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

5.1 PRODUCTION

Prior to World War II, multimillion pound quantities of cresols were produced annually in the United States, and domestic production and sales of cresols have steadily increased over the past several decades. In 1987, the national capacity for producing cresylics (compounds relating to cresols) was 208 million pounds per year (CMR 2004). More recent data indicate that the total U.S. production capacity for cresols, xylenols, and cresylics is approximately 470 million pounds (CMR 2004). Overall demand for cresols, xylenols, and cresylics was 340 million pounds in 2002, 365 million pounds in 2003, and is projected to increase to 385 million pounds by 2007 (CMR 2004). Information regarding the production levels of individual isomers and specific mixtures was unavailable. These production totals include data on the manufacture of cresylic acid and exclude information on cresol production by coke and gas-retort ovens. The commercial mixture of cresol isomers, in which the *m*-isomer predominates and contains <5% phenol, is sometimes referred to as cresylic acid (Windholz et al. 1983). However, cresylic acids generally are composed of cresols, phenols, and xylenols; they are defined as those mixtures in which over 50% will boil at temperatures above 204 °C (Lewis 2001).

Cresols are used widely by industry. Information from the EPA's Toxic Release Inventory (TRI) on facilities that either manufactured or processed *o*-, *m*-, *p*-, or mixed isomers of cresols in 2004 is outlined in Tables 5-1 through 5-4, respectively. The TRI data should be used with caution since only certain types of facilities were required to report. This is not an exhaustive list. According to the 2005 Directory of Chemical Producers (SRI 2005), cresols are currently produced by five manufacturers in New York, Pennsylvania, Illinois, and Texas. Stanford Research Institute (SRI 2005) data for individual isomers and the mixture *o*-, *p*-, and *m*-isomers are included in Table 5-5.

The oldest cresol production method used in the United States is through the recovery of fractional distillates from coal tars. Most domestic cresols are formed via catalytic and thermal cracking of naphtha fractions during petroleum distillation. Since 1965, quantities of coal tar and petroleum isolates have been insufficient to meet the rising demand. Consequently, several processes for the manufacture of the various isomers have been developed. One General Electric facility produces *o*-cresol at an annual capacity of 10,000 tons by the methylation of phenol in the presence of catalysts. The Sherman-Williams Company uses the toluene sulfonation process and maintains an annual capacity for *p*-cresol of

Table 5-1. Facilities that Produce, Process, or Use *o*-Cresol

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	4	0	999,999	1, 6, 9, 12, 13, 14
AR	1	1,000	9,999	12
CA	8	1,000	999,999	2, 3, 6, 7
DE	1	10,000	99,999	6
GA	4	100	99,999	2, 3, 6, 7, 8
IL	12	100	9,999,999	1, 2, 3, 4, 6, 7, 12
IN	8	100	99,999	7, 8, 10, 11, 12
KS	1	100	999	12
KY	10	100	999,999	2, 3, 6, 7, 8, 10, 11, 12
LA	7	1,000	9,999,999	1, 2, 3, 6, 12, 13
MI	1	1,000	9,999	7
MO	4	100	99,999	9, 12
MS	1	10,000	99,999	1, 3, 6
NE	2	1,000	99,999	12
NJ	6	1,000	999,999	6, 7, 9, 12
NY	9	1,000	999,999	1, 5, 6, 7, 13
OH	9	0	999,999	1, 3, 6, 7, 8, 12
OK	2	100	999	6, 7
PA	6	1,000	999,999	1, 4, 8, 9, 13
RI	4	1,000	99,999	6, 7, 8
SC	1	10,000	99,999	12
TN	8	100	9,999,999	2, 3, 6, 8, 9, 11, 12
TX	26	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13
UT	2	10,000	999,999	1, 3, 4, 5, 6
WI	4	1,000	999,999	6, 7

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses
14. Process Impurity

Source: TRI04 2006 (Data are from 2004)

Table 5-2. Facilities that Produce, Process, or Use *m*-Cresol

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AR	2	100	9,999	12
CA	3	0	999,999	4, 7
FL	1	1,000	9,999	7, 8
GA	3	10,000	999,999	2, 3, 6, 7, 10, 11
IL	6	100	99,999	1, 5, 6, 10, 12, 13
IN	14	100	999,999	2, 3, 6, 7, 8, 10, 11, 12
KS	3	1,000	99,999	6, 12
KY	10	1,000	999,999	1, 2, 3, 6, 8, 10, 11, 12
LA	1	1,000	9,999	6
MA	2	1,000	99,999	6, 11
MI	2	10,000	99,999	6
MO	8	100	999,999	1, 4, 8, 9, 10, 11, 12
MS	4	100	999,999	6, 10
NC	3	0	99,999	6, 10, 11, 12
NJ	1	1,000	9,999	12
NY	6	10,000	999,999	1, 5, 6, 9, 10, 13
OH	6	100	999,999	1, 3, 5, 6, 7, 12
OK	4	100	99,999	6, 7, 10
PA	8	1,000	999,999	1, 4, 6, 8, 9, 13
RI	3	10,000	99,999	6, 7, 8
SC	4	10,000	9,999,999	6, 12
TN	9	0	9,999,999	6, 7, 8, 9, 11, 12
TX	18	0	9,999,999	1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 14
WI	1	10,000	99,999	7
WV	1	100,000	999,999	6

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses
14. Process Impurity

Source: TRI04 2006 (Data are from 2004)

Table 5-3. Facilities that Produce, Process, or Use *p*-Cresol

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	5	100	999,999	1, 2, 6, 12, 13, 14
AR	3	0	9,999	12
AZ	1	1,000	9,999	7
CA	3	1,000	9,999,999	1, 3, 6, 7
CT	2	10,000	999,999	6
GA	1	10,000	99,999	2, 3, 6, 7
IL	7	1,000	9,999,999	1, 3, 4, 6, 7, 10, 12
IN	11	0	999,999	7, 8, 10, 11, 12
KS	5	100	999,999	2, 3, 6, 8, 12
KY	9	1,000	999,999	2, 3, 6, 8, 10, 11, 12
LA	12	0	999,999	1, 2, 3, 4, 5, 6, 12
MO	8	100	999,999	8, 10, 11, 12
MS	1	1,000	9,999	10
NC	4	1,000	99,999	6, 8, 10, 12
NE	2	1,000	99,999	12
NJ	6	1,000	999,999	2, 3, 6, 12
NY	3	1,000	999,999	1, 5, 6, 13
OH	5	1,000	999,999	6, 12
OK	3	100	99,999	6, 7, 10
PA	8	100	999,999	1, 4, 6, 8, 9, 12, 13
RI	2	10,000	99,999	6, 8
SC	3	10,000	999,999	6, 12
TN	8	0	49,999,999	7, 8, 9, 11, 12
TX	17	0	9,999,999	1, 2, 4, 5, 6, 8, 11, 12, 13, 14
WV	1	100,000	999,999	6

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses
14. Process Impurity

Source: TRI04 2006 (Data are from 2004)

Table 5-4. Facilities that Produce, Process, or Use Cresol (Mixed Isomers)

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	24	0	999,999	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 14
AR	17	0	99,999	1, 2, 3, 5, 6, 7, 8, 9, 12, 13
CA	40	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
CT	6	100	9,999	1, 5, 7, 10, 11
DE	5	10,000	99,999	1, 3, 5, 6, 7, 12
FL	8	0	99,999	1, 5, 7, 8, 11, 12, 13
GA	24	0	999,999	1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13
IA	1	100	999	7
ID	5	0	999	1, 5, 13
IL	34	1,000	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
IN	46	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
KS	8	1,000	999,999	1, 4, 5, 7, 12, 13
KY	27	0	9,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
LA	47	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
MA	3	1,000	99,999	2, 3, 6, 10, 11
MD	7	0	999,999	1, 5, 12, 13
ME	1	0	99	1, 13
MI	16	0	999,999	1, 4, 5, 6, 7, 12, 13
MN	6	100	99,999	1, 2, 3, 4, 5, 6, 9, 11, 12, 13
MO	23	0	999,999	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14
MS	23	0	999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
NC	18	0	999,999	1, 2, 3, 5, 6, 7, 10, 11, 12, 13
NE	2	1,000	99,999	12
NH	6	1,000	999,999	2, 3, 7, 10, 11
NJ	17	1,000	999,999	2, 3, 4, 6, 7, 9, 12
NM	3	10,000	999,999	1, 2, 3, 7, 10, 12, 13
NV	1	10,000	99,999	12
NY	20	100	9,999,999	1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 13
OH	29	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	4	10,000	999,999	1, 3, 4, 6, 7, 9, 10, 13
OR	6	0	9,999,999	1, 2, 3, 5, 7, 9
PA	26	0	9,999,999	1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
PR	1	100	999	2, 3, 4, 7, 9
RI	1	10,000	99,999	6
SC	13	0	999,999	1, 2, 3, 5, 6, 7, 12, 13
TN	14	0	999,999	1, 5, 6, 7, 9, 10, 11, 12, 13, 14
TX	66	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	12	1,000	999,999	1, 3, 4, 5, 6, 7, 9, 10, 12, 13

Table 5-4. Facilities that Produce, Process, or Use Cresol (Mixed Isomers)

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
VA	10	0	999,999	1, 5, 10, 11, 12
VI	1	100	999	2, 3, 4, 7, 9
WA	23	0	9,999,999	1, 2, 3, 4, 5, 7, 12, 13, 14
WI	6	0	999,999	1, 5, 6, 13
WV	12	0	9,999,999	1, 2, 3, 4, 5, 6, 8, 12, 13
WY	5	0	99,999	1, 3, 4, 5, 6, 7, 13

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses
14. Process Impurity

Source: TRI04 2006 (Data are from 2004)

Table 5-5. Current U.S. Producers of Cresol

Company	Location[a]	Isomer
Merisol Antioxidants, LLC	Oil City, Pennsylvania	*m*-cresol
Merisol USA, LLC	Houston, Texas	*m*-cresol *m/p*-cresol *o*-cresol *p*-cresol (*o,m,p*)-cresol
General Electric Company	Selkirk, New York	*o*-cresol
PMC Specialties Group, Inc.	Chicago, Illinois	*o*-cresol
Bell Flavors and Fragrances, Inc.	Northbrook, Illinois	*p*-cresol

Source: Derived from SRI 2005

15,000 tons. The Hercules Powder Company produced *p*-cresol until 1972 by the cymene-cresol process. This method is capable of producing *p*- or *m*-cresol from the corresponding cymene (isopropyltoluene). Alkaline chlorotoluene hydrolysis is used to formulate a cresol mixture with a high *m*-cresol content. However, information pertaining to domestic use of this process was unavailable (Fiege and Bayer 1987).

5.2 IMPORT/EXPORT

In 2005, 1,098,386 kg of cresol and cresol salts were imported from other countries netting $2,754,000 (OTII 2005). The largest exporters of cresol and cresol salts to the United States were Spain and the United Kingdom with export amounts for 2005 of 165,040 and 822,170 kg, respectively. Money spent on the import of cresols and their salts to the United States has increased from $698,000 in 2003 to $1,363,000 in 2004 and $2,754,000 in 2005 (USITC 2006).

In 2005, 20,303,166 kg of cresol and cresol salts were exported to other countries netting $47,280,000 (OTII 2005). The largest importers of cresol and cresol salts from the United States were China, Japan, the Netherlands, and the United Kingdom with export values for 2005 of 3,200,351; 2,436,843; 6,317,298; and 6,140,655 kg, respectively. Money from export of cresols and their salts from the United States has increased from $29,736,000 in 2003 to $38,534,000 in 2004 and $47,280,000 in 2005 (USITC 2006).

5.3 USE

A considerable amount of *o*-cresol is used directly as either a solvent or disinfectant. *o*-Cresol is also used as a chemical intermediate for a wide variety of products. *o*-Cresol is hydrogenated to 2-methylcyclohexanol or 2-methylcyclohexanone, which are also solvents. Coumarin is made from the carbonate ester of *o*-cresol and is a deodorizing and odor-enhancing agent that also has pharmaceutical applications (Lewis 2001). Alkylation of *o*-cresol with propene gives 3-isopropyl-6-methylphenol (carvacrol). Carvacrol is used as an antiseptic and in fragrances (Windholz et al. 1983). *o*-Cresol also serves as an intermediate for the production of various antioxidants. Several dye intermediates are manufactured from *o*-cresol. *o*-Cresotinic acid, produced from *o*-cresol via the Kolbe synthesis, is used as a dye, a dye intermediate, and a pharmaceutical intermediate. Recently, an increasing proportion of *o*-cresol has been devoted to the formulation of epoxy-*o*-cresol novolak (ECN) resins. ECN resins are sealing materials for integrated circuits (silicon chips). *o*-Cresol is also used as an additive to phenol-formaldehyde resins. The manufacture of certain herbicides and pesticides, including 4-chloro-2-methyl-

phenoxyacetic acid (MCPA), 2-(4-chloro-2-methylphenoxy)-propionic acid (MCPP), γ(4-chloro-2-methylphenoxy)-butyric acid (MCPB), and 4,6-dinitro-*o*-cresol (DNOC), is also dependent upon *o*-cresol (Fiege and Bayer 1987).

p-Cresol is used largely in the formulation of antioxidants such as 2,6-di-tert-butyl-*p*-cresol (BHT), 2,6-dicyclopentyl-*p*-cresol, 2,2'-methylene- or 2,2'-thiodiphenols, and Tinuvin 326. Tinuvin 326 absorbs ultraviolet (UV) light and is added to polyethylene and polypropylene films and coatings for protection against photodegradation. *p*-Cresol also has many applications in the fragrance and dye industries (O'Neil et al. 2001). Synthetic food flavors also contain *p*-cresol (Lewis 2001). *p*-Cresol carboxylic acid esters and anisaldehyde are used in perfumes (Lewis 2001). The latter is made from *p*-cresol methyl ether (Fiege and Bayer 1987).

m-Cresol, either pure or mixed with *p*-cresol, is important in the production of contact herbicides such as O,O-dimethyl-O-(3-methyl-4-nitrophenyl)thionophosphoric acid (fenitrothion, Follithion, and Sumithion) and O,O-dimethyl-O-(3-methyl-4-methylthiophenyl)thionophosphoric acid ester (fenthion, Baytex, and Lebaycid) (Fiege and Bayer 1987). *m*-Cresol is also a precursor to the pyrethroid insecticides. Furthermore, many flavor and fragrance compounds, such as (-)-methanol and musk ambrette, are derived from *m*-cresol. Several important antioxidants are produced from *m*-cresol. *m*-Cresol is also used to manufacture an explosive, 2,4,6-nitro-*m*-cresol.

Mixtures of *m*- and *p*-cresol often serve as disinfectants and preservatives (O'Neil et al. 2001). Because cresols are bactericides and fungicides, they are added to soaps as disinfectants. Crude cresols are used as wood preservatives. Tricresyl phosphate and diphenyl cresyl phosphate are produced from *m*- and *p*-cresol mixtures. These neutral phosphoric acid esters are used as flame-retardant plasticizers for polyvinylchloride (PVC) and other plastics, fire-resistant hydraulic fluids, additives for lubricants, and air filter oils. Cresol mixtures condensed with formaldehyde are important for modifying phenolic resins. However, the *m*-isomer content is critical to the mixture because *m*-cresol is the most reactive of the three isomers. Cresols are also used in paints and textiles. Mixtures of cresols are used as solvents for synthetic resin coatings such as wire enamels, metal degreasers, cutting oils, and agents to remove carbon deposits from combustion engines. Other uses of cresol mixtures include ore flotation and fiber treatment (Fiege and Bayer 1987; Windholz et al. 1983).

5.4 DISPOSAL

Cresols may be disposed of by landfill, land applications, biological waste water treatment, or incineration. In an activated sludge system, cresols exhibit a 96% reduction of the chemical oxygen demand and a biodegradation rate of 55 mg of oxygen/g/hour. Cresols may be disposed of in a rotary kiln incinerator with a temperature range of 820–1,600 °C and a residence time of seconds. Cresols may also be disposed of in a fluidized bed incinerator with a temperature range of 450–980 °C and a residence time of seconds (HSDB 2006).