

## 6. POTENTIAL FOR HUMAN EXPOSURE

### 6.1 OVERVIEW

Phenol has been identified in at least 595 of the 1,678 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2006). However, the number of sites evaluated for phenol is not known. The frequency of these sites can be seen in Figure 6-1. Of these sites, 589 are located within the United States and 4 are located in the Commonwealth of Puerto Rico (not shown) and 2 are located in the Virgin Islands (not shown).

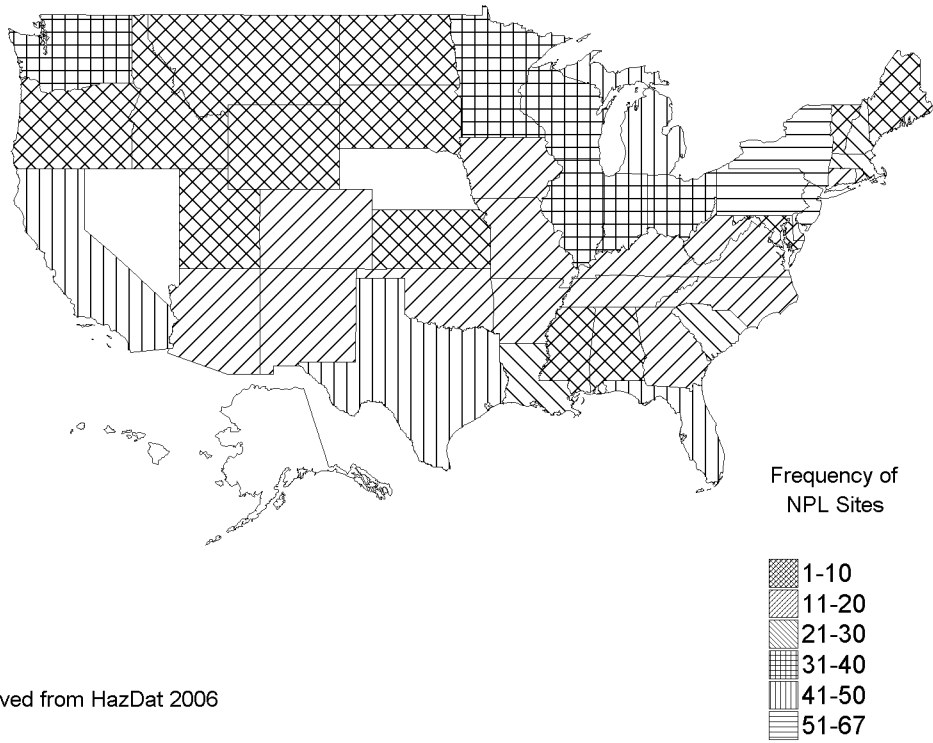
Phenol is released to the air and water as a result of its manufacture, its use in phenolic resins, and organic synthesis (Wallace et al. 1996). Phenol is found in petroleum products such as coal tar, and creosote and can be released by combustion of wood and auto exhaust (Wallace et al. 1996). Phenol is also produced by the natural degradation of organic wastes including benzene. Phenol is a major metabolite of benzene (Rothman et al. 1998), which is found extensively in the environment (Agency for Toxic Substances and Disease Registry 2006), therefore, phenol may be formed in the environment as a result of the natural degradation of benzene.

Phenol mainly enters the water from industrial effluent discharges. Phenol is degraded rapidly in air by gas-phase hydroxyl radical reaction (estimated half-life 14.6 hours), but may persist in water for a somewhat longer period. Half-lives for biodegradation range from <1 day in samples of lake water to 9 days in estuarine water; a typical half-life for photooxidation by photochemically produced peroxy radicals is approximately 19 hours. In soil, phenol will generally biodegrade rapidly; however, biodegradation of phenol in water or soil may be hindered or precluded by the presence of high, toxic concentrations of phenol or other chemicals, or by other factors such as a lack of nutrients or microorganisms capable of degrading phenol. If biodegradation is sufficiently slow, phenol in sunlit water will undergo photooxidation with photochemically produced peroxy radicals, and phenol in soil will leach to groundwater. Phenol may remain in air, water, and soil for much longer periods if it is continually or consistently released to these media from point sources. Since plants can metabolize phenol readily, exposure through eating food derived from plants grown in phenol-containing soil is probably minimal.

Phenol has been measured in effluents (up to 53 ppm), ambient water (1.5–>100 ppb), drinking water (not quantified), groundwater (1.9–>10 ppb), rain (0.075–1.2 ppb), sediment (>10 ppb), and ambient air (0.03–44 ppb). Occupational exposures occur through inhalation and dermal exposure; air concentrations

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**Figure 6-1. Frequency of NPL Sites with Phenol Contamination**



Derived from HazDat 2006

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monitored in various workplaces range from 0.1 to 12.5 mg/m<sup>3</sup> (0.03–32 ppm). Occupational as well as consumer exposure may also occur through dermal contact with phenol or phenol-containing products.

## 6.2 RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ 10 or more full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes  $\geq 25,000$  pounds of any TRI chemical or otherwise uses  $> 10,000$  pounds of a TRI chemical in a calendar year (EPA 2005).

### 6.2.1 Air

Estimated releases of 7.6 million pounds (~3,480 metric tons) of phenol to the atmosphere from 677 domestic manufacturing and processing facilities in 2004, accounted for about 64% of the estimated total environmental releases from facilities required to report to the TRI (TRI05 2007). These releases are summarized in Table 6-1.

During manufacturing, phenol is released primarily to the atmosphere from storage tank vents and during transport loading (EPA 1979c). Other major sources of release to the atmosphere are residential wood burning and automobile exhaust (EPA 1981a). Volatilization from environmental waters and soils has been shown to be a slow process (see Section 6.3.1) and is not expected to be a significant source of atmospheric phenol. Phenol is released into the atmosphere from industrial combustion processes. For example, phenol has been detected at a concentration of 0.36 ppb in the emissions of a waste incinerator plant in Germany (Jay and Stieglitz 1995). In Brazil, an estimated 64 kg/year of phenol is released to the urban areas located near coal-fired power stations, indicating that people who live near coal-fired power stations may have an increased risk of exposure to phenol (Moreira dos Santos et al. 2004). Phenol is also

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**Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Phenol<sup>a</sup>**

State <sup>c</sup>	RF <sup>d</sup>	Reported amounts released in pounds per year <sup>b</sup>								
		Air <sup>e</sup>	Water <sup>f</sup>	UI <sup>g</sup>	Land <sup>h</sup>	Other <sup>i</sup>	Total release			
							On-site <sup>j</sup>	Off-site <sup>k</sup>	On- and off-site	
AL	33	407,745	278		0	8,213	0	408,261	7,975	416,236
AR	15	53,803	136		0	4,781	0	54,241	4,479	58,720
AZ	2	5,499	No data		0	100	0	5,499	100	5,599
CA	33	100,135	1,974		0	5,544	305	102,117	5,841	107,958
CO	2	32	No data		0	0	0	32	0	32
CT	4	5,631	No data		0	649	728	5,631	1,377	7,008
DE	2	160	44,595		0	0	0	44,755	0	44,755
FL	12	114,230	950		0	91	0	115,272	0	115,272
GA	25	146,687	518		0	1,468	2,102	147,242	3,533	150,775
IA	5	17,126	36		0	100,501	0	17,162	100,501	117,663
ID	2	1,005	5		0	4,428	0	1,010	4,428	5,438
IL	28	614,954	602		0	50,925	251	616,526	50,206	666,732
IN	32	391,396	3,660	100,000		35,975	5	495,190	35,845	531,035
KS	7	76,565	54		0	5,869	1,829	76,637	7,680	84,317
KY	13	108,867	809		0	56,542	0	109,676	56,542	166,218
LA	36	124,638	15,173	150,002		10,660	120	295,401	5,192	300,593
MA	6	15,108	No data		0	803	0	15,108	803	15,911
MD	2	13,004	No data		0	0	0	13,004	0	13,004
ME	5	25,852	15		0	906	0	25,893	880	26,773
MI	29	121,520	660	19		78,038	44,762	122,188	122,810	244,998
MN	8	55,892	150		0	98	3	56,117	26	56,143
MO	9	15,024	0		0	0	0	15,024	0	15,024
MS	12	67,983	207		0	1,238	0	68,190	1,238	69,428
MT	5	3,724	25		0	23	0	3,772	0	3,772
NC	23	186,812	311		0	164,098	0	187,269	163,952	351,221
ND	1	220	49	2,100		0	0	2,369	0	2,369
NE	4	888	No data		0	147	0	896	139	1,035
NH	2	6,203	No data		0	1	0	6,203	1	6,204
NJ	10	6,218	1,828		0	10,327	0	16,022	2,351	18,373
NM	1	1,078	No data		0	0	0	1,078	0	1,078
NY	23	57,689	62		0	22,704	56,518	57,777	79,196	136,973
OH	45	522,126	1,219	34		119,210	807	528,880	114,516	643,397
OK	10	21,713	558		0	17,557	4,855	38,249	6,434	44,683
OR	22	186,431	189		0	12,935	3,453	187,736	15,272	203,008
PA	29	424,309	9,699		0	4,994	2,093	434,776	6,319	441,096
PR	3	4,974	No data		0	4,561	0	4,974	4,561	9,535
RI	1	724	No data		0	0	0	724	0	724

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		Air <sup>e</sup>	Water <sup>f</sup>	UI <sup>g</sup>	Land <sup>h</sup>	Other <sup>i</sup>	Total release		
							On-site <sup>j</sup>	Off-site <sup>k</sup>	On- and off-site
SC	20	93,387	1,284	0	148,473	0	115,489	127,656	243,145
TN	15	81,725	305	0	2,006	45	82,439	1,642	84,081
TX	75	233,116	7,659	1,225,465	99,083	118	1,416,533	148,909	1,565,442
UT	3	31,100	No data	0	7,600	0	38,700	0	38,700
VA	12	56,625	299	0	31,225	750	87,264	1,635	88,899
VI	1	78,848	612	0	1	0	79,460	1	79,461
WA	19	127,933	5,382	0	427	181	133,355	568	133,923
WI	23	305,630	55	0	27,762	30	305,685	27,792	333,477
WV	6	20,279	188	0	69	44	20,475	105	20,580
WY	2	750	No data	0	0	0	750	0	750
<b>Total</b>	<b>677</b>	<b>4,935,360</b>	<b>99,546</b>	<b>1,477,621</b>	<b>1,040,033</b>	<b>118,999</b>	<b>6,561,054</b>	<b>1,110,505</b>	<b>7,671,559</b>

<sup>a</sup>The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.

<sup>b</sup>Data in TRI are maximum amounts released by each facility.

<sup>c</sup>Post office state abbreviations are used.

<sup>d</sup>Number of reporting facilities.

<sup>e</sup>The sum of fugitive and point source releases are included in releases to air by a given facility.

<sup>f</sup>Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).

<sup>g</sup>Class I wells, Class II-V wells, and underground injection.

<sup>h</sup>Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other on-site landfills, land treatment, surface impoundments, other land disposal, other landfills.

<sup>i</sup>Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown

<sup>j</sup>The sum of all releases of the chemical to air, land, water, and underground injection wells.

<sup>k</sup>Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI05 2007 (Data are from 2005)

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found in cigarette smoke and in plastics (Graedel 1978), but no data are available to determine the extent of exposure to phenol from these sources.

### 6.2.2 Water

Estimated releases of 99,546 pounds (~45 metric tons) of phenol to surface water from 677 domestic manufacturing and processing facilities in 2005, accounted for about 0.1% of the estimated total environmental releases from facilities required to report to the TRI (TRI05 2007). These releases are summarized in Table 6-1.

The most common anthropogenic sources of phenol in natural water include coal tar (Thurman 1982) and waste water from manufacturing industries such as resins, plastics, fibers, adhesives, iron, steel, aluminum, leather, rubber (EPA 1981b), and effluents from synthetic fuel manufacturing (Parkhurst et al. 1979). Phenol is also released from paper pulp mills (Keith 1976) and wood treatment facilities (Goerlitz et al. 1985). Other releases of phenol result from commercial use of phenol and phenol-containing products, including slimicides, general disinfectants (Budavari et al. 1989; Hawley 1981), and medicinal preparations such as throat lozenges, mouthwashes, gargles, and antiseptic lotions (Darisimall 2006). Two natural sources of phenol in aquatic media are animal wastes and decomposition of organic wastes (EPA 1980). As a metabolite of benzene, phenol may be released from publicly owned treatment works (POTWs) and sewage overflow. For example, it has been estimated that 3.8 kg/day of phenol are released to Newark Bay, in New Jersey, from municipal treatment facilities (Crawford et al. 1995). Phenol was detected in 2% of the effluent samples from New York City sewage waste facilities collected during 1989 to 1993 at concentrations of 6–310 g/L (Stubin et al. 1996). Because it is a metabolite, phenol is likely to be found in other sewage and POTWs facilities. No data are available to determine the extent of exposure from these sources.

Estimated releases of 85,700 pounds (~39 metric tons) of phenol to surface water from 689 domestic manufacturing and processing facilities in 2004, accounted for about 0.1% of the estimated total environmental releases from facilities required to report to the TRI (TRI05 2007). These releases are summarized in Table 6-1.

The most common anthropogenic sources of phenol in natural water include coal tar (Thurman 1982) and waste water from manufacturing industries such as resins, plastics, fibers, adhesives, iron, steel, aluminum, leather, rubber (EPA 1981b), and effluents from synthetic fuel manufacturing (Parkhurst et al.

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### 6.2.3 Soil

Estimated releases of 1 million pounds (~472 metric tons) of phenol to soils from 689 domestic manufacturing and processing facilities in 2005, accounted for about 14% of the estimated total environmental releases from facilities required to report to the TRI (TRI05 2007). An additional 1.5 million pounds (~670 metric tons), constituting about 19% of the total environmental emissions, were released via underground injection (TRI05 2007). These releases are summarized in Table 6-1.

Phenol may be released to the soil during its manufacturing process, when spills occur during loading and transport, and when it leaches from hazardous waste sites and landfills (Xing et al. 1994). Generally, data on concentrations of phenol found in soil at sites other than hazardous waste sites are lacking. This may be due in part to a rapid rate of biodegradation and leaching (see Sections 6.3.1 and 6.3.2.3). Phenol can be expected to be found in soils that receive continuous or consistent releases from a point source. Phenol that leaches through soil to groundwater spends at least some time in that soil as it travels to the groundwater. Phenol has been found in groundwater, mainly at or near hazardous waste sites.

## 6.3 ENVIRONMENTAL FATE

### 6.3.1 Transport and Partitioning

Phenol is released into the air and discharged into water from both manufacturing and use. Based on its high water solubility (see Table 4-2) and the fact that it has been detected in rainwater, some phenol may wash out of the atmosphere; however, it is probable that only limited amounts wash out because of the short atmospheric half-life of phenol. During the day, when photochemically produced hydroxyl radical concentrations are highest in the atmosphere, very little atmospheric transport of phenol is likely to occur.

In water, neither volatilization nor sorption to sediments and suspended particulates are expected to be important transport mechanisms. Using the Henry's Law constant of  $3 \times 10^{-7}$  atm m<sup>3</sup>/mol (Gaffney et al. 1987), a volatilization half-life of 88 days was calculated for phenol evaporation from a model river 1 m deep with a current of 1 m/second, and wind velocity of 3 m/second (Lyman et al. 1982). The biological

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treatment of waste water containing phenol has shown that <1% of phenol is removed by stripping (Kincannon et al. 1983; Petrasek et al. 1983).

Phenol has been reported in sediments at levels as high as 608 ppm dry weight; however, it is not known whether the location of the site where this concentration was reported is at or near a point source of release, such as a hazardous waste dump. The concentrations of the overlying waters were not reported. The moderately low soil sorption partition coefficient (1.21–1.96) suggests that sorption to sediment is not an important transport process. There is very little sorption of phenol onto aquifer materials (Ehrlich et al. 1982), suggesting that phenol sorption to sediments may also be minimal. Based on the soil adsorption coefficient, phenol is expected to leach to groundwater; however, the rate of phenol biodegradation in the soil may be so rapid, except in cases of large releases such as spills or continuous releases such as leaching from landfill sites, that the probability of groundwater contamination may be low (Ehrlich et al. 1982). Phenol has been detected in groundwater as a result of leaching through soil from a spill of phenol (Delfino and Dube 1976), from landfill sites (Clark and Piskin 1977), and from hazardous waste sites (Plumb 1987). The sorption coefficient for phenol by soils increases with increasing soil organic matter which may indicate that soil organic matter may be the primary phenol sorbent in soil (Xing et al. 1994).

Phenol is not expected to bioconcentrate significantly in aquatic organisms. Reported log bioconcentration factors (BCF) in fish for phenol include 0.28 for goldfish, (Kobayashi et al. 1979) and 1.3 for golden orfe (Freitag et al. 1984). The highest mean level of phenol detected in bottom fish from Commencement Bay in Tacoma, Washington, was 0.14 ppm (Nicola et al. 1987). The levels of phenol in the water or sediments were not stated.

The pKa of phenol is 10 (O'Neil 2001), indicating that phenol will primarily exist as the protonated acid at environmental pH values. In alkaline soils and water, phenol will partially exist as an anion, which can affect its fate and transport processes.

Although it has been shown that plants readily uptake phenol (DOE 1987), bioaccumulation does not take place due to a high rate of respiratory decomposition of phenol to CO<sub>2</sub>.



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**6.3.2 Transformation and Degradation****6.3.2.1 Air**

The gas-phase reaction of phenol with photochemically produced hydroxyl radicals is probably a major removal mechanism in the atmosphere. An estimated half-life for phenol for this reaction is 0.61 days (EPA 1979a). The reaction of phenol with nitrate radicals during the night may constitute a significant removal process. This is based on a rate constant of  $3.8 \times 10^{-12}$  cm<sup>3</sup>/molecule second for this reaction, corresponding to a half-life of 15 minutes at an atmospheric concentration of  $2 \times 10^8$  nitrate radicals per cm<sup>3</sup> (Atkinson et al. 1987). The reaction of phenol with nitrate radicals present in the atmosphere during smog episodes may decrease the half-life of phenol in polluted atmospheres. The above data indicate that phenol has a short half-life in the atmosphere, probably <1 day. Phenol does not absorb light in the region of 290–330 nm (Lide and Milne 1994); therefore, it should not photodegrade directly in the atmosphere.

**6.3.2.2 Water**

Although phenol does not absorb light at wavelengths >290, phenols react rapidly to sunlit natural water via an indirect reaction with photochemically produced hydroxyl radicals and peroxy radicals; typical half-lives for hydroxyl and peroxy radical reactions are on the order of 100 and 19.2 hours of sunlight, respectively (Canonica et al. 1995; Mill and Mabey 1985). These reactions require dissolved natural organic materials that function as photosensitizers (Canonica et al. 1995). The estimated half-life for the reaction of phenol with photochemically produced singlet oxygen in sunlit surface waters contaminated by humic substances is 83 days (assuming Switzerland summer sunlight and a singlet oxygen concentration of  $4 \times 10^{-14}$  molar [M]) (Scully and Hoigne 1987).

Phenol is readily biodegradable in natural water, provided the concentration is not high enough to cause significant inhibition through microbial toxicity. Complete degradation in <1 day has been reported in water from three lakes; the rates of degradation were affected by the concentration of organic and inorganic nutrients in the water (Rubin and Alexander 1983). Complete removal of phenol in river water has been reported after 2 days at 20 °C and after 4 days at 4 °C (Ludzack and Ettinger 1960). The degradation of phenol is somewhat slower in salt water, and a half-life of 9 days has been reported in an estuarine river (EPA 1979b). Rapid degradation of phenol also has been reported in various sewage and water treatment processes. Removal in aerobic activated sludge reactors is frequently >90% with a retention time of 8 hours (Stover and Kincannon 1983). In aerobic reactors using municipal seed

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(conventional activated sludge organisms) and in reactors using an industrial seed (mixture of organisms), it was noted that concentrations as low as 50 mg/L inhibited organism respiration rates, but complete inhibition was not observed at concentrations as high as 200 mg/L (Davis et al. 1981). Utilization is also very high in anaerobic reactors, although acclimation periods are longer and degradation usually takes about 2 weeks (Boyd et al. 1983; Healy and Young 1978). One method of phenol breakdown is accomplished by the bacterium *Pseudomonas* sp. CF600, which uses a set of enzymes encoded by the plasmid *dmp* operon (Powlowski and Shingler 1994). The use of sequence batch reactors (SBR) in treating sludge contaminated with phenolic compounds has proven effective in breaking down the compounds biologically with no evidence of phenol volatility (Al-Harazin et al. 1991). Levels as high as a one-time treatment of 1,600 mg/L can be broken down by 75% with a 1-day retention time. Lower concentrations as high as 800 mg/L can be broken down to <0.5 mg/L with a 1-day retention time. The alga *Ochromonas danica* has also been shown to degrade phenol (Semple and Cain 1996). When grown in the dark with 0.1–1 mM phenol as the sole carbon source, phenol was removed within 3 days. Because of the rapid rate of biodegradation, groundwater is generally free of phenol even though it is highly mobile in soil. However, monitoring data in Section 6.4.2 contain groundwater concentrations in areas of large phenol releases.

While the evidence presented in the literature cited above suggests that phenol can be rapidly and virtually completely degraded under both natural water and sewage treatment plant conditions, monitoring data presented in Section 6.4 below indicate that phenol, despite this apparent biodegradability, is still present in the environment. This suggests that the exact conditions under which phenol is rapidly degraded are not present in all instances. In some situations, the concentration of phenol may be too high or the populations of microorganisms may not be present in sufficient concentration for significant biodegradation to occur.

### 6.3.2.3 Sediment and Soil

Available data indicate that phenol biodegrades in soil under both aerobic and anaerobic soil conditions. The half-life of phenol in soil is generally <5 days (Baker and Mayfield 1980), but acidic soils and some surface soils may have half-lives of up to 23 days (Shiu et al. 1994). Mineralization in an alkaline, para-brown soil under aerobic conditions was 45.5, 48, and 65% after 3, 7, and 70 days, respectively (Haider et al. 1974). Half-lives for degradation of low concentrations of phenol in two silt loam soils were 2.70 and 3.51 hours (Scott et al. 1983). Plants have been shown to be capable of metabolizing phenol readily (DOE 1987).

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While degradation is slower under anaerobic conditions, evidence presented in the literature suggests that phenol can be rapidly and virtually completely degraded in soil under both aerobic and anaerobic conditions (Baker and Mayfield 1980).

#### 6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to phenol depends in part on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of phenol in unpolluted atmospheres and in pristine surface waters are often so low as to be near the limits of current analytical methods. In reviewing data on phenol levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable. The analytical methods available for monitoring phenol in a variety of environmental media are detailed in Chapter 7.

##### 6.4.1 Air

There are very few monitoring data concerning the presence of phenol in ambient air. Phenol was found at a median concentration of 30 parts per trillion (ppt) in 7 samples from 1 U.S. urban/suburban site in 1974 and at an overall median concentration of 5,000 ppt in 83 samples from 7 source-dominated sites between 1974 and 1978 (EPA 1982). The individual medians of the seven source sites ranged from 520 to 44,000 ppt (EPA 1982). Phenol was detected, but not quantified, in air above the Niagara River in September of 1982 (Hoff and Chan 1987). Phenol concentrations in two urban areas ranged from 13 to 91 ppt and from <5 to 75 ppb with 50% of all measurements <8 ppb (EPA 1981a). Phenol was found at approximately 1 ppb in the ambient air near a fishmeal factory in Japan (Hoshika et al. 1981). In a study to determine contaminants in the air of agricultural areas, phenol was found in 42 out of 53 air samples taken from 8 farms at an average concentration of 10  $\mu\text{g}/\text{m}^3$  (Sunesson et al. 2001). Phenol was detected in indoor and outdoor air in the city of Ottawa, Canada at concentration ranges of 0.01–5.16 and 0.01–1.41  $\mu\text{g}/\text{m}^3$ , respectively (Zhu et al. 2005).

In a study of various air samples from Helsinki, Finland, 92% of outdoor air and 86% of indoor air did not have detectable quantities of phenol (Edwards et al. 2001). Workplace and personal exposure samples also had low relative percentages of phenol with only 12 and 11% of the samples above the limits of detection, respectively (Edwards et al. 2001).

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Higher phenol concentrations may occur when there is smog or in highly contaminated air. During a smog episode in West Covina, California, in July of 1973, phenol concentrations ranged from 16 to 91 ppt, with a mean concentration of 60 ppt (Cronn et al. 1977). During a haze episode in 1998 in Brunei, Syria, phenol was found in 8 out of 15 sites tested in concentrations ranging from 0.07 to 0.41  $\mu\text{g}/\text{m}^3$ ; of these sites, 4 were near a hospital (Muraleedharan et al. 2000).

Phenol and other volatile organic compounds were measured in the air of 50 homes or apartments in Finland (Kostiainen 1995). The average concentration was 0.23 ppb, with a range of 0–0.77 ppb. Phenol levels were not significantly higher in houses in which people complained of symptoms that resembled those of a sick building syndrome.

Phenol has been detected in the ash phase of burning pine, oak, and eucalyptus in concentrations of 524, 300, and 434 mg/kg, respectively (Schauer et al. 2001). Phenol has also been identified in the combustion of soft fireplace wood, hard fireplace wood, stove wood, and synthetic wood at concentrations of 158, 247, 142, and 8.58 mg/kg, respectively (McDonald et al. 2000).

Phenol is released to the atmosphere from burning coal. In a study of three urban sites in Brazil near coal-fired power stations, phenol was detected in all three locations with concentrations ranging from 0.98 to 1.60  $\mu\text{g}/\text{m}^3$  (Moreira dos Santos et al. 2004). This indicates that families living near coal-fired power stations may be exposed to higher concentrations of phenol.

#### 6.4.2 Water

Phenol has been detected in surface waters, rainwater, sediments, drinking water, groundwater, industrial effluents, urban runoff, and at hazardous waste sites. Background levels of phenol from relatively pristine sites can be as high as 1 ppb for unpolluted groundwater and have been reported to range from 0.01 to 1 ppb in unpolluted rivers (Thurman 1985). Phenol has been detected in Lake Huron water at 3–24 ppb (Konasewich et al. 1978) and industrial rivers in the United States at 0–5 ppb (Sheldon and Hites 1978, 1979). The annual mean concentration of phenol in water from the lower Mississippi River was 1.5 ppb (EPA 1980). River water in an unspecified location in the United States was reported to contain 10–100 ppb of phenol (Jungclaus et al. 1978). Phenol was detected, but not quantified, in a Niagara River watershed (Elder et al. 1981) and in 2 of 110 raw water samples analyzed during the National Organic Monitoring Survey (EPA 1980).

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In a study of 95 organic waste components from 139 streams in 30 states from 1999 to 2000, phenol was detected in 85 samples with a median concentration of 0.7 µg/L (Kolpin et al. 2002). Phenol has been detected in China in water samples taken near the Huanchao River water factory, in the Tanking River, and near the Tanking River water factory at concentrations of 0.053, 0.044, and 0.033 µg/L, respectively (Huang et al. 2003).

Each year about 30 million m<sup>3</sup> of mine water is pumped into the Samara River in the Ukraine. Phenol was detected in the surface water in the Samara River from 1987 to 1990 with concentrations ranging from 1.5 to 8.3 µg/L (Goncharuk and Milyukin 1999). In a study of organic contaminants in the groundwater from creosote contaminated sites in Denmark, phenol was detected in all 11 sites tested with concentrations ranging from 11 to 249 µg/L (Johansen et al. 1997).

In general, higher levels of phenol appear to be found in lakes and rivers that serve as water sources and discharge receivers for industrial and population centers, probably as a result of industrial activity and commercial use of phenol-containing products. For example, the presence of higher levels of phenol in the Delaware River near Philadelphia is the result of industrial effluents discharged into the sewer system (Sheldon and Hites 1979). Phenol was detected in 23% of samples of influent of waste water from New York City during 1989 to 1993 at concentrations ranging from 8 to 490 g/L; phenol was detected in 2% of effluent samples at concentrations ranging from 6 to 310 g/L during the same period (Stubin et al. 1996).

The presence of phenol in drinking water probably results from using contaminated surface water or groundwater as a source. Its presence in groundwater is probably the result of release to soil, often industrial releases or leachate from waste dumps, and the subsequent leaching of phenol through the soil to the groundwater. Phenol has been detected, but not quantified, in drinking water from 5 of 14 drinking water treatment plants between July 1977 and June 1979 in one of three sites (groundwater source), in three out of ten (surface water source) as well as water source used after distribution (Fielding et al. 1981). Phenol levels in tap water, spring water, and mineral water in Italy were 0.58, 0.051, and 0.161 µg/L, respectively (Achilli et al. 1995). Phenol was detected at a maximum concentration of 1,130 ppm in ninewells in Wisconsin after a spill, and was detected for at least 1.5 years after the spill (Delfino and Dube 1976). It was found at concentrations up to 10.4 ppm in groundwater from a sand aquifer adjacent to waste ponds at a wood-preserving facility in Florida (Goerlitz et al. 1985), and was detected at 6.510,000 ppb in two aquifers 15 months after the completion of a coal gasification project (Stuermer et al. 1982). Phenol was detected at a maximum concentration of 1.9 ppm in leachates from landfill sites in Illinois (Clark and Piskin 1977). Near a landfill in central Florida, phenol was found in

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groundwater and surface water at about 17 and 15 ppb, respectively (Chen and Zoltek 1995). Phenol was detected, but not quantified, in the groundwater at 13.6% of 178 CERCLA hazardous waste sites (Plumb 1987).

Phenol was detected during seven rain events in Portland, Oregon, between February and April of 1984. Concentrations in rain ranged from >75 to 1,200 ppt, and averaged above 280 ppt. Gas-phase concentrations ranged from 220 (56.1 ppt) to 410 ng/m<sup>3</sup> (105 ppt) and averaged 320 ng/m<sup>3</sup> (82 ppt) (Leuenberger et al. 1985).

Phenol can also be transported in snow and rain. In Germany, phenol has also been detected in clouds at Mount Brocken in June 1994 and during April to May in Great Dun Fell with mean concentrations of 3.0 µg/L and 5.4 µg/L, respectively (Lüttke 1999). Snow from Neulaniemi, Muonio, and Levi, Finland, contained phenol in concentrations of 0.16, 0.04, and 0.02 µg/kg, respectively (Poliakova et al. 2000). In Russia, phenol was detected in snow samples at concentrations of 0.02, 0.21, and 1.3 µg/kg in Butovo, Moscow State University, and Shosse Entuzoastov (a heavily industrial district in Moscow), respectively (Poliakova et al. 2000).

Phenol has been detected in the effluent discharges of a variety of industries. It was found in petroleum refinery waste water at concentrations of 33.5 ppm (Pfeffer 1979) and 100 ppb (Paterson et al. 1996), in the treated and untreated effluent from a coal conversion plant at 4 and 4,780 ppm, respectively (Parkhurst et al. 1979), and in shale oil waste water at a maximum of 4.5 ppm (Hawthorne and Sievers 1984). It has also been detected in the effluent from a chemical specialties manufacturing plant at 0.01–0.30 ppm (Jungclaus et al. 1978), in effluent from paper mills at 5–8 ppb (Keith 1976; Paterson et al. 1996), and at 0.3 ppm in a 24-hour composite sample from a plant on the Delaware River, 2 and 4 miles downriver from a sewage treatment plant (Sheldon and Hites 1979).

A study of the seasonal effects on the concentration of pesticides as well as other contaminants in Gulf of Gdansk in the Baltic Sea from autumn 2001 to spring 2003 showed only 1 out of 14 samples taken in autumn to have a detectable level of phenol with a concentration of 2.3 µg/L (Kot-Wasik et al. 2004). In the spring, phenol was detected in 11 of the 14 samples at concentrations ranging from 0.3 to 0.8 µg/L (Kot-Wasik et al. 2004).

Phenol has also been found in the primary and secondary effluent from the Los Angeles City Treatment Plant at concentrations of 32 and <10 ppb, respectively (Young et al. 1983). It was found in 3 of

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86 samples of runoff from 2 of 15 cities at 3–10 ppb by the U.S. Nationwide Urban Runoff Program as of July of 1982 (Cole et al. 1984).

### 6.4.3 Sediment and Soil

Very few data concerning the presence of phenol in soils were found. Phenol generally does not adsorb very strongly to soils and tends to leach rapidly through soil, which may account for the lack of monitoring data, since any phenol released to soils is likely to leach to groundwater. Moreover, phenol is readily degraded in the environment, which is expected to attenuate its levels in soil.

Sediment collected 6 km northwest of the Los Angeles County waste-water treatment plant discharge zone at Palos Verdes, California, contained 10 ppb (dry weight) phenol (Gossett et al. 1983).

In a study of contaminants in stream bed sediments across the United States, phenol was detected at 536 sites at a maximum concentration of 210  $\mu\text{g}/\text{kg}$  (Lopes and Furlong 2001).

### 6.4.4 Other Environmental Media

Phenol has been reported at concentrations of 7 and 28.6 ppm in smoked summer sausage and smoked pork belly, respectively (EPA 1980), and was identified but not quantified in mountain cheese (Dumont and Adda 1978), fried bacon (Ho et al. 1983), fried chicken (Tang et al. 1983), and black fermented tea (Kaiser 1967). Phenol has also been found in honey at concentrations ranging from 0 (detection limit 0.1 ppm) to 19 ppm (Sporns 1981). It was present each time the honey was collected with phenol-treated boards. Phenol has been reported in three different types of fermented soybean curds at concentrations ranging from 450 to 6,000  $\mu\text{g}/\text{kg}$  (Chung 1999).

Phenol has been found in bottomfish from five sites in Commencement Bay in Tacoma, Washington, at a highest maximum average and overall maximum concentration of 0.14 and 0.22 ppm, respectively (Nicola et al. 1987). Phenol has been reported to be a natural component of animal matter; it has been found at 0–1.6 ppm in rabbit muscle tissue (EPA 1980).

Phenol has been detected in the eggs of birds in the Lake Baikal Region of Italy in concentrations ranging from 840 to <20  $\mu\text{g}/\text{kg}$  dry weight (Lebedev et al. 1998).

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Phenol is also found in medicinal preparations including throat lozenges, mouthwashes, gargles, and antiseptic lotions (Darisimall 2006). Commercial antiseptic lotions may contain up to 1.4% phenol (Darisimall 2006). Package labeling information indicates that commercial throat lozenges contain up to 29 mg of phenol per lozenge (Darisimall 2006). Other consumer products such as disinfectants and cleaners may contain phenol (O'Neil 2001).. It has been found that the smoke of 1 nonfilter cigarette contains 60–140 µg of phenol, 19–35 µg for a filter-tipped cigarette, and 24–107 µg in cigars (IARC 1986; NCI 1998). Using a testing method developed by the U.S. Federal Trade Commission (FTC), analysis of the smoke from several different brands and types of cigarettes found phenol in concentrations ranging from 0.3 to 68 µg/cigarette (Roemer et al. 2004). The lowest concentration came from an electrically heated prototype cigarette, while most of the commercial brands were within a range of 2.6–23.4 µg/cigarette (Roemer et al. 2004).

While not detected in topsoil from Holy Cross Mountain Park, Poland, and surrounding area, phenol was detected in 4 out of the 12 pine needle samples taken from the same area (Migaszewski 1999).

Phenol was detected in 303 of 389 samples of settled dust from indoor residences in Sweden; the mean concentration of phenol was 4 µg/g dust (Nilsson et al. 2005).

### 6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Data concerning concentrations of phenol in ambient air are insufficient to estimate the potential for exposure by inhalation. However, smoke from a single nonfilter cigarette was observed to contain 60–140 µg phenol, while levels of phenol range from 19 to 35 µg in the smoke of filter-tipped cigarettes, and from 24 to 107 µg in the smoke of cigars (IARC 1986; NCI 1998). Therefore, indoor environments polluted with tobacco smoke are likely to contain measurable amounts of phenol (Guerin et al. 1992). Nonsmokers who live with smokers are thought to be exposed to as much as 1.1 µg/m<sup>3</sup>. This would account for a daily inhalation of 6–14 µg/day (Nazaroff and Singer 2004).

Phenol concentrations in surface and drinking waters are expected to vary with location and proximity to varying industrial and municipal discharges. Considering the lack of quantitative, current monitoring data and the probable seasonal, spatial, and temporal variations in the concentrations of phenol at these sources, it is not possible to estimate accurately a potential daily dose of phenol from drinking contaminated water or from dermal exposure to contaminated water. Nonetheless, it is probable that only those systems that receive their water from contaminated surface water and groundwater contain phenol.



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Although phenol has been identified in various food products, a quantitative estimate regarding the intake of phenol from the ingestion of food has not been estimated.

Few data concerning occupational exposures to phenol were located. The average airborne concentrations of phenol to which workers were exposed at three locations within two wood creosote impregnation plants ranged from 0.03 to 0.5 ppm (Heikkila et al. 1987). A phenol concentration of approximately 0.5 ppm was measured in the workroom air at a casting factory in Osaka City, Japan (Kuwata et al. 1980), and concentrations as high as 3.2 ppm were measured in Japanese Bakelite factories (Ohtsuji and Ikeda 1972). Considering the lack of quantitative monitoring data for phenol in occupational atmospheres, it is not possible to estimate the potential for occupational exposure to phenol. The data, however, do show that exposure to phenol through breathing and dermal contact with contaminated workroom atmospheres is possible. The National Occupational Exposure Survey (NOES) conducted by NIOSH estimated that 584,372 workers were exposed to phenol in the United States (NIOSH 1990). The NOES database does not contain information on the frequency, concentration, or duration of exposures. The survey provides only estimates of workers potentially exposed to chemicals in the workplace.

Other occupations that may have increased exposure risk include laboratory workers, morticians, and house cleaners. Phenol is a common solvent used in laboratory research as well as a component of embalming fluid. The general population may be exposed to phenol found in consumer products such as general disinfectants used to clean toilets, floors, drains, and other areas (Lewis 2001; O'Neil 2001). House cleaners and people who work with these products daily are likely to have increased exposure.

Exposure to phenol also occurs through the use and subsequent ingestion of phenol-containing products, including mouthwashes, gargles, and throat sprays (Darisimall 2006). The concentration of phenol in throat sprays ranged from 0.5 to 1.4% phenol. Determining actual dosage from these sprays would be difficult as the delivery method is not precise. Cepastat<sup>®</sup> lozenges, a readily available remedy for sore throats, contains 14.5–29 mg phenol/lozenge (Darisimall 2006). If a patient (adults and children over 6) takes the maximum recommended daily number of 18 lozenges, this would result in approximate doses of 270–520 mg phenol/day. There is no control over the intake of non-prescription drugs and therefore, some individuals may consume considerably higher doses of phenol.

The estimated relative contributions of the various exposure routes and sources of total phenol exposure cannot be estimated using the available data. Nonetheless, for persons not exposed to phenol in the workplace, exposure will most likely result from: inhalation of contaminated ambient air, primarily in the

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vicinity of industries and municipalities that release significant amounts of phenol into the atmosphere; ingestion of drinking water from contaminated surface waters or groundwaters; ingestion of phenol-containing products; and dermal exposure to contaminated water and to phenol-containing products. Dermal contact with phenol or ingestion of phenol-containing products probably constitutes the largest consumer exposure, although this exposure may occur on an acute basis. Inhalation and dermal exposures appear to be most significant in occupational settings. Total phenol exposure for workers exposed to phenol in the workplace is probably substantially higher than for those not exposed in the workplace.

Exposure to benzene is likely to increase phenol exposure because phenol is a metabolite of benzene and is often used to detect benzene exposure. Major releases of benzene include cigarette smoke, auto exhaust, and gasoline fumes.

### 6.6 EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from adults in susceptibility to hazardous substances are discussed in Section 3.7, Children's Susceptibility.

Children are not small adults. A child's exposure may differ from an adult's exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume. A child's diet often differs from that of adults. The developing human's source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child's behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Oral, dermal, and combined oral-dermal exposures are the most likely routes by which children will be exposed to phenol. Oral exposure to low levels of phenol among children is likely because many consumer products contain phenol, particularly in medicines such as gargles, throat lozenges, and others (Darisimall 2006). Products other than medicines that contain phenols include general disinfectants, cleaners, and epoxies.

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Some foods containing phenol have been identified (see Section 6.4.4) and ingestion of these could result in low levels of phenol exposure in children. In addition, phenol is produced endogenously as a breakdown product of protein metabolism; normal concentrations in urine generally do not exceed 20 mg/L (ACGIH 2001).

Since phenol can be readily absorbed through the skin (ACGIH 2001), children may be more susceptible to low levels of phenol exposure since they have a higher skin-surface-area to weight ratio. Since young children are more likely to come in contact with the floor and other low-lying areas, they may be exposed to phenol found in consumer products such as general disinfectants used to clean toilets, floors, drains, and other areas (Lewis 2001; O'Neil 2001).

Exposure to phenol through inhalation is a less probable route than oral and dermal. It is known that both cigarettes and cigars contain small amounts (19–140 µg) of phenol (IARC 1986; NCI 1998), and smoking these products indoors produces a measurable amount of phenol (Guerin et al. 1992). If children are present in indoor environments polluted with tobacco smoke, they may be exposed to low levels of phenol.

### 6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Populations with potentially high exposure to phenol generally include those who are exposed to relatively highly contaminated environments over long periods of time. These include populations exposed to both identified and unidentified phenol-containing waste disposal sites and landfills. Populations residing in the vicinity of industries that manufacture or use phenol and large population centers may be exposed to potentially high levels of phenol. Persons who work at establishments that manufacture or use phenol have a risk for high exposure to phenol. Populations that regularly ingest food contaminated with phenol or that regularly ingest or come in contact with phenol-containing products are at risk for high exposure to phenol. Populations that live near a phenol spill site, especially those whose water supply sources are near the spill sites, have a risk for high exposure to phenol. Relatively high exposure may also result from exposure to emissions from municipal waste incinerators and cigarette smoke, although no quantitative data concerning phenol emission from these sources were located. Low income communities and minority populations are more likely to live adjacent to waste disposal sites and landfills where phenol is present.

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THE NOES conducted by NIOSH estimated that 584,372 workers were exposed to phenol in the United States (CDC Website). Workers in the petroleum industry, as well as workers in industries that manufacture of caprolactam (nylon manufacture), bisphenol A (epoxy resin and polycarbonate manufacture), herbicides, wood preservatives, hydraulic fluids, heavy-duty surfactants, lube-oil additives, tank linings and coatings, and intermediates for plasticizers and other specialty chemicals, may be exposed to phenol. Phenol is also used in throat lozenges, disinfectants, and ointments. It is also used for facial skin peels and to cause nerve block (Gingell et al. 2001). A list of estimated work induced exposure events for 19 different industries is presented in Table 6-2 (Brandorff et al. 1995).

People who are exposed to large amounts of benzene are also likely to be exposed to large amounts of phenol, a metabolite of benzene. Elevated levels of phenol have been detected in workers occupationally exposed to benzene. Workers exposed to 0.8–25.1 or 33.1–331.7 ppm for 2.5–3 hours during an 8-hour workday had median urinary phenol levels of 55.6 and 351 ng/g creatine, respectively (Rothman et al. 1998). Control workers who were not exposed to benzene at the workplace had urinary phenol levels of 17.3 ng/g creatine (Rothman et al. 1998).

## 6.8 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of phenol is available. Where adequate information is not available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of phenol.

### 6.8.1 Identification of Data Needs

**Physical and Chemical Properties.** Knowledge of physical and chemical properties is essential for estimating the partitioning of a chemical in the environment. Information about the physical and chemical properties of phenol is available (Hawley 1981; HSDB 2008; IARC 1989), and the database is adequate for the input requirements of environmental models that predict the behavior of a chemical under specific conditions.

**Production, Import/Export, Use, Release, and Disposal.** According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required

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**Table 6-2. Estimated Exposure To Phenol At Various Industry Sites**

Industry	Estimated number of exposure events	Estimated weight used in tonnes of substance
Manufacture of basic metals	180	1.7
Manufacture of fabricated metal products	8,200	27
Electrical machinery and apparatus	1,400	0.0012
Manufacture of transport equipment	700	40
Painters and carpenters	440	0.021
Construction	4,300	11
Wholesale trade	840	16
Manufacture of textiles and leather	2,600	1
Manufacture of wood and furniture	670	1.2
Manufacture of chemicals	580	0.85
Manufacture of non-metallic mineral products	1,300	4,100
Manufacture of precision and optical instruments	1,300	0.0023
Manufacture of plastic and boat building repair	840	<0.0001
Personal services, cleaning, and hair dressing	260	0.0002
Sewage and refuse disposal	210	0.0009
Agricultural, hunting, and forestry	550	0.65
Health sciences and pharmacies	1,200	0.25

Source: Brandorff et al. 1995

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to submit substance release and off-site transfer information to the EPA. The TRI, which contains this information for 2005, became available in May of 2007. This database is updated yearly and should provide a list of industrial production facilities and emissions.

Additional production data are available from the Chemical Marketing Reporter (CMR 2005), and import/export data for phenol are available on the U.S. International Trade Commission website (USITC 2008). Additional data are not needed at this time.

**Environmental Fate.** Based on the physical properties of phenol, volatilization and sorption of phenol to sediments are not expected to be important transport mechanisms (Lyman et al. 1982). The adsorption of phenol to soils has been shown to increase with increasing organic matter (Xing et al. 1994). Photochemical degradation of phenol is thought to be an important process both in air (EPA 1979a) and water (Scully and Hoigne 1987). Phenol is also readily biodegradable (Ludzack and Ettinger 1960; Rubin and Alexander 1983; Scott et al. 1983; Stover and Kincannon 1983). Soil sorption data are available (Artiola-Fortuny and Fuller 1982; Boyd 1982; Briggs 1981; Sacan and Balcioglu 1996; Scott et al. 1983). Additional data are not needed at this time.

**Bioavailability from Environmental Media.** Data from monitoring studies indicate that phenol is present in the environment (EPA 1981a, 1982; Gossett et al. 1983; Hoff and Chan 1987; Konasewich et al. 1978; Sheldon and Hites 1978, 1979; Thurman 1985) as well as in environmental organisms (Nicola et al. 1987). Exposure to phenol is most likely to be highest in areas at or near industrial centers and population centers where drinking and bathing water, ambient air, and certain foods, such as fish, are obtained from sources contaminated with phenol. Reliable data on the bioavailability of phenol from inhaled air and from skin exposed to phenol vapor have been reported for humans (Piotrowski 1971). Studies of bioavailability of phenol from ingested soil and foods and dermal contact with contaminated water are needed for evaluating the hazards posed by ingesting materials that have been contaminated with phenol.

**Food Chain Bioaccumulation.** No studies were located regarding the food chain bioaccumulation of phenol from environmental media. Data from monitoring studies indicate that phenol is present in the environment as well as in environmental organisms (Nicola et al. 1987). The available bioaccumulation studies are concerned only with exposure of fish to aqueous concentrations of phenol. Although the results of these studies indicate a low potential for bioaccumulation (see Section 6.3.1), the detection of phenol in fish (see Section 6.4.4) indicates that phenol can be found in aquatic organisms; it is possible

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that food chain bioaccumulation may occur. A clearer understanding of the potential for bioaccumulation would aid in determining how levels in the environment affect the food chain and potentially impact human exposure levels. A study examining phenol levels in organisms from several trophic levels is needed.

**Exposure Levels in Environmental Media.** Reliable monitoring data for the levels of phenol in contaminated media at hazardous waste sites are needed so that the information obtained on levels of phenol in the environment can be used in combination with the known body burden of phenol to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

Phenol has been measured in air (Cronn et al. 1977; EPA 1981a, 1982), water (EPA 1980; Sheldon and Hites 1978, 1979; Thurman 1985), and sediments (Gossett et al. 1983). Additional more recent monitoring data would help to estimate human exposure to phenol.

**Exposure Levels in Humans.** Data concerning exposure levels in humans are incomplete and not current (Heikkila et al. 1987; Kuwata et al. 1980; Ohtsuji and Ikeda 1972). A detailed recent database of exposure would be helpful in determining the current exposure levels, thereby allowing the estimation of the average daily dose associated with various scenarios such as living near a hazardous waste site or landfill, or with drinking water containing phenol. An environmental media monitoring program would provide the necessary information for estimating environmental exposures, while a detailed examination of the uses of phenol and the kinds of potential exposure in addition to workplace monitoring would probably provide adequate workplace information. The environmental media that would provide the most useful information are air, groundwater, and surface and drinking water in urban and industrial locations, and air, groundwater, and surface water at hazardous waste sites. Performing the monitoring over a 1-year period would allow estimation of seasonal variations.

This information is necessary for assessing the need to conduct health studies on these populations.

**Exposures of Children.** Children are likely to be exposed to low levels of phenol from the use of many consumer products including medicines and cleaning agents (Budavari et al. 1989; Douglas 1972; EPA 1980; Hawley 1981). There are no known data that quantify the level of exposure to phenol in children. It is likely that young children may be exposed to low levels of phenol because they come into contact with the floor and other areas where disinfectants containing phenol might be used. More studies are needed to assess whether children differ in their weight-adjusted intake of phenol, as little or no

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information is known. Studies are needed to measure the baseline phenol level in children's urine in order to use phenol levels in urine as a biomarker of exposure.

Child health data needs relating to susceptibility are discussed in Section 3.12.2, Identification of Data Needs: Children's Susceptibility.

**Exposure Registries.** No exposure registries for phenol were located. This substance is not currently one of the compounds for which a sub-registry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for sub-registries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance.

### 6.8.2 Ongoing Studies

The Federal Research in Progress (FEDRIP 2006) database provides additional information obtainable from a few ongoing studies that may fill in some of the data needs identified in Section 6.8.1. The only study pertaining to the potential for human exposure found in this database was an exposure assessment study done at Mount Sinai School of Medicine at New York University and supported by National Institute of Environmental Health Sciences. Part of this research is to design new approaches to assess and quantify the levels of exposures to known toxicants in children and infants.