

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

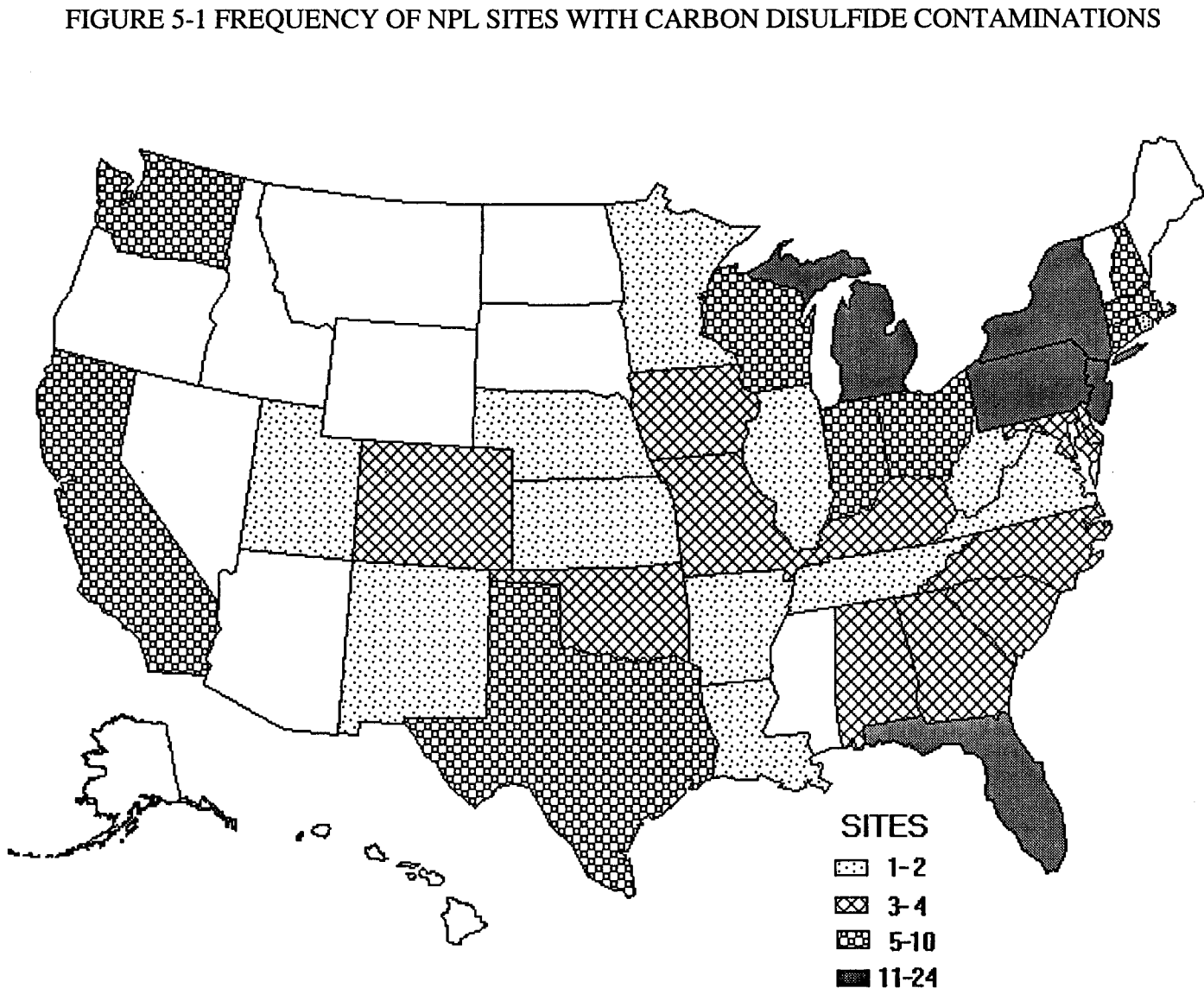
The primary disposition of carbon disulfide in the environment is related to its use as an industrial solvent and chemical intermediate. Releases from industrial processes are almost exclusively to the atmosphere. Releases of the compound to surface waters and soils are expected to partition rapidly to the atmosphere through volatilization. Hydrolysis and biodegradation do not appear to be important processes in determining the environmental fate of carbon disulfide. It has been detected at generally low levels in ambient air, surface water, groundwater, drinking water, food products, and human milk. Concentrations in environmental media are greatest near source areas (e.g., industrial point sources, oceans and marshes, volcanoes).

Inhalation of carbon disulfide in workplace air is generally the main route of human exposure to the compound, with skin exposure also important when the solvent is handled manually.

Carbon disulfide has been identified in at least 200 of the 1,430 current or former EPA National Priorities List (NPL) hazardous waste sites (HazDat 1996). It is not known how many of the 1,430 sites have been evaluated for carbon disulfide. As more sites are evaluated by EPA, this number may change. The frequency of these sites within the United States can be seen in Figure 5-1. Of these sites, 1 is located in the Commonwealth of Puerto Rico.

5.2 RELEASES TO THE ENVIRONMENT

According to the Superfund Amendments and Reauthorization Act (SARA), Section 313, Toxics Release Inventory (TRI93 1995), an estimated total of at least 93,308,704 pounds of carbon disulfide were released to the environment from manufacturing and processing facilities in the United States in 1993 (see Table 5-1). This total includes an estimated 2,805 pounds that were released through underground injection. The TRI data must be viewed with caution, however, since only certain types of facilities are required to report.



*Derived from HAZDAT 1996

Table 5-1. Releases to the Environment from Facilities That Manufacture or Process Carbon Disulfide

State ^b	Number of facilities	Range of reported amounts released in pounds per year ^a							
		Air	Water	Land	Underground injection	Total environment ^c	POTW transfer	Off-site waste transfer	
AL	5	130-42610000	0-14000	0	0	130-42624000	0	0-120320	
AR	2	589679-1113000	0-250	0	0	589679-1113250	0	0	
AZ	2	10-1000	0	0	0	10-1000	0-5	0	
CA	2	10-8272	0	0	0	10-8272	0	0	
CT	2	11-2148	0	0	0	11-2148	2-4137	0	
DE	1	0	0	3	0	3	0	0	
GA	3	310-2240	0	0	0	310-2240	0-250	0	
IL	5	0-3532872	0-250	0	0	0-3532872	0-130000	0-250	
IN	3	250-2340000	0	0	0	250-2340000	0	0	
KS	2	337706-948000	0	0	0	337706-948000	0	0-250	
KY	1	3080	0	0	0	3080	170	51	
LA	9	21-2719497	0	0	0-2800	21-2719497	0	0-10	
MN	1	0	0	0	0	0	0	0	
MO	3	0-644	0-1	0	0	0-645	0-4	0-382	
MS	1	5	0	0	0	5	0	0	
MT	1	3433	0	0	0	3433	0	0	
NJ	2	167-25000	0-11	0	0	178-25000	0-1000	0-55830	
NY	2	3748-544000	0	0	0	3758-544000	570-9300	0-3890	
OH	4	427-317000	0	0	0-5	427-317000	0	0-2	
OK	1	413200	0	0	0	413200	0	0	
PA	1	70900	250	0	0	71150	0	510	
SC	2	2-1000	0	0	0	2-1000	250	0	
TN	5	1-22250000	0-18023	0	0	1-22250000	0-71000	0	
TX	12	5-288660	0-250	0-5	0	5-288660	0-750	0-15737	
VA	1	4900	50	0	0	49050	0	0	

Table 5-1. Releases to the Environment from Facilities That Manufacture or Process Carbon Disulfide

Range of reported amounts released in pounds per year ^a								
State ^b	Number of facilities	Air	Water	Land	Underground injection	Total environment ^c	POTW transfer	Off-site waste transfer
WA	1	10	0	0	0	10	0	0
WI	1	257450	0	0	0	257450	1260	130
WV	5	121-522074	0-788	0	0	121-522074	0	0-255

Source: TRI93 1995

^a Data in TRI are maximum amounts released by each facility

^b Post office state abbreviations used

^c The sum of all releases of the chemical to air, land, water, and underground injection wells by a given facility

POTW = publicly owned treatment works

5.2.1 Air

There are several known natural sources of carbon disulfide, including wetlands (Hines et al. 1993), oceans (Chin and Davis 1993), and microbial activity in soils (Banwart and Bremner 1975; Kanda et al. 1995). The quantity of carbon disulfide emitted from such natural sources as volcanic and geothermal activity is not known but is thought to be small compared to anthropogenic sources, particularly combustion of fossil fuels and other carbonaceous material (Chin and Davis 1993). Certain crop plants and trees emit small amounts of carbon disulfide as well (Batten et al. 1995; Hartel and Reeder 1993).

Historically, carbon disulfide was used in the processing of rubber, but changing technology made the old practices outmoded. Nevertheless, the use of sulfur to crosslink rubber during the vulcanization process may account for the carbon disulfide released from ground tire treads in laboratory experiments (Pos and Berresheim 1993). Automotive tire wear has been suggested as a potential source of atmospheric carbon disulfide. Currently, the largest single use of carbon disulfide is in the viscose rayon industry. For every kg of viscose used, 20-30g of carbon disulfide are emitted (WHO 1979). The largest nonpoint source of man-made levels of carbon disulfide results from its use in the laboratory and as a fumigant and from the degradation of rubber products (EPA 1975b). Small amounts of carbon disulfide have also been detected in a landfill simulator (Vogt and Walsh 1985) and in the odoriferous emissions from a sewage treatment plant (Ruby et al. 1987).

Point sources of carbon disulfide include the biological degradation and incineration of wastes such as municipal refuse, sewage sludge, and industrial wastes (EPA 1975b). Monitoring of air over the North Atlantic Ocean found the highest levels of carbon disulfide off the New Jersey/New York coast, downwind of industrial pollution sources in the northeastern United States (Cooper and Saltzman 1993).

According to TRI93 (1995), an estimated total of 93,271,722 pounds of carbon disulfide, amounting to 99.9% of the total environmental release, was discharged to the air from manufacturing and processing facilities in the United States in 1993 (TRI93 1995) (see Table 5-1). The data listed in TRI should be used with caution since only certain types of facilities are required to report.

Carbon disulfide has been detected in the magmatic gas over volcanoes, during the aging of roasted coffee, during the pressure cooking of grain-water mixtures, as a volatile constituent in the vapor of burning cigarettes, and in the vapor space above liquid sulfur (EPA 1978a). Carbon disulfide has been measured in atmospheric samples collected during the major eruptions of Mount St. Helens. Low levels desorbed from volcanic ash were found to decrease with increasing distance from the volcanic activity (Rasmussen et al. 1982).

During analytical measurements of sulfur compounds at five wetland areas in Florida, carbon disulfide was often not detected while large amounts of dimethylsulfide were found (Cooper et al. 1987). However, low levels of carbon disulfide were consistently detected in samples collected from the same area using a slightly modified procedure (Hines et al. 1993). Based on their measurements and assumptions in the study of sulfur emissions from a North Carolina salt marsh, Aneja et al. (1980) estimated that carbon disulfide produced by marshes ($0.022 \text{ g sulfur/m}^2$ per year) contributes less than 0.07% of biogenic sulfur and less than 8% to the stratospheric aerosol layer. DeMello et al. (1987) speculated that carbon disulfide generation from coastal areas in Florida was related to the concentration of organic matter in the sediment. Staubes et al. (1987) found that humic soils were stronger sources for biogenic sulfur than soils with lower organic content; however, a low humic content coupled with high moisture favors the production of carbon disulfide over dimethylsulfide.

In order to avoid the difficulties of naturally occurring variations in study conditions, Fall et al. (1988) studied the emission of sulfur gases from several plant/soil systems using a flux chamber. The study was designed so that emissions from soil could be separated from emissions from plants. Variable amounts of carbon disulfide were emitted from wheat. The effects of light and temperature were observed. Further work was proposed so that systematic investigation could accurately measure the contributions of a number of sulfur compounds under varying conditions.

5.2.2 Water

According to TRI, an estimated total of at least 34,169 pounds of carbon disulfide, amounting to 0.04% of the total environmental release, was discharged to water from manufacturing and processing facilities in the United States in 1993 (TRI93 1995) (see Table 5-1). In addition, an estimated total of 226,215 pounds, amounting to 0.24% of the total environmental release, was discharged to publicly

owned treatment works. The TRI data should be used with caution since only certain types of facilities are required to report.

Carbon disulfide is widely found in coastal and ocean waters and extensive study has been done to determine levels over the different types of water bodies. The measurements of Carroll (1985) show that the ocean appears to be a source of carbon disulfide, possibly via anaerobic microorganisms. Concentrations of less than 10 nmol/L have been found in a sulfide-rich lake in Spain (Simo et al. 1993). Carbon disulfide has also been detected in the vent fluids and sediment surface waters of undersea hydrothermal sites (Marchand et al. 1994).

Carbon disulfide was found at a concentration of 25 µg/L in groundwater samples collected from only 1 of 19 municipal solid waste landfills examined by Battista and Connelly (1989).

The South Carolina Department of Health (1986) found unspecified levels of carbon disulfide in groundwater samples collected from 1 of 11 wells constructed in a surficial aquifer near a recycling and disposal company that had been storing chemicals.

In a study of 63 industrial effluents collected from a wide range of chemical manufacturers from across the United States, carbon disulfide was found in six of the effluents at concentrations less than 10 pg/L and in two of the effluents at 10-100 µg/L (EPA 1979). Analysis of influent and effluent samples from a waste water treatment plant in Tokyo showed carbon disulfide to be the least prevalent among five sulfur-containing odorous compounds for which testing was done (Hwang et al. 1995).

5.2.3 Soil

According to TRI, an estimated total of at least 8 pounds of carbon disulfide was discharged to soils from manufacturing and processing facilities in the United States in 1993 (TR193 1995) (see Table 5-1). The TRI data should be used with caution since only certain types of facilities are required to report.

Little information was found regarding releases of carbon disulfide to soils. Fain et al. (1987) reported 0.9 mg/L carbon disulfide (dry weight basis) in a typical refinery oily waste applied to a land treatment unit.

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

Releases of carbon disulfide to the environment as a result of industrial activity are expected to be primarily to the atmosphere. Any carbon disulfide released to surface waters in effluent streams is expected to partition rapidly to the atmosphere as a result of the high ratio of vapor pressure to the solubility (Henry's law constant = 1.01×10^{-2} atm • m³/mol) of the compound. Hydrolysis is not a significant removal mechanism since the evaporation half-life from a saturated solution is estimated to be 11 minutes (EPA 1978a).

Although no information was found evaluating the partitioning of carbon disulfide from water onto sediments, it is not expected to be removed significantly from the aquatic phase through adsorption. The low K_{oc} value, calculated from water solubility data, is 54 (EPA 1986b), indicates high soil mobility, but it probably will be less mobile in soils of high organic content.

Although Roy and Griffin (1985) did not conduct adsorption studies, they classified carbon disulfide as a mobile solvent exhibiting a low tendency to be retained by soils. Carbon disulfide released to soils in spills should rapidly volatilize to the atmosphere, but a portion of the compound remaining on soil surfaces could be available for transport into groundwater since it does not have much affinity for soil particles. Farwell et al. (1979) indicated that carbon disulfide volatilizes from a variety of soils, although rates were not provided.

No experimental data on biomagnification were found in the available literature. Estimated bioconcentration factor (BCF) values (equal to 2.94×10^3) were calculated from solubility and K_{ow} , ($\log K_{ow}$ is 2.16) data. The calculated values, 6.8 and 25.8 respectively for solubility and K_{ow} data, indicate that carbon disulfide will not significantly bioaccumulate in aquatic organisms (EPA 1986b).

5.3.2 Transformation and Degradation

5.3.2.1 Air

Carbon disulfide reacts with hydroxyl radicals in the troposphere to produce carbonyl sulfide (Cox and Sheppard 1980). The lifetime of carbon disulfide in the troposphere, assuming a reaction rate constant of $4.3 \times 10^{-13} \text{ cm}^3 \text{ molecule}^{-3}$, is ≈ 73 days (uncertain); other estimates (assuming different reaction rate constants) range from less than 1 week to more than 10 weeks (Cox and Sheppard 1980; EPA 1978a; Wine et al. 1981).

The photo-oxidation products of carbon disulfide in the laboratory were identified as carbon monoxide, carbonyl sulfide, sulfur dioxide, and a polymer that adhered to the sides of the reaction vessel (Heicklen et al. 1971). Although carbon disulfide absorbs light at wavelengths between 280 and 350 nm, dissociation does not occur under environmental conditions because of low molar absorptivity (Atkinson et al. 1978; Wood and Heicklen 1971) and direct photolysis of carbon disulfide in the atmosphere does not appear to be significant. EPA (1978a) stated that the information available indicated that carbon disulfide is relatively persistent in the atmosphere. For the atmospheric oxidation of carbon disulfide to sulfur dioxide, carbonyl sulfide, and carbon monoxide, the half-life was estimated to be about 12 days.

According to Wine et al. (1981), electronically excited carbon disulfide is rapidly produced in the troposphere from absorption of solar photons. This excited carbon disulfide reacts with oxygen on a time scale of 1-2 weeks to yield carbonyl sulfide, the predominant sulfur-containing compound in the troposphere.

The lifetime of carbon disulfide in the atmosphere has been estimated to be 12 days, too short a time to reach the stratosphere. Removal was suggested to occur by a hydroxyl radical reaction, or an oxygen atom reaction but not by dissociation (Khalil and Rasmussen 1984).

Based on the estimates of a lifetime in the troposphere for carbon disulfide on the order of weeks and the troposphere to stratosphere turnover time on the order of years, very little tropospheric carbon disulfide is expected to be transported to the stratosphere (EPA 1986b).

5.3.2.2 Water

Carbon disulfide is stable to hydrolysis in the pH region of environmental concern (pH 4-10). At pH 13, carbon disulfide has a hydrolysis half-life at of about 1 hour at 25°C; by extrapolation, at pH 9, carbon disulfide has a half-life of 1.1 years (EPA 1978a). In oxygenated seawater, carbon disulfide was found to be stable for over 10 days (Lovelock 1974). The volatilization half-life from a saturated water solution has been estimated to be 11 minutes (EPA 1978a). The compound apparently does not undergo biodegradation at rates that are competitive with its volatilization from surface waters.

5.3.2.3 Sediment and Soil

No data were found in the available literature on the biodegradation of carbon disulfide in soil. However, since the chemical is rapidly volatilized (high Henry's law constant) and probably highly mobile in soil (low K_{oc}), it is unlikely that it remains in the soil long enough to be significantly biodegraded.

Microbial degradation of large amounts of carbon disulfide in soil would not be expected to be significant since this compound is a soil disinfectant and toxic to bacteria. Hydrolysis of carbon disulfide on wet soil surfaces is also unlikely (EPA 1986b). Oxidation of carbon disulfide by a *Thiobacillus* species isolated from soil has been observed (Plas et al. 1993).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

Carbon disulfide was detected at 41 parts per trillion (ppt) in 61 rural samples and at 65 ppt in 88 urban/suburban air samples collected by Brodzinsky and Singh (1983). Carroll (1985) sampled air in the vicinity of San Juan, Puerto Rico; Albany, New York; and Wallops Island, Virginia. Carbon disulfide showed considerable spatial variability and a correlation with cloud activity. It was observed that the ocean appears to be a source of carbon disulfide. The air at Wallops Island coming in from the ocean had levels of 30 ppt. Air samples taken at Sapelo Island, Georgia, revealed carbon disulfide levels of about 380 ppt above a saltwater marsh, about 100 ppt above a freshwater marsh, and

negligible amounts above a swamp (Berresheim 1993). Levels of about 12 parts per trillion by volume (pptv) were measured near the island of Fiji in the southern Pacific Ocean (Thornton and Bandy 1993), while levels of 5.8 and 4.2 pptv were measured in marine and continental air, respectively, over the North Atlantic (Cooper and Saltzman 1993). Tropospheric carbon disulfide levels above the Atlantic Ocean were 0.5-5 pptv and 1-30 pptv in areas influenced by anthropogenic or marsh emissions, respectively (Bandy et al. 1993b).

Air in the Philadelphia, Pennsylvania, area that had been influenced by anthropogenic sources was measured at 65-339 pptv carbon disulfide by Maroulis and Bandy (1980). Daily mean carbon disulfide levels in Philadelphia were highly dependent on wind direction.

Air measurements in the vicinity of a municipal landfill showed downwind concentrations three to four times higher than upwind (background) levels (Marquardt 1987). The maximum concentration of carbon disulfide measured in samples from eight solid waste composting facilities was $150 \mu\text{g}/\text{m}^3$ (0.05 ppm) (Eitzer 1995).

Breath and air collected at sites in and around New York City were measured for carbon disulfide by Phillips (1992). The group tested consisted of four types (male smokers, male nonsmokers, female smokers, and female nonsmokers) with no significant divergence observed among any of the different group types (see Table 5-2). Carbon disulfide was detected in all air and breath samples taken from both indoor air and outdoor locations (see Table 5-3). A general population survey in Italy found low levels of carbon disulfide in the blood of all 208 subjects tested and in the urine of all 1,256 samples taken (Brugnone et al. 1994).

5.4.2 Water

It has been suggested that anaerobic conditions on the ocean floor result in formation of carbon disulfide (Lovelock 1974). Measurements made off the coast of Ireland showed carbon disulfide present at every location, with the highest concentrations in stagnant bays.

In a preliminary report to Congress, EPA (1975a) noted that carbon disulfide had been found (detection levels unspecified) in the drinking water of two of five U.S. cities studied. Krill and

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TABLE 5-2. Carbon Disulfide Levels in Breath and Air^a

	Number of observations	Mean age (years)	Standard deviation	Mean carbon disulfide concentration (pmol/L) ^{b,c}	Standard deviation
Male smokers	8	35.7	4.82	4.80	3.19
Male nonsmokers	12	32.9	6.44	6.32	5.24
Female smokers	12	36.8	9.34	5.79	3.49
Female nonsmokers	10	34.5	9.20	3.67	2.79
All volunteers	42	34.9	7.68	5.25	3.89
Room air	9			8.26	5.58
Outdoor air	6			3.92	0.63

^a Adapted from Phillips (1992)

^b No significant differences observed between any of the groups

^c 1 pmol/L = 0.025 ppb

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TABLE 5-3. Carbon Disulfide in Outdoor Air at Sites in and around New York City^a

Collection site	Carbon disulfide (pmol/L) ^b
Empire State Building (observation deck)	4.01
Times Square	3.98
Bayley Seton Hospital, Staten Island (roof)	4.61
New Jersey Turnpike (Newark Airport toll plaza)	4.13
Central Park (West 85th Street entrance)	4.08
Brighton Beach boardwalk, Brooklyn	2.72

^a Adapted from Phillips (1992)^b 1 pmol/L = 0.025 ppb

Sonzogni (1986) reported on an analytical survey of municipal and private groundwater sources in Wisconsin in which carbon disulfide was found in two private wells at concentrations lower than 830 µg/L (the published health advisory level). Carbon disulfide was also found in borings on the site of a landfill in Jacksonville, Florida (EPA 1986c). A survey of groundwater samples in northeastern Florida found no detectable levels of carbon disulfide in underground storage tank system sites and only one landfill site with a measurable level of 21.5 µg/L (Pawlowicz 1993).

Carbon disulfide was measured in Lake Ontario (Kaiser et al. 1983). Mapping of the results showed that levels were high in Toronto Harbor where textile, glass, metal, and plastic manufacturing plants are adjacent to the lake (the highest level detected was 3.9 mg/L). Carbon disulfide was also found in the Niagara River at 25 µg/L. Kaiser and Comba (1983) measured levels as high as 25 µg/L in Thompson Creek near a chemical plant discharge (Welland River watershed in Ontario).

5.4.3 Sediment and Soil

Very little information is available on the levels of carbon disulfide in soils. EPA (1986d) reported finding carbon disulfide at low pg/kg levels in the soil where paint sludges had been dumped on the ground in a gravel pit in Michigan.

5.4.4 Other Media

An analysis of fumigated grains for carbon disulfide showed levels ranging from 0.8 to 2.2 ppm decreasing with time after fumigation, as would be expected from the volatility of carbon disulfide (McMahon 1971). Lovegren et al. (1979) detected 2-3 ppb carbon disulfide in dried legumes. In a study of fumigant residues in foods, Daft (1987) reported finding carbon disulfide residues in samples of pickling spice, mustard seed, and other grain foods. Heikes (1987) examined table-ready foods and found carbon disulfide in plain granola, and Daft (1988a, 1988b) found carbon disulfide in raw onions, raw radishes, corn chips, and oat cereal. The pesticide sodium tetrathiocarbonate may be converted to carbon disulfide after application to fruit crops, and EPA has set a tolerance level of 0.1 ppm carbon disulfide from this source for grapefruit, grapes, lemons, and oranges (EPA 1993, 1995d).

The levels of carbon disulfide and other sulfur species emitted in oil shale off-gases were measured (Sklarew et al. 1984). The concentration of carbon disulfide ranged from 8 to 28 ppm. They

concluded that strategies for the use of oil shale as an alternative fuel must include abatement strategies.

Carbon disulfide was also found in the incinerator ash of hazardous waste incinerators (Wolbach et al. 1987). This finding was not anticipated because of the volatility of carbon disulfide. In addition, Kallonen et al. (1985) identified carbon disulfide at low levels (less than 1 µg/L) in fire gas emissions from the combustion of wool. Exposures at this level do not usually result in significant body concentration of carbon disulfide.

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Exposure to carbon disulfide is primarily confined to occupational situations. Inhalation is the principal route of exposure for humans; absorption through the skin is a much less important route than inhalation, and other routes are negligible (WHO 1979). Very little information is available concerning exposure to carbon disulfide outside the workplace or the effects on the general population. Teisinger and Soucek (1949) reported that, in spite of considerable variation among individuals, absorption seems to be proportional to the concentration of carbon disulfide in inhaled air. Assuming an inhalation intake of 20 m³ air/day, and concentrations in urban and rural air of 65 ppt and 41 ppt, respectively, the average daily intake of carbon disulfide via inhalation is 4.1×10^{-3} mg in urban areas and 2.6×10^{-3} mg in rural areas.

From the limited data available, it appears that individuals living close to workplaces where carbon disulfide is used can be exposed to high enough concentrations to result in measurable uptake (WHO 1979). However, in a study that compared 70 children living 400 meters from a factory discharging carbon disulfide into the atmosphere with a control group of 30 children living 15 km from the factory, physical examinations did not show any health disorders in the exposed group even though urine concentrations of carbon disulfide indicated increased uptake compared with the controls (Helasova 1969).

Airborne concentrations of carbon disulfide in a domestic rayon plant were reported to range from 10 to 15 ppm (NIOSH 1977).

During a 1991 study of a Belgian viscose rayon factory, workers from various departments in the company were monitored with charcoal tubes for carbon disulfide (Vanhoorne et al. 1991). The geometric mean for carbon disulfide ranged from 3.67 mg/m³ (1.17 ppm) to 147.23 mg/m³ (47.11 ppm) (Vanhoorne et al. 1991). Eighty-nine percent of the job classifications studied exceeded the present TLV for carbon disulfide of 31 mg/m³ (10 ppm) (Vanhoorne et al. 1991). Typically, workers are simultaneously exposed to both carbon disulfide (4-12 mg/m³) and hydrogen sulfide (0.2-8.9 mg/m³) (Vanhoorne et al. 1995). Various studies throughout the world (see Table 5-4) indicate that there has been a recent decline in personal exposure of workers in Western countries to carbon disulfide, but in the Far East and Eastern Europe (Rigterink 1988) exposure to carbon disulfide of workers is still substantial.

According to the National Occupational Exposure Survey (NOES) conducted by NIOSH from 1980 to 1983, an estimated 44,438 workers, including 4,881 women, were potentially exposed to carbon disulfide in the workplace in 1980. The NOES database does not contain any information about the concentration levels to which these workers may have been exposed or the frequency and duration of the exposure (NIOSH 1989).

Carbon disulfide was found at unspecified levels in all eight samples of human breast milk tested during a study conducted in New Jersey, Pennsylvania, and Louisiana (Pellizzari et al. 1982). Cai and Bao (1981) measured the levels of carbon disulfide in the milk of mothers employed in rayon factories at 68-123 µg/L and found that carbon disulfide was still present in the milk after a month or more away from the factory.

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Human exposure to carbon disulfide is expected to be highest among certain occupational groups (e.g., rayon plant workers). In addition, members of the general population living in the vicinity of industrial point emission sources are exposed to higher than background levels of carbon disulfide. The compound has been detected in both ambient air and water in low concentrations, with somewhat higher concentrations in localized areas around industrial and disposal sites. No information was found regarding the number of people potentially exposed in the vicinity of hazardous waste sites. However, since carbon disulfide has been found near hazardous waste sites, people living near them may be exposed to higher than background levels.

TABLE 5-4. Personal Carbon Disulfide Exposure in Some References in the Viscose Study^a

Country	Type of viscose production ^b	n ^c	Average carbon disulfide (mg/m ³) ^d		Method ^g	Reference
			Minimum ^e	Maximum ^f		
United States	a	25	0.21	15.40	A	Fajen et al. 1981
China	a	8	0.08	15.55	B	Sugimoto et al. 1982
Sweden	a	7	1.40	2.40	A	Westberg et al. 1984
France	a	23	<0.30	39.90	A	Cicolella and Vincent 1986
	b	14	2.10	35.40	A	
	c	7	0.60	68.70	A	
	d	29	9.60	33.30	A	
	e	26	<0.30	29.10	A	
The Netherlands	b	11	6.20	50.60	B	Verwijst 1988
Belgium	c	17	3.67	147.23	A	Vanhoorne et al. 1991 Vanhoorne et al. 1995
			4.00			

^aAdapted from Vanhoorne et al 1991

^bType of production: (a) staple fibre; (b) yarn, continuous; (c) yarn, discontinuous; (d) sponges;
(e) sausage casings

^cNumber of jobs studied

^dMilligram per cubic meter of air; 1 mg/m³ = 0.32 ppm

^eJobs with the lowest average exposure

^fJobs with the highest average exposure

^gMethods: (a) charcoal tubes-personal sampling pump; (b) diffusive sampling

Of particular concern would be a worker with occupational exposure to carbon disulfide who lived close enough to the plant to be exposed to elevated levels at home as well, particularly if that worker was in poor health from other causes (e.g., smoking, neurological problems, or heart disease).

5.7 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 carbon disulfide is available. Where adequate information is not available, ATSDR, in conjunction with the 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 carbon disulfide.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

5.7.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of carbon disulfide are sufficiently well defined to allow an assessment of its environmental fate (EPA 1995h; Flick 1985; HSDB 1995; MCA 1968; NFPA 1986; NIOSH 1984b; RTECS 1995; Sax and Lewis 1987; Timmerman 1978; Verschueren 1983; Weast 1989; Weiss 1980; Windholz 1983; Worthing 1987). Therefore, no data needs have been identified at this time.

Production, Import/Export, Use, Release, and Disposal. Little specific information is available on the levels of carbon disulfide emitted from industrial sources. Most of the literature concentrates on the viscose rayon industry (EPA 1975b; Battista and Connelly 1989; Carroll 1985; CIS 1989; Cooper et al. 1987; DeMello et al. 1987; EPA 1979, 1978a; Fain et al. 1987; Rasmussen et al. 1982; Ruby et al. 1987; Sax and Lewis 1987; South Carolina DOH 1986; Spencer 1982; SRI 1989; Staubes et al. 1987; Timmerman 1978; TRI93 1995; View 1989; Vogt and Walsh 1985; WHO 1979,

1981; Windholz 1983; Worthing 1987) and natural sources (Timmerman 1978; Who 1979). Although future production levels of carbon disulfide are uncertain because of a long-term decline in the demand for viscose rayon and cellophane and restrictions on the use of fluorocarbon propellants, it is expected that the demand for this chemical in many other specialty areas will continue at relatively stable levels (Timmerman et al. 1978). Carbon disulfide is used primarily in industry. Releases from industrial processes are almost exclusively to the atmosphere. Sources and releases of carbon disulfide to the immediate environment should be identified and quantified, and additional information is needed on the disposal of carbon disulfide. Current disposal methods include liquid injection incineration, rotary kiln incineration, fluidized bed incineration, and air stripping (HSDB 1995), however, data on the efficiency of these methods are lacking. This information will be useful in identifying the media of concern for human exposure and populations at risk of adverse health effects from exposure to carbon disulfide.

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The TRI, which contains this information for 1988, became available in May of 1990. This database is updated yearly.

Environmental Fate. Releases of carbon disulfide to the environment as a result of industrial activity are expected to be primarily to the atmosphere. Carbon disulfide volatilizes from a variety of soils (Farwell et al. 1979). Carbon disulfide reacts with hydroxyl radicals in the troposphere to produce carbonyl sulfide (Cox and Sheppard 1980). Further oxidation would produce carbon disulfide, a major contributor to the greenhouse effect (Cox and Sheppard 1980). The lifetime of carbon disulfide in the troposphere is ≈ 73 days (Cox and Sheppard 1980). Carbon disulfide is stable to hydrolysis in the pH region of environmental concern (pH 4-10), with a hydrolysis half-life at pH 13 of about 1 year (EPA 1976). No data are available concerning the biodegradation of carbon disulfide in soil. Concerted efforts should be made to measure the spatial and temporal variations in the atmospheric levels of carbon disulfide in the vicinity of specific point or nonpoint sources. Although volatilization is the primary fate of carbon disulfide released to the environment (Farwell et al. 1979; Roy and Griffin 1985), data on the partitioning of carbon disulfide from water onto sediments and on the hydrolysis rate of carbon disulfide in surface and groundwater could be useful in determining the persistence of low levels of the compound in the environment. Additional information on the transport and transformation of carbon disulfide in soils, particularly on biotransformation, would also be useful.

Bioavailability from Environmental Media. Carbon disulfide is absorbed following inhalation of contaminated ambient air (Soucek 1957; Teisinger and Soucek 1949) and from dermal contact with contaminated soils or water (Helasova 1969; NIOSH 1989). The average daily intake of carbon disulfide via inhalation has been estimated to be 4.1×10^{-3} mg in urban areas and 2.6×10^{-3} mg in rural areas. Data are lacking on the bioavailability of carbon disulfide following ingestion of contaminated soils and groundwater or foods grown with contaminated water. This information would be useful in determining the importance of these routes of exposure.

Food Chain Bioaccumulation. An estimated bioconcentration factor (BCF) of 2.94×10^3 was calculated from solubility and K_{ow} data. Based on these data, carbon disulfide does not significantly bioaccumulate in aquatic organisms. Although it is generally accepted that carbon disulfide does not bioaccumulate because of its rapid metabolism (EPA 1986b), the data are insufficient to determine the bioconcentration and biomagnification of carbon disulfide at various levels in the food chain. This information would be particularly useful in determining the risks associated with the generally low levels of carbon disulfide in environmental media.

Exposure Levels in Environmental Media. The monitoring data available for carbon disulfide are too limited to allow adequate characterization of potential human exposure to the compound. Studies of background levels in air have been conducted (Bandy et al. 1993b; Brodzinsky and Singh 1983; Carroll 1985; Cooper and Saltzman 1993; Maroulis and Bandy 1980; Marquardt 1987), but site specific concentration data for ambient air, drinking water, and biota, particularly at hazardous waste sites, are lacking. These data would be helpful in estimating the exposure of the general population as well as those living near hazardous waste sites. The sites with highest concentrations of carbon disulfide need to be determined. In addition, estimates of human intake from various media would be helpful in assessing human exposure for carbon disulfide for populations living near hazardous waste sites.

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

Exposure Levels in Humans. Carbon disulfide can be detected in exhaled breath, blood, urine, and milk, and metabolites can be detected in urine, exhaled air, and blood (ACGIH 1986; Baselt 1980; Cai and Bao 1981; Campbell et al. 1985; Cox et al. 1992; Djuric 1967; Helasova 1969; Lieben 1974; McKee et al. 1943; NIOSH 1989; Pellizzari et al. 1982; Teisinger and Soucek 1949; WHO 1979). However, because of the rapid metabolism and elimination of carbon disulfide, these fluid and breath levels do not correlate well with environmental levels, except for the urinary marker, 2-thiothiazolidine-4-carboxylic acid. In addition, the interaction of carbon disulfide with other potential confounders may affect the reliability of urinary metabolites as biomarkers of exposure. Biomarkers may therefore be of limited utility in the quantitative assessment of human exposure to carbon disulfide at hazardous waste sites; however, biomarkers may be useful in qualitatively establishing that possible exposure has occurred.

Additional information on biological monitoring is necessary for assessing the need to conduct health studies on general populations and on those populations living near hazardous waste sites.

Exposure Registries. No exposure registries for carbon disulfide were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for subregistries 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 compound.

5.7.2 On-going Studies

As part of the Third National Health and Nutrition Evaluation Survey (NHANES III), the Environmental Health Laboratory Sciences Division of the National Center for Environmental Health, Centers for Disease Control and Prevention, will analyze human blood samples for carbon disulfide and other volatile organic compounds. These data will give an indication of the frequency of occurrence and background levels of these compounds in the general population.

The data generated as a result of the remedial investigation/feasibility studies of the 200 NPL sites known to be contaminated with carbon disulfide should add to the current knowledge regarding the environmental transport and fate of the compound.

No long-term research projects or other on-going studies of occupational or general population exposures were identified.