

| Year | Capacity (10 ³ tons/year) | Production volume (10 ³ tons/year) |
|------|---|--|
| 1960 | 1,111 | 848 |
| 1965 | 1,613 | 1,409 |
| 1970 | Not available | 2,008 |
| 1975 | 3,803 | 2,067 |
| 1977 | 4,005 | 2,742 |
| 1978 | 4,086 | 2,948 |
| 1982 | Not available | 2,185 |
| 1986 | Not available | 2,517 |
| 1990 | Not available | 3,048 |

Source: Gerberich et al. 1980; data for 1982, 1986, and 1990 are from IARC 1995.

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4.2 IMPORT/EXPORT

The Chemical Marketing Reporter (CMR) reported that 140 million pounds of formaldehyde were imported into the United States in 1997. In 1994, import and export volumes were 87 and 25 million pounds, respectively (Anonymous 1995b). The export volume for the same year was reported as 25 million pounds (Anonymous 1998).

4.3 USE

Formaldehyde has been used for many years in consumer goods to deter spoilage caused by microbial contamination (WHO 1989). It has been used as a preservative in household cleaning agents, dish-washing liquids, fabric softeners, shoe-care agents, car shampoos and waxes, and carpet-cleaning agents (WHO 1989). Generally, the formaldehyde content in these products is less than 1% (WHO 1989).

Formaldehyde is used as a chemical intermediate in the manufacture of a large variety of organic compounds, ranging from amino and phenolic resins to slow release fertilizers (Gerberich et al. 1980). Table 4-3 shows the distribution of formaldehyde use for select periods between 1963 and 1977. The demand for formaldehyde in North America was 11.6 billion pounds in 1995, a slight increase from the 11.3 billion pounds reported for 1994 (Anonymous 1995b). These figures include the import and export volumes discussed in Section 4.2. The demand for formaldehyde will continue to track the demand in the housing industry and the various board products used in residential construction and furniture (Anonymous 1998). The most prominent use of formaldehyde in the United States is manufacturing urea-formaldehyde resins; 23% of the annual capacity is used in this market (Anonymous 1998). In 1993, the urea-formaldehyde resins market was described as being mature. Approximately 95% of the particle board products manufactured are based on urea-formaldehyde resins; the remainder are based on phenolic-resins (Gerberich et al. 1980). The market's average annual growth rate of 1–1.5% is projected to continue through 1997 (Anonymous 1993). Urea formaldehyde resins are also used as urea formaldehyde foam insulation or as reinforcing foams in the insulation of buildings and in mining, where hollow areas are filled with the foam (WHO 1989). Anonymous (1993) also reports that the fastest growing formaldehyde market in the United States is in the production of acetylenic chemicals and methylene diisocyanate (MDI). The most recent breakdown found for formaldehyde use is the following: urea-formaldehyde, 23%; phenolic resins, 19%; acetylenic chemicals, 12%; polyacetal resins, 11%; MDI, 6%; pentaerythritol, 5%; urea-formaldehyde concentrates, 4%; hexamethylenetetramine

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**Table 4-3. Distribution of Formaldehyde Production
According to Uses in the United States**

| | Percentage of consumption | | | | |
|----------------------------|---------------------------|------|------|------|---------------|
| | 1963 | 1969 | 1972 | 1975 | 1977 |
| Phenol-formaldehyde resins | 22 | 22 | 26 | 22 | 25 |
| Urea-formaldehyde resins | 21 | 25 | 26 | 25 | 25 |
| Acetal resins | 4 | 6 | 7 | 7 | 9 |
| Acetylenics | Not available | 2 | 4 | 7 | 6 |
| Melamine resins | 6 | 7 | 6 | 3 | 5 |
| Pentaerythritol | 9 | 7 | 7 | 7 | 5 |
| Hexamethylenetetramine | 6 | 9 | 6 | 5 | 5 |
| Fertilizer | 3 | 3 | 4 | 4 | Not available |
| Trimethylolpropane | Not available | 1.1 | 1.5 | 1.5 | Not available |
| Ethylene glycol | 12 | 4 | 0 | 0 | 0 |
| Miscellaneous | 17 | 14 | 12 | 18 | 20 |

Source: Gerberich et al. 1980

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(HMTA), 4%; melamine resins, 4%; and miscellaneous (including chelating agents, trimethylolpropane, pyridine chemicals, nitroparaffin derivatives, textiles treating, and trimethylolethane), 12% (Anonymous 1998).

The use of formaldehyde in the manufacture of chelating agents represents a modest but important market for formaldehyde. Approximately 75% of the formaldehyde used in the synthesis of chelating agents is consumed in the manufacture of ethylenediaminetetraacetic acid (EDTA). The remaining 25% is used to produce nitrilotriacetic acid (NTA), primarily for export (Gerberich et al. 1980).

Products manufactured using organic compounds, where formaldehyde is used as a chemical intermediate in their production, include: plywood adhesives, abrasive materials, insulation, foundry binders, and brake linings made from phenolic resins; surface coatings, molding compounds, laminates, and wood adhesives made from melamine resins; phenolic thermosetting, resins curing agents, and explosives made from hexamethylenetetramine; urethanes, lubricants, alkyd resins, and multifunctional acrylates made from trimethylolpropane; plumbing components from polyacetal resins; and controlled-release fertilizers made from urea formaldehyde concentrates (WHO 1989). Polyacetal plastics produced by polymerization of formaldehyde are incorporated into automobiles to reduce weight and fuel consumption. They are also used in the manufacture of functional components of audio and video electronics equipment (IARC 1995).

Formaldehyde solutions have also been used for disinfecting dwellings, ships, storage houses, utensils, and clothing (Windholz et al. 1983). Solutions containing 2–8% formaldehyde have been used as germicides to disinfect inanimate objects (HSDB 1999). Formaldehyde is used as a tissue preservative and disinfectant in embalming fluids.

In the agricultural industry, formaldehyde has been used as a fumigant, as a preventative for mildew and spelt in wheat, and for rot in oats (HSDB 1999). It has been used as a preplanting soil sterilant in mushroom houses (HSDB 1999). Formaldehyde has been used as a germicide and fungicide for plants and vegetables; as an insecticide for destroying flies and other insects; and in the manufacture of slow-release fertilizers. Approximately 80% of the slow-release fertilizer market is based on urea-formaldehyde-containing products (HSDB 1999). During the early 1980s, seed treatments, starch formulations, and paper production were included among the minor uses for formaldehyde (IARC 1982). Formaldehyde continues to be used in the manufacture of glass mirrors, explosives, artificial silk, and

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dyes; for waterproofing fabrics; for preserving and coagulating rubber latex; and for tanning and preserving animal hides (Windholz et al. 1983). In the photography industry, formaldehyde has been used for hardening gelatin plates and papers, toning gelatin-chloride papers, and for chrome printing and developing (Windholz et al. 1983).

Formaldehyde is used as an antimicrobial agent in many cosmetics products, including soaps, shampoos, hair preparations, deodorants, lotions, make-up, mouthwashes, and nail products (IARC 1995).

Formaldehyde is incompatible with ammonia; alkalies; tannin; iron preparations; and salts of copper, iron, silver, potassium permanganate, iodine, and peroxide (Windholz et al. 1983). When it is used as a preservative in shampoos, formaldehyde may interact unfavorably with both fragrance components and color additives (HSDB 1999). Some cosmetics have reportedly contained 0.6% formaldehyde, while concentrations as high as 4.5% have been detected in nail hardeners. Formaldehyde concentrations in dry-skin lotions, creme rinses, and bubble bath oils have reportedly ranged from 0.4 to 0.5% (WHO 1989). Formaldehyde has also been found in sun-tan lotion and hand cream (Bartnik et al. 1985), bath products, mascara and eye make-up, cuticle softeners, nail creams, vaginal deodorants, and shaving creams. Trace amounts of formaldehyde found in cosmetic products could also result from its use as a disinfectant of the manufacturing equipment (WHO 1989).

Compared to its use in product manufacturing, the use of formaldehyde in the medical fields is relatively small. Consumption in this area averages approximately 1.5% of the total production volume (WHO 1989). Some of the earlier, minor, medicinal applications for formaldehyde included its use during vasectomies, as a foot antiperspirant or as a preservative in such products, as a treatment for athlete's foot, and as a sterilant for *echinococcus* cysts prior to their surgical removal (IARC 1982). In veterinary medicine, formaldehyde has been used therapeutically as an antiseptic and as a fumigant. It has also been used to treat tympany, diarrhea, mastitis, pneumonia, and internal bleeding in animals (Windholz et al. 1983). In animal nutrition, formaldehyde is used to protect dietary protein in ruminants. It is used as a food additive to improve the handling characteristics of animal fat and oilseed cattle food mixtures (WHO 1989).

Other industries using formaldehyde in their processes include the sugar industry where formaldehyde is used as an infection inhibitor in producing juices; the rubber industry where it is used as a biocide for latex, an adhesive additive, and an anti-oxidizer additive for synthetic rubber; and the food industry where it is used for preserving dried foods, disinfecting containers, preserving fish and certain oils and

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fats, and modifying starch for cold swelling (WHO 1989). It has been used as a bacteriostatic agent in some foods, such as cheese (IARC 1995). In the petroleum industry, formaldehyde is used as a biocide in oil well-drilling fluids and as an auxiliary agent in refining. Formaldehyde has been used as an anti-corrosive agent for metals. In the plastics industry, for the preparations of phenol, urea, and melamine resins, where the presence of water could interfere with the production process, paraformaldehyde may be used in place of aqueous formaldehyde solutions (IARC 1995). In addition to its use in selected pesticide applications, paraformaldehyde has also been used in making varnish resins, thermosets, and foundry resins, the synthesis of chemical and pharmaceutical products, the preparation of disinfectants and deodorants, and the production of textile products (IARC 1995). Formaldehyde was used in the textile industry as early as the 1950s when formaldehyde-based resins were initially used to produce crease-resistant fabrics. Postproduction analysis indicated that these early resins contained a substantial amount of extractable formaldehyde (more than 0.4% by weight of the fabric) (IARC 1995). With the introduction of new resins and other process modifications in the 1970s, the level of extractable formaldehyde in crease-resistant fabrics gradually decreased to 0.01–0.02% (IARC 1995).

4.4 DISPOSAL

The regulations governing the treatment and disposal of formaldehyde-containing wastes are detailed in Chapter 7. Formaldehyde manufacturing is listed among the regulations for commodity organic chemicals for which process waste water discharges are regulated by the Clean Water Effluent Guidelines given in Title 40, Section 414, of the Code of Federal Regulations (CFR) (EPA 1987a).

The Resource Conservation and Recovery Act (RCRA) identifies formaldehyde as a toxic waste if it is discarded as a commercial product, manufacturing intermediate, or off-specification commercial chemical product (EPA 1980). Formaldehyde is identified as the hazardous constituent in waste assigned the hazardous waste number U122 under RCRA (EPA 1988b). Formaldehyde is also among the chemicals that are on the listed hazardous waste identified by the #K010 (EPA 1981). The technology-based standards given in 40 CFR 268.42 identify wet air oxidation, chemical, or electrolytic oxidation followed by carbon adsorption, or incineration as the treatment process for waste waters containing formaldehyde (EPA 1986b). For nonwaste waters, the regulations suggest that the materials be used as fuel substitutes in hazardous waste disposal units (EPA 1986b). When formaldehyde is disposed of in a rotary kiln incinerator, the unit should be operated at a temperature range of 820–1,600 EC (HSDB 1999). Disposal of formaldehyde in a fluidized bed incinerator requires an operating temperature range

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of 450–980 EC (HSDB 1999). The residence time identified for incineration is a matter of seconds. Evaporation and alkaline hydrolysis are not recommended for the disposal of formaldehyde or formaldehyde-containing wastes (IRPTC 1985).

