6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

Asbestos has been identified in at least 83 of the 1,585 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2001). However, the number of sites evaluated for asbestos is not known. The frequency of these sites can be seen in Figure 6-1. All of these sites are located in the United States.

Although asbestos is neither volatile nor soluble, small fibers or clumps of fibers may occur in suspension in both air and water. These fibers are very stable and do not undergo significant degradation in the environment. Large fibers are removed from air and water by gravitational settling at a rate dependent upon their size, but small fibers may remain suspended for long periods of time.

The general population is exposed to low levels of asbestos primarily by inhalation. Small quantities of asbestos fibers are ubiquitous in air. They may arise from natural sources (e.g., weathering of asbestos-containing minerals), from windblown soil from hazardous waste sites where asbestos is not properly stored, and from deterioration of automobile clutches and brakes or breakdown of asbestos-containing (mainly chrysotile) materials, such as insulation. Tremolite asbestos is a contaminant in some vermiculite and talc. These sources would also contribute to asbestos levels in air. Higher levels of airborne asbestos occur near asbestos mines and may occur near industries that produced asbestos-containing products (Case 1991; Case and Sebastien 1987, 1989; WHO 1998). While the use of asbestos in most products has been phased out, higher asbestos levels may be present in soil near these industries. Higher exposure levels may result when asbestos is released from asbestos-containing building materials such as insulation, ceiling tiles, and floor tiles that are in poor condition or disturbed. In general, levels of asbestos in air inside and outside buildings with undisturbed asbestos-containing materials are low, but indoor levels may be somewhat higher than outside levels. In most cases, the exposure of the general population to asbestos has been found to be very low. The concentrations of asbestos fibers in outdoor air are highly variable, ranging from below 0.1 ng/m^3 (equivalent to $3x10^{-6}$ f/mL measured by phase contrast microscopy [PCM]) in rural areas to over 100 ng/m^3 ($3x10^{-3}$ PCM f/mL) near specific industrial sources such as asbestos mines. Typical concentrations are $1x10^{-5}$ PCM f/mL in rural areas and up to an order of magnitude higher in urban areas. In the vicinity of an asbestos mine or factory, levels may reach 0.01 f/mL or higher. The concentration of fibers in indoor air is also highly variable, depending on the amount and condition of asbestos-containing materials in the building. Typical concentrations range from

Figure 6-1. Frequency of NPL Sites with Asbestos Contamination

1 to 200 ng/m^3 ($3x10^{-5}$ to $6x10^{-3}$ PCM f/mL) (Nicholson 1987). For a human exposed for a lifetime (70 years), this range of exposures corresponds to cumulative doses of approximately 0.002–0.4 PCM f-yr/mL. Children may be exposed to asbestos in the same ways that adults are exposed outside the workplace—from asbestos in air, especially near emission sources or in buildings with deteriorating asbestos-containing material. Since children are more apt to play in dirt, they may be exposed to higher levels of asbestos if the dirt they are playing in contains asbestos and they inhale the dust.

Fibers in water arise mainly by erosion of natural deposits of asbestos or by corrosion of fibers from pipes made with asbestos-containing cement. Asbestos concentrations in most water supplies are less than 1 million fibers per liter (MFL), but may exceed 100 MFL in some cases. For a human consuming 2 L/day, this would yield a dose of about 2–200 million fibers per day.

Occupational exposure occurs primarily through inhalation of asbestos-containing air in the workplace. Workers involved in the mining and processing of asbestos ores or in the production of asbestos-containing products may be exposed to asbestos fibers in air. The presence of asbestiform minerals has been detected in certain mining areas, and people employed in mining and processing of other ores may therefore be exposed to asbestos. In particular, tremolite asbestos can be found in certain sources of vermiculite or talc. It is also a contaminant in the chrysotile mined in Quebec, Canada (Case et al. 2000; Frank et al. 1998; Sebastien et al. 1989; Srebro and Roggli 1994). Asbestos-containing material had been commonly used in buildings in insulation, fireproofing, dry wall, ceiling and floor tile, and other materials, and disturbing this material might release asbestos fibers into the air. Therefore, workers involved in demolition work or asbestos abatement, as well as in building maintenance and repair, are potentially exposed to higher levels of asbestos.

According to the Toxics Release Inventory (TRI), in 1999, total releases of asbestos (friable) to the environment (including air, water, and soil) from 87 facilities that reported producing, processing, or using asbestos were 13.6 million pounds (TRI99 2001). Table 6-1 lists amounts released from these facilities grouped by state.

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Asbestos

		Reported amounts released in pounds per year[a]						
State[b]	Number of facilities	Air[c]	Water	Underground injection	Land	Total on-site release[d]	Total off-site release[e]	Total on and off-site release
AL	3	0	No data	No data	49,048	49,048	No data	49,048
AR	1	23	No data	No data	No data	23	2	25
AZ	1	0	No data	No data	No data	0	336	336
CA	9	255	No data	No data	3,242,237	3,242,492	103,699	3,346,191
DE	1	No data	No data	No data	No data	No data	No data	No data
FL	3	103	No data	No data	No data	103	5,726	5,829
IL	4	250	No data	No data	No data	250	1,500	1,750
IN	2	0	No data	No data	No data	0	264	264
KS	1	19	No data	No data	No data	19	2,800	2,819
KY	3	250	No data	No data	59,160	59,410	880,084	939,494
LA	12	19	0	No data	636,000	636,019	268,890	904,909
MD	1	No data	No data	No data	No data	No data	22,908	22,908
MI	1	0	No data	No data	No data	0	No data	0
NC	2	No data	No data	No data	No data	No data	24,000	24,000
NJ	2	175	No data	No data	186	361	3,080	3,441
NV	2	1	No data	No data	76,000	76,001	No data	76,001
NY	5	17	0	No data	770,000	770,017	78,829	848,846
OH	3	1,371	0	No data	No data	1,371	178,000	179,371
OK	1	18	No data	No data	100,579	100,597	No data	100,597
OR	3	0	No data	No data	8,157,587	8,157,587	170	8,157,757

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Asbestos

		Reported amounts released in pounds per year[a]						
State[b]	Number of facilities	Air[c]	Water	Underground injection	Land	Total on-site release[d]	Total off-site release[e]	Total on and off-site release
PA	4	252	0	No data	0	252	433,414	433,666
SC	2	2	No data	No data	No data	2	160	162
TN	2	107	No data	No data	No data	107	145,100	145,207
TX	10	253	0	No data	3,560	3,813	200,532	204,345
UT	3	20	No data	No data	450,426	450,446	42,003	492,449
VA	2	296	No data	No data	No data	296	2,451,886	2,452,182
WA	1	1	No data	No data	No data	1	No data	1
WV	1	No data	No data	No data	0	0	No data	0
WY	2	No data	No data	No data	29,000	29,000	No data	29,000
Total	87	3,432	0	No data	13,573,783	13,577,215	4,843,383	18,420,598

Source: TRI99 2001

[a]Data in TRI are maximum amounts released by each facility.
[b]Post office state abbreviations are used.
[c]The sum of fugitive and stack releases are included in releases to air by a given facility.
[d]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[e]Total amount of chemical transferred off-site, including to publicly owned treatment works (POTW).

6.2 RELEASES TO THE ENVIRONMENT

According to the TRI, in 1999, total releases of asbestos (friable) to the environment (including air, water, and soil) from 87 facilities that reported producing, processing, or using asbestos were 13.6 million pounds (TRI99 2001). Table 6-1 lists amounts released from these facilities grouped by state. The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.

6.2.1 Air

Although asbestos is not volatile, small fibers and clumps of fibers may be released to air as dust. Asbestos originating from the weathering of natural deposits of asbestos-bearing rocks is found in air and has been deposited in ice cores dating back to 1750. No estimates of the amounts of asbestos released to the air from natural sources is available. Asbestos is much more likely to be released to the atmosphere when asbestos deposits are disturbed—as in mining operations. In Canada, over 95% of asbestos is mined in open-mining operations that involve drilling and blasting, and this contributes more air emissions than underground mining operations (Sebastien et al. 1984). Other anthropogenic sources of asbestos emissions besides mining are the crushing, screening, and milling of the ore, the processing of asbestos into products, the use of asbestos-containing materials, and the transport and disposal of asbestos-containing wastes.

In 1992, the EPA estimated that emissions from asbestos processing, including milling, manufacturing, and fabrication were about 2,240 pounds per year (EPA 1992b). This estimate assumed full compliance with the current National Emission Standards for Hazardous Air Pollutants (NESHAP) (EPA 1990a) applicable to asbestos. Based on new data, EPA later determined that asbestos emissions from processing facilities were much lower than the original estimates used to list these facilities as source categories under the 1990 Clean Air Act Amendments of 1992 (OSHA 1994).

Another potential source of asbestos release to air is from clutches and brakes on cars and trucks; a wide range of air concentrations of asbestos fibers (0.004–16.0 f/mL) has been reported in numerous air sampling studies of workplaces during maintenance and replacement of vehicle brakes (WHO 1998). Release of asbestos from insulation or other building materials is discussed in Section 6.4.1, below. Estimated asbestos emissions from waste disposal from all sources were about 499,000 pounds

(22.7 metric tons) per year (EPA 1990a). If all sources were in full compliance with the NESHAP for asbestos, waste disposal emissions would be reduced to 1,320 pounds (600 kg) per year (EPA 1990a).

According to TRI, in 1999, the estimated release of asbestos (friable) was 3,432 pounds to the air from 87 facilities that reported producing, processing, or using asbestos. This accounted for about 0.02% of total environmental releases (TRI99 2001). Table 6-1 lists amounts of asbestos released from these facilities to air.

Asbestos has been identified in air at 17 of the 1,585 current or former NPL hazardous waste sites where it was detected in some environmental media (HazDat 2001).

6.2.2 Water

Asbestos is released to water from a number of sources, including erosion of natural deposits and waste piles, corrosion from asbestos-cement pipes, and disintegration of asbestos roofing materials with subsequent transport via rainwater into cisterns, sewers, etc. (Millette et al. 1980). Waste water from asbestos-related industries may also carry significant burdens of asbestos fibers (EPA 1976). The total amount of asbestos released to water has been estimated to be 110,000–220,000 pounds (50–100 metric tons) per year (NRC 1984).

According to TRI, in 1999, no asbestos (friable) was released to water from 87 facilities that reported producing, processing, or using asbestos (TRI99 2001). Table 6-1 lists the amount of asbestos released from these facilities.

Asbestos has been identified in groundwater and surface water samples respectively collected from 11 and 9 of the 1,585 current or former NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2001).

6.2.3 Soil

Soil may be contaminated with asbestos by the weathering of natural asbestos deposits, or by land-based disposal of waste asbestos materials. While disposal of waste asbestos to landfills was a common practice in the past, current regulations restrict this practice (see Chapters 5 and 8).

In 1999, the disposal of 13,573,783 pounds of asbestos (friable) on land was reported by 87 U.S. facilities that produced, processed, or used asbestos (TRI99 2001). An additional 4,843,383 pounds of asbestos were transferred to other locations, including publically owned treatment works (POTWs), in 1999, and it is likely that most of this was ultimately released on land. No asbestos was injected underground in 1999. Table 6-1 lists the amounts of asbestos released from these facilities by state.

Asbestos has been identified in soil and sediment samples respectively collected from 27 and 7 of the 1,585 current or former NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2001).

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

Asbestos fibers are nonvolatile and insoluble, so their natural tendency is to settle out of air and water, and deposit in soil or sediment (EPA 1977, 1979c). However, some fibers are sufficiently small that they can remain in suspension in both air and water and be transported long distances. For example, fibers with aerodynamic diameters of 0.1–1 μm can be carried thousands of kilometers in air (Jaenicke 1980), and transport of fibers over 75 miles has been reported in the water of Lake Superior (EPA 1979c). Adsorptive interactions between the fibers and natural organic contaminants may favor coagulation and precipitation of the fibers (EPA 1979c).

6.3.2 Transformation and Degradation

6.3.2.1 Air

Asbestos fibers in air are not known to undergo any significant transformation or degradation (EPA 1979c).

6.3.2.2 Water

Chrysotile asbestos may undergo some dissolution in the aquatic environment, especially at low pH. Magnesium hydroxide leaches from the outer brucite layer, but the basic silicate structure of the fiber remains intact. Amphibole asbestos is much more resistant to attack in acidic media (Chissick 1985; Choi and Smith 1972; Morgan and Holmes 1986; WHO 1998).

Asbestos degrades in the environment very slowly (NRC 1984). Although the estimated half-life of asbestos in aquatic systems is not known, it is expected to be quite long (NRC 1984), and asbestos may persist in the environment virtually unchanged for very long periods of time following its release (EPA 1989f).

6.3.2.3 Sediment and Soil

Asbestos fibers are not known to undergo significant transformation or degradation in soil.

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Numerous measurements have been performed to determine the concentration of asbestos fibers in environmental media, primarily air. These studies have reported their results in a variety of units, including ng/m^3 (measured by midget impinger counting analysis), TEM f/mL (fibers measured by transmission electron microscopy), and PCM f/mL (fibers measured by phase contrast microscopy). The most accurate and sensitive method for measuring asbestos fiber content in air is electron microscopy, and preferably transmission electron microscopy (TEM) must be used. Phase contrast microscopy cannot distinguish between asbestos and nonasbestos fibers or between different types of asbestos. However, in certain occupational settings where the predominant fiber is asbestos, PCM should give an adequate measure of asbestos concentration. In nonoccupational environments where a large fraction of the fibers are not asbestos (e.g., wool, cotton, glass), PCM may greatly overestimate the asbestos levels in air. Regulations regarding asbestos determine what fibers are counted in the analysis. Established methods define fiber material having a length $5 μm and a length to diameter ratio of $3:1. In the same air sample, the fibers counted by TEM can be 50–70 times higher than those counted by PCM. This relates to the fact that PCM cannot detect fibers less than about 0.20–0.30 μm in diameter while TEM is capable of detecting fibers with diameters as small as 0.01 μm. Therefore, PCM may miss thin fibers as well as include nonasbestos fibrous material. The conversion factors between fibers counted by PCM and those

counted by TEM are highly variable, depending on the size and length distribution of the fibers. No single set of factors will be accurate for all samples, although a conversion factor can be established for specific fiber types and occupational settings. A comparison was made between fiber counts by PCM and TEM using samples from a chrysotile mine, crusher, mill and tailings site, a brake manufacturing industry, and a taping products industry (Verma and Clark 1995). It was anticipated that such a study would allow extrapolations to be made from occupational exposures to low-level nonoccupational exposures. Fibers from 65 filters were counted using PCM and TEM, and ratio of the fiber counts by the two methods determined for various operations and locations. In addition, the fiber determinations by TEM were made to include different groups of fibers. The fiber concentration ratios determined were TEM to PCM for all TEM fibers, for all TEM asbestos fibers, for TEM asbestos fibers with length >5 μm and diameter <3 μm, and for TEM asbestos fibers with length >5 μm and diameters >0.3 μm and <3 μm. The results for 'all TEM fibers' and 'all TEM asbestos fibers' showed that for the operations studied, the airborne fibers were 93–100% asbestos. The fiber concentration ratios of TEM to PCM for 'all asbestos fibers' were highly variable for the different samples, ranging between 19 and 76. The high of 76 was for milling where a predominance of small fibers resulted from more efficient dust collection. The fiber concentration ratios of TEM to PCM for 'TEM fibers of length >5 μm and diameter >0.3 μm and <3 μm' was fairly consistent, varying between 1.2 and 10.4 but mostly <4.4 or between 1.4 and 3.2 when data were grouped by operation rather than by individual occupations or locations. This indicates that this method of counting and sizing the fibers was consistent. The TEM fibers of length >5 μm and diameter >0.3 μm and <3 μm was 4–18% of the total TEM fibers. The proportion of long, thin fibers increased as the asbestos operation moved from the primary sector (mining) to end use (manufacturing).

In 1984, the NRC (1984) recommended that a conversion be used to measure asbestos fibers. It was suggested that crude approximations could be achieved by assuming that 1 PCM f/mL is equal to 60 TEM f/mL. Both 1 PCM f/mL and 60 TEM f/mL are approximately equal to a mass concentration of 30 $\mu g/m^3$. Since the health effects data regarding inhalation exposure to asbestos are usually expressed in terms of PCM f/mL, ambient air data reported in units of ng/m^3 or TEM f/mL are converted to units of PCM f/mL using the factors suggested by NRC (1984).

6.4.1 Air

Ambient outdoor air, remote from any special sources, is generally found to contain 0.001–0.1 ng/m^3 of asbestos ($3x10^{-8}$–$3x10^{-6}$ PCM f/mL) (NRC 1984). Another source reports the average concentration of asbestos fibers in rural outdoor air as $1x10^{-5}$ PCM f/mL (HEI 1991). In urban areas, most ambient air

concentrations range from 0.1 to 10 ng/m^3 ($3x10^{-6}$–$3x10^{-4}$ PCM f/mL), but may range up to 100 ng/m^3 ($3x10^{-3}$ PCM f/mL) as a result of local sources (Corn 1994; EPA 1991b; IARC 1977; Nicholson and Pundsack 1973; Selikoff et al. 1972). The median concentration in U.S. cities has been estimated to be 2.3 ng/m^3 ($7x10^{-5}$ PCM f/mL) (NRC 1984). Two other investigations of asbestos in outdoor air in the United States reported levels of asbestos from not detected (ND) to $8x10^{-3}$ PCM f/mL, with a median of $3x10^{-4}$ PCM f/mL and a mean of $5x10^{-5}$ PCM f/mL (WHO 1998). These levels are sufficiently low that they are not likely to be of significant health concern to most people. Near industrial operations involving asbestos, levels may be as high as 50–5,000 ng/m^3 (10.0015–15 PCM f/mL) (IARC 1977). A recent analysis of monitoring data for asbestos in ambient air worldwide estimated rural and urban levels at about $1x10^{-5}$ TEM f/mL ($2x10^{-7}$ PCM f/mL) and $1x10^{-4}$ TEM f/mL ($2x10^{-6}$ PCM f/mL), respectively (HEI 1991). Higher levels were measured near source-dominated locations.

Average asbestos fiber concentrations (>5 Fm) in chrysotile mining towns in Quebec that had been 0.08 f/mL in 1973 and 1974 declined to 0.007 by 1982 and have remained below 0.01 f/mL between 1982 and 1994 (WHO 1998). A comprehensive study of asbestos air levels around various asbestos-related industries was conducted in Taiwan (Chang et al. 1999). Samples (n=246) were obtained as a function of distance around 41 factories producing cement, friction products, textiles, tile, insulation, and refractory materials. Samples around 14 of these plants, randomly chosen to include all types of plants, were analyzed by TEM; the remainder of the samples were analyzed by PCM. The results of this study appears in Table 6-2. In general, the asbestos concentrations around asbestos-related industries were low and inversely related to distance from the factory. The large geometric standard deviation reflects unevenly distributed levels for the same type of plant. Asbestos levels around refractory plants were low indicating a low release during the wet, clay-like material in the manufacturing process. In contrast, higher levels of asbestos fibers were found around textile plants where the manufacturing process is dry and open. Asbestos concentrations obtained by PCM were much higher than those obtained by TEM. This overestimation of fiber concentrations by PCM is much greater when the levels of nonasbestos fibers are high. For the same factory, levels of TEM asbestos substances were generally lower than nonasbestos substances and in some samples combined concentration of asbestos and nonasbestos substances were similar to results obtained by PCM.

McDonald et al. (1986b) reported that TEM and chemical analysis of samples of airborne fibers from various locations of the Libby, Montana, vermiculite mine and mill showed several morphologies (straight with uniform diameter, needle shape, and curved), chemical content compatible with the

Table 6-2. Asbestos Levels in Ambient Air Around Taiwanese Factories

Factory type	Number of factories	Method	GM (GSD) asbestos concentrations (f/mL)		
			Distance from factory		
			200 m	400 m	600 m
Cement	5	TEM	0.006 (1.230)	0.007 (1.487)	0.006 (1.301)
		PCM	0.01 (3.49)	0.01 (2.91)	<0.01
Friction	3	TEM	0.008 (2.441)	0.008 (1.978)	0.002 (2.221)
		PCM	0.01 (322)	0.02 (2.88)	<0.01
Textile	2	TEM	0.012 (2.221)	0.020 (1.432)	0.006 (1.765)
		PCM	0.02 (3.21)	0.02 (3.33)	<0.01
Ground tile	2	TEM	0.033 (1.412)	0.021 (1.421)	0.025 (2.321)
		PCM	0.4 (3.21)	<0.01	0.01 (2.21)
Insulation	1	TEM	0.012 (2.321)	0.020 (2.210)	0.006 (2.773)
		PCM	<0.01	<0.01	<0.01
Refractory	1	TEM	<0.0001	<0.0001	<0.0001
		PCM	<0.01	<0.01	<0.01
Overall	14	TEM	0.0015 (1.943)	0.0011 (2.022)	0.007 (2.221)
		PCM	0.06 (3.29)	0.01 (3.21)	0.01 (2.21)

Source: Chang et al. 1999

GM = geometric mean; GSD geometric standard deviation; PCM = phase contrast microscopy; TEM = transmission electron microscopy

tremolite-actinolite series with some evidence of sodium content; ranges for diameter, length, and length:width ratio of 0.1–2, 1–70, and 3–100 µm, respectively. Greater than 60% of fibers were reported to be longer than 5 µm (McDonald et al. 1986b). Tremolite asbestos is a contaminant in some vermiculite.

Asbestos fibers may be released to indoor air due to the possible disturbance of asbestos-containing building materials such as insulation, fireproofing material, dry wall, and ceiling and floor tile (EPA 1991b; HEI 1991; Spengler et al. 1989). Measured indoor air values range widely, depending on the amount, type, and condition (friability) of asbestos-containing materials used in the building. For example, asbestos in floor tile is less friable than that in insulation or sprayed coatings. The release of asbestos fibers from asbestos-containing materials (ACM) is sporadic and episodic. Human activity and traffic may facilitate release of asbestos fibers and stir up asbestos-containing dust. Therefore, monitoring performed at night or on weekends may underestimate human exposure to asbestos in buildings. In addition, asbestos levels are apt to be higher in some areas of a building (e.g., boiler room) than in others and these areas may not be accessible to most people using the building. In a review of indoor air monitoring data from a variety of locations, Nicholson (1987) reported that arithmetic mean concentrations ranged from 1 to 200 ng/m^3 (3x10^{-5} to 6x10^{-3} PCM f/mL). In a survey performed by EPA (1988c), levels of asbestos in 94 public buildings that contained asbestos ranged from not detected (ND) to 0.2 TEM f/mL (ND–3x10^{-3} PCM f/mL), with an arithmetic mean concentration of 0.006 TEM f/mL (10^{-4} PCM f/mL) (Spengler et al. 1989). Analysis of data based on air samples from 198 buildings with ACM indicated mean asbestos levels ranging from 4x10^{-5} to 2.43x10^{-3} TEM f/mL (7x10^{-7}–4x10^{-5} PCM f/mL) (HEI 1991). Asbestos concentrations in 41 schools that contained asbestos ranged from ND to 0.1 TEM f/mL (ND–2x10^{-3} PCM f/mL), with an arithmetic mean of 0.03 TEM f/mL (5x10^{-4} PCM f/mL) (EPA 1988c; Spengler et al. 1989). Another study reported average concentrations of airborne asbestos fibers $5 µm in length of 8.0x10^{-5} and 2.2x10^{-5} TEM f/mL in 43 nonschool buildings and 73 school buildings, respectively (Chesson et al. 1990; HEI 1992; Spengler et al. 1989). The average outdoor level in these studies were comparable to those measured indoors (Spengler et al. 1989). Building survey and air sampling, both inside and outside the building was conducted on 315 buildings nationwide over a 5-year period. The study was undertaken by consultants for defendants for litigation from buildings in which asbestos removal was alleged to be necessary because of risk to occupants from exposure to asbestos-containing materials (Lee et al. 1992). In the study a total of 2,892 air samples were obtained and analyzed by TEM. Public, commercial, residential, school and university buildings were included in the study, all of which were occupied. The airborne asbestos concentrations from this study (see Table 6-3) include all chrysotile and amphibole particles having a length:width ratio $3, concentrations of fibers $5 µm long, and the

Table 6-3. Exposure to Airborne Asbestos in U.S. Buildings[a]

			Asbestos structure and fiber concentrations						
			Asbestos structures[b] (f/mL)			Fibers[c] (f/mL)		Optical equivalents (f/mL)[d]	
Building type	Number of buildings	Number of Samples	Mean	Median	90th percentile	Mean[e]	90th percentile	Mean[e]	90th percentile
School	177	921	0.04015	0.01017	0.08134	0.00018	0.00071	0.00011	0.00056
University	78	426	0.00865	0.00165	0.02543	0.00008	0.00000	0.00007	0.00000
Commercial	28	213	0.00162	0.00101	0.00476	0.00003	0.00000	0.00002	0.00000
Public	32	123	0.00538	0.00335	0.01551	0.00016	0.00054	0.00007	0.00015
Residential	1	10	0.00486			0.00000		0.00000	
Outdoor		759	0.00188	0.00000	0.00437	0.00005	0.00000	0.00002	0.00000
Personal		106	0.00866	0.00316	0.02368	0.00012	0.00000	0.00009	0.00000
Indoor[f]	315		0.02485			0.00013		0.00008	

Source: Lee et al. 1992

[a]All analyses performed by TEM.
[b]All asbestos particles having a length:width ratio $3.
[c]Asbestos fibers $5 µm long.
[d]Optically equivalent asbestos fibers (i.e., fibers $5 Fm long and $0.25 Fm in width).
[e]Median concentrations for all categories are 0.00000 f/mL.
[f]Indoor air samples include schools, universities, public, commercial, and residential buildings.

GM = geometric mean; GSD = geometric standard deviation; TEM = transmission electron microscopy

concentration of structures with lengths of $5 µm and widths of at least 0.25 µm. The latter category is referred to as "optically equivalent" structures and represent those structures that would have been identified by PCM. The average concentration of all asbestos structures was 0.025 f/mL. The average concentration of asbestos fibers $5 µm was $1.3x10^{-4}$ f/mL, while for those that could be detected by optical methods, it was $8.0x10^{-5}$ f/mL. In 48% of indoor samples and 75% of outdoor samples, no asbestos fibers $5 µm were found. There are significant differences in the concentration of total asbestos structures among building types, but not for fibers $5 µm. Additionally, there was no difference in the indoor and outdoor levels of asbestos fibers $5 µm for commercial, public, or university buildings, although a higher level indoors was found for school buildings. Outdoor levels were consistently lower than indoor levels when all asbestos structures were considered. Most of the chrysotile fibers were very thin (97% less than 0.2 µm in diameter [and would have been missed by PCM]) and short (85% less than 1 µm long). Only 2% of the fibers were amphiboles and these fibers were generally longer and thicker than the chrysotile fibers.

In studies from a Health Effects Institute-Asbestos Research Study, mean concentrations of fibers $5 µm ranged from 0 to $2.5x10^{-4}$ f/mL in public and commercial buildings and from $1.0x10^{-5}$ to $1.11x10^{-3}$ f/mL in schools and universities (Lee et al. 1992). Average concentrations in the United States are 10–100 times less than those found in Britain, Germany, and Canada. The structures found in buildings are much smaller and coarser than those found in occupational settings. Corn (1994) reported the mean, 90th percentile, and maximum asbestos levels in 231 buildings, including schools, universities, and public, commercial, and residential buildings as $1.0x10^{-4}$, $5.1x10^{-4}$, and $2.06x10^{-3}$ PCM f/mL, respectively; outdoor levels were $6.0x10^{-5}$ f/mL.

A study of 49 buildings in the United States reported mean asbestos fiber levels of $9.9x10^{-4}$ PCM f/mL in buildings with no ACM, $5.9x10^{-4}$ PCM f/mL in buildings with ACM in good condition, and $7.3x10^{-4}$ PCM f/mL in buildings with damaged ACM (WHO 1998). In general, direct comparison of levels inside and outside ACM buildings indicates that typical (nondisturbed) indoor levels are usually low, but may be higher than outside levels (Chesson et al. 1990). Buffing asbestos-containing floor tile in a commercial building led to a small increase in asbestos bodies <5 µm long, but no increase in those >5 µm in length (Demyanek et al. 1994).

Asbestos may also be released to indoor air from the use of asbestos-contaminated household water (Hardy et al. 1992; Webber et al. 1988). Limited studies indicate that both amphibole and chrysotile

fibers can be aerosolized by portable home humidifiers (Hardy et al. 1992). The airborne asbestos concentrations in the home were directly proportional to the asbestos concentrations in the water used in the humidifiers.

6.4.2 Water

The concentration of asbestos fibers in water (expressed as million TEM fibers per liter, MFL) varies widely. Concentrations in most areas are <1 MFL (EPA 1979b), but values of 1–100 MFL and occasionally higher have been detected in areas contaminated by erosion from natural asbestos deposits (EPA 1976; Kanarek et al. 1980) or from mining operations (Sigurdson et al. 1981).

Sources of asbestos in drinking water may be a result of natural deposits from releases due to the use of asbestos-cement pipes in water distribution systems. The amount of asbestos contributed from asbestos-cement pipe is negligible in some locations (Hallenbeck et al. 1978), but may result in concentrations of 1–300 MFL at other locations (Craun et al. 1977; Howe et al. 1989; Kanarek et al. 1981). In one reported incident, grossly deteriorated asbestos-cement pipe in the water distribution system resulted in water concentrations of asbestos up to 1,850 MFL (Webber et al. 1989). The variability in the amount of fibers coming from asbestos-cement pipe appears to depend on a number of parameters, but is mostly related to characteristics of the water such as low pH and low hardness, which influence the rate at which the water can corrode the pipe (NAS 1982). In a recent Austrian study, the asbestos content of drinking water that was contaminated by natural asbestos deposits or the use of asbestos cement pipe was compared with that in control areas (Neuberger et al. 1996). In 10 areas with asbestos deposits and 14 areas that had asbestos-cement pipes, the asbestos concentration in drinking water was low (median 32,000 total asbestos fibers per liter) and was not significantly different from 6 control areas. The highest concentration, 190,000 f/L, was found in an area with natural asbestos deposits at the source of the supply. In areas without natural deposits, the increased asbestos concentration was not significant and was unrelated to aggressiveness of the water supply or to age or length of the pipe. It should be noted that asbestos-cement pipes in areas with aggressive water are coated in Austria. Elevated asbestos concentrations of asbestos were found in water in an uncoated asbestos-cement cistern. In a similar study involving 59 aqueducts in Tuscany, Italy, 76% of the samples were below the detection limit of 0.002 MFL (Cherubini et al. 1998). Asbestos fibers in the other samples were present at concentrations lower than 0.04 MFL. Samples of aggressive water taken from asbestos-cement pipes were too few to determine whether a significant correlation existed between water quality and asbestos release from the

pipes. The majority of all fibers found in these studies was chrysotile, and most fibers were less than 5 µm in length (Hallenbeck et al. 1978; Millette et al. 1980; Neuberger et al. 1996; Pitt 1988).

6.4.3 Sediment and Soil

The serpentine and amphibole mineral groups occur over a wide a range of geological environments. The preponderance of these minerals are of a nonfibrous form. Fibrous forms of these mineral groups are minor constituents of many rocks and can be found in soils. For example, tremolite asbestos is found as an impurity in some commercially mined deposits of talc, vermiculite, and chrysotile (Amandus et al. 1987; Boutin et al. 1989; Case 1991; Davis et al. 1985; Lockey et al. 1984; McDonald et al. 1986a; Ross 1981; Skinner et al. 1988). Ross (1981) has reviewed the occurrence of different forms of asbestos minerals and the history of their exploitation. The occurrence of asbestiform minerals is a function of the chemical composition of the underlying rock and the temperatures and pressures that were instrumental in forming these rocks. Commercially exploitable deposits of asbestos minerals are associated with certain types of rocks and for some asbestos minerals, these deposits are rare.

No studies were located regarding the concentration of asbestos fibers that occur in soil. Asbestos was found in about 80% of a number of samples of street dirt at concentrations ranging from 100 million to 1 billion fibers per gram (f/g) (Pitt 1988). These were primarily chrysotile fibers, but most were <2 µm in length and therefore, were not comparable with fiber concentrations that are $5 µm. The concentration of fibers $5 µm in length was not reported. It is likely that the main source of this asbestos was release from automobile brakes.

6.4.4 Other Environmental Media

Tremolite-actinolite is present in or around some deposits of chrysotile asbestos. However, levels of amphibole asbestos in commercial chrysotile were not reported. Tremolite is a contaminant in talc from New York and California, but the extent and fibrosity of the tremolite is unclear (DOL 1980; Wagner et al. 1982c; American Thoracic Society 1990). The tremolite in some talc from California has been described as flake-like and that from New York as having fine fibers (Wagner et al. 1982a). Some tremolite in the chrysotile from Quebec has been described as having coarse fibers. A British survey of talc powders used for various purposes identified 3 out of 24 samples as containing tremolite. Ten of 20 samples of cosmetic talc purchased in New York City between 1971 and 1975 contained 1–14% (w/w) of fibrous tremolite and anthophyllite (Paoletti et al. 1984). Paoletti et al. (1984) conducted a survey of

asbestos fibers in talc powders from Italian and international markets using electron microscopy, electron diffraction, and x-ray microanalysis. The fiber criteria used was that accepted by the Council of European Communities (i.e., those having a length:width ratio $3 and a width <3 µm). Three of 14 samples of talc provided by European Pharmacopoeia from the international market contained tremolite asbestos; in 2 of the samples, the percent of asbestos fibers was about 20% by weight. In the 15 samples of Italian industrial, pharmaceutical, and cosmetic talc, 7 contained fibers of tremolite, ranging from 0.2 to 1.6% by weight. Interestingly, about three-quarters of the asbestos fibers observed in each sample had diameters less than about 0.4 µm and therefore, were probably below the resolving power of phase contrast microscopy.

Raw vermiculite (vermiculite concentrate) is a mica-like mineral that rapidly expands upon heating to produce a lightweight, bulky material, vermiculite, that is used in fireproofing, insulation, packaging, and in horticultural/agricultural products, as a soil conditioner, fertilizer carrier, etc. One of the largest vermiculite deposits in the United States is in Libby, Montana, where raw vermiculite was mined and milled from 1923 until 1990. Vermiculite from the mine was marketed under the trade name Zonolite. Atkinson et al. (1982) found fibrous tremolite-actinolite, nonfibrous tremolite-actinolite, and nonfibrous anthophyllite in raw ore and vermiculite concentrate samples from the vermiculite mine and mill in Libby, Montana: fibrous tremolite-actinolite accounted for ~21–26% of the weight of raw ore and 2–6% of the weight of vermiculite concentrate (as cited in Amandus et al. 1987). In a 1984 study of samples from Libby, Montana conducted by W.R. Grace, fiber percentage by weight varied from 3.5 to 6.4% in raw ore and from 0.4 to 1.0% in the concentrate (cited in Amandus et al. 1987). Amandus et al. (1987) noted that among 599 fibers counted in eight airborne membrane filter samples from Libby, 96 and 16% had length:width ratios >10 and >50, respectively. Percentages of fibers with lengths >10, >20, and >40 µm were 73, 36, and 10%, respectively. Moatamed et al. (1986) analyzed samples of vermiculite ores from Libby, Montana; Louisa County, Virginia; and South Africa for the presence of amphibole fiber (asbestos) contamination. Two samples of Montana unexpanded vermiculite ore were determined to have 0.08 and 2.0% amphibole content by weight; two samples of expanded Montana vermiculite both showed 0.6% amphibole content. The South African unexpanded and expanded samples showed 0.4 and 0.0% amphibole content, respectively. The unexpanded and expanded Virginia samples were both determined to be 1.3% amphibole by weight. The number of fibers detected by microscopy in the Virginia samples were reported to be “extremely low” in comparison to the Montana samples, and the South African vermiculite samples showed a “near absence of fibers” or “rare, short fibrous structures.” Based on energy-dispersive x-ray analysis of random fibers in the samples, the fibers in the Montana and Virginia samples were classified predominantly as actinolite, whereas the fibers in the South African samples were

predominantly anthophyllite. The size of fibers in the Montana and South African samples indicate that these amphiboles were asbestiform, while the actinolite present in the Virginia samples may have been predominantly nonasbestiform cleavage fragments (Moatamed et al. 1986).

Recently, EPA conducted a survey of vermiculite products, primarily those used in gardening, to determine whether products currently on the market contain asbestos and if so, whether consumers are at risk from using these products (EPA 2000d). Five of the 16 products purchased in garden stores in the Seattle area contained asbestos, 3 of which contained enough asbestos to be quantified reliably. These samples contained between 0.1 and 2.8% tremolite-actinolite asbestos. Samples taken from the same bag of material were variable in fiber concentration with higher levels of fibers found in the fine particles taken from the bottom of a bag. The use of these products were then simulated to see whether the fibers became airborne. Fibers were detected in air samples at (0.16–0.95 f/mL) from the Zonolite Chemical Packaging. Asbestos was detected in 17 of an additional 38 vermiculite products purchased around the country, of which only 5 contained quantifiable levels. The study concluded that consumers face only minimal health risks by using vermiculite products and these can be minimized by keeping the product moist to avoid creating dust and using the product in well ventilated areas. Fibrous and nonfibrous tremolite has been detected in vermiculite from both Montana and South Carolina, but the levels in South Carolina vermiculite may be lower (American Thoracic Society 1990). Actinolite was found in Virginia samples, but at lower levels than in Montana vermiculite and mostly as cleavage fragments (Moatamed et al. 1986).

In the past, filters made from asbestos were employed in the preparation of wines, beers, and other items consumed by humans, and asbestos concentrations in these materials ranged from 1 to 10 MFL (Cunningham and Pontefract 1973). Analysis of 47 brands of sake purchased in Japan from 1983 to 1985 indicated that asbestos concentrations in sake ranged from less than the detection limit (7.8×10^{-3} MFL) to 196 MFL (Ogino et al. 1988).

The use of asbestos filters in food or pharmaceutical preparation has been discontinued in the United States, and intake of asbestos through foods or drugs is now unlikely.

Asbestos fibers may be incorporated in sewage sludge as a result of their presence in waste water. Asbestos has been reported in municipal sewage sludges and sewage sludge composts from large and small cities in the United States (Manos et al. 1991, 1993; Patel-Mandlik et al. 1988). Asbestos was detected in 34 of 51 sludge ash samples at levels ranging from 1 to 10% by volume (Manos et al. 1991).

In a 1993 study of the prevalence of asbestos in sludge from 16 sewage plants in large American cities, asbestos was detected in 13 of the sludges at up to 7% by volume (Patel-Mandlik et al. 1994). The sludge disposal methods of the participating treatment plants were land application, 44%; land filling, 37%; and incineration, 19%.

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

As noted above, the concentrations of asbestos found in indoor air, outdoor air, and drinking water vary widely, and it is not possible to calculate human exposure levels accurately except on a site-by-site basis. With this limitation in mind, Table 6-4 presents some rough estimates of exposure levels for a general population living in an urban or suburban area and for asbestos workers. The exposure levels used for the general public are intended to represent the central portion of the typical range of exposures; thus, some persons could be exposed to higher levels, while others could be exposed to less. The workplace air concentration used to estimate worker exposure (0.1 f/mL) is the same as the current U.S. workplace exposure limit (OSHA 1998a, 1998b, 1998c). Actual workplace exposures could be higher or lower. It has been estimated that about 568,000 workers in production and services industries and 114,000 in construction industries may be exposed to asbestos in the workplace (OSHA 1990). Rough estimates of dose of fibers transferred to the gastrointestinal tract after inhalation exposure were calculated using the same assumptions (e.g., 30% of inhaled fibers are transferred to the gastrointestinal tract) as employed in similar calculations by NAS (1983).

The exposure of the general population (nonoccupational exposure) to asbestos in both indoor and outdoor air is extremely low. Older buildings may contain ACM, which had been used for insulation, surface treatment (e.g., fireproofing), floor and ceiling tiles, insulating boards, and spackling, patching, and plastering compounds and asbestos levels are generally higher in indoor air than outdoors (HEI 1991; Spengler et al. 1989). However, exposure appears to be low regardless of whether the buildings do not contain ACM, contain ACM in good condition, or contain damaged ACM (Spengler et al. 1989). As mentioned in Section 6.4.4, the release of asbestos fibers from ACM is sporadic and episodic, and human activity and traffic in occupied buildings would result in higher air concentration of asbestos fibers than in unoccupied buildings. Unfortunately, many investigators fail to report the time when monitoring was performed and whether the building was occupied at the time. One recent investigation found mean asbestos levels in indoor air of occupied buildings having ACM to be 8.0×10^{-5} f/mL, while outdoor air levels were 2.0×10^{-5} f/mL; in both cases, median levels were below detection limits (Lee et al. 1992). Exposure of custodial and maintenance personnel would be higher as they are more likely to be in areas

Table 6-4. Summary of Typical General Population and Occupational Exposures

Exposed population	Exposure medium	Typical concentration	Assumed exposure	Cumulative exposure level (f-yr/mL)	Estimated dose to gastrointestinal tract[a] (MF/day)
General population	Ambient (outdoor) air	$2x10^{-6}$ PCM f/mL	20 m^3/day, 70 years (10% of time outdoors)[e]	0.000014[b]	0.0000012[c]
	Indoor air[e]	$3x10^{-6}$ PCM f/mL	20 m^3/day, 70 years (90% of time indoors)[b]	0.00019[f]	0.000016[g]
	Drinking water	0.017 MFL[e]	2 L/day	–	0.034
Asbestos worker	Workplace air	0.1 PCM f/mL[h]	40 years, 8 m^3/day, 5 days/week, 49 weeks/year[i]	1.1[j]	0.16[k]

[a]Assumes 30% of inhaled fibers are transferred to stomach (NAS 1983)
[b]Approximate value based on EPA 1989e
[c]Cumulative exposure level (values in []): Typical concentration [$2x10^{-6}$ f/mL] x Life span [70 years] x Fraction of time outdoors [0.1]
[d]Dose to gastrointestinal tract:(values in []): Typical concentration [$2x10^{-6}$ f/mL] x Volume inhaled/day [20 m^3] x Fraction of time outdoors [0.1] x Fraction of inhaled fibers transferred to gastrointestinal tract [0.3] x 10^6 mL/m^3 x 10^{-6} MF/f
[e]Millette et al. 1980; concentration converted from TEM basis to PCM basis using 1 TEM f=1/60 PCM f (NRC 1984).
[f]Cumulative exposure level (values in []): Typical concentration [$3x10^{-6}$ f/mL] x Life span [70 years] x Fraction of time indoors [0.9]
[g]Dose to gastrointestinal tract:(values in []): Typical concentration [$3x10^{-6}$ f/mL] x Volume inhaled/day [20 m^3] x Fraction of time indoors [0.9] x Fraction of inhaled fibers transferred to gastrointestinal tract [0.3]x10^6 mL/m^3 x 10^{-6} MF/f
[h]Time-weighted average (TWA) Permissible Exposure Limit (PEL) (OSHA 1998c)
[i]NAS 1983
[j]Cumulative exposure level (values in []): Typical concentration [0.1 f/mL] x Working life span [40 years] x Fraction of air breathed in workplace [8 m^3/day/20 m^3/day x 5 days/7 days x 49 weeks/52 weeks]
[k]Dose to gastrointestinal tract:(values in []): Typical concentration [0.1 f/mL] x Volume inhaled/workday [8 m^3 x 5 days/7 days x 49 weeks/52 weeks] x Fraction of time outdoors [0.1] x Fraction of inhaled fibers transferred to gastrointestinal tract [0.3]x10^6 mL/m^3 x 10^{-6} MF/f

f/mL = fibers per milliliter; MF = million fibers; MFL = million fibers per liter; PCM = phase contrast microscopy; TEM = transmission electron microscopy

of a building that may contain asbestos (e.g., boiler room) and may come into contact or disturb ACM, thereby increasing air levels during the course of their activities.

People living in the vicinity of asbestos mines and asbestos-related industries may be exposed to higher levels of asbestos (Case 1991; Case and Sebastien 1987, 1989; Churg 1986b; Churg and DePaoli 1988). The magnitude of such exposures tend to be overestimated when researchers use PCM in situations where the concentrations of nonasbestos fibers are high (e.g., around textile and friction product factories) or if the actual concentration of asbestos is very low (e.g., around refractory plants). In their investigation of exposure levels around asbestos-related industries in Taiwan, Chang et al. (1999) found differences in asbestos fiber levels around different types of plants; those using dry and more mechanical operations (e.g., textiles) tended to have higher levels than other plants. Also, asbestos levels were inversely related to distance from the plant. In a study of the contribution of airborne asbestos fibers to the work environment from the operation of an overhead crane having asbestos brake pads, the 8-hour time-weighted-average (TWA) asbestos fiber concentration ranged from <0.005 to 0.011 f/mL (PCM) and from <0.0026 to 0.0094 f/mL (TEM) (Spencer et al. 1999). No asbestos fibers were detected by TEM during the operation of the cranes.

Workers involved in mining of asbestos or minerals contaminated with asbestos or manufacturing or using asbestos-containing products may be occupationally exposed to elevated levels of asbestos. Average asbestos fiber concentrations (>5 Fm) in the Quebec chrysotile mining industry declined markedly from 16 f/mL in 1973 to 2 f/mL in 1978 and has remained below 2 f/mL between 1978 and 1994 (WHO 1998). The highest asbestos concentration in 1973 was 52 f/mL.

A simulation of bandsawing sheet asbestos gasket material was performed in order to retrospectively evaluate worker exposure from this operation (Fowler 2000). The work was performed on 1/8-inch chrysotile asbestos (80%)/neoprene sheet (purchased in 1996) using a conventional 16-inch woodworking bandsaw. Personal samples and area samples at the breathing zone were assessed using PCM, TEM (total), and TEM (>5 µm). Personal air concentrations of fibers >5 µm during bandsawing were between 2.2 and 4.9 f/mL by PCM. The personal air concentrations by TEM were higher; 22.2–49.3 f/mL for all asbestos fibers and 8.2–17.6 f/mL for fibers >5 µm. Area results were somewhat lower with PCM results between 0.75 and 2.3 f/mL and TEM results in the ranges of 14.3–22.7 f/mL (total) and 5.7–7.6 f/mL (>5 µm). These results show that airborne fiber levels were well above the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) of 0.1 and 1.0 f/mL for PEL (TWA) and PEL (ceiling), respectively.

A similar simulation was performed by Esmen and Corn (1998) to estimate the exposure of workers in the historically important process of splitting open bags of asbestos and transferring the contents to a container. In splitting open a bag of powdery material, there is generally an immediate but short duration release of material. Exposure depends on the number of bags opened and the air exchange rate. The 8-hour TWA exposure levels were determined for various scenarios and air exchange rates using PCM (fibers >3 μm). In the case where one 4.5 kg bag of chrysotile asbestos was opened and boxed every 15 minutes for 8 hours, air asbestos levels ranged from 21 f/mL at 0.5 air exchanges per hour (ACH) to 0.45 f/mL at 30 ACH. Peak exposure levels reached 80 f/mL.

In 1985, a comprehensive study of Japanese plants producing asbestos-containing products was conducted to assess exposure levels to asbestos fibers using phase-contrast microscopy. Personal exposures ranges were 0.07–0.66, 0.25–0.41, and 0.06–0.78 f/mL for disintegrating (feeding), mixing, and cutting/grinding/drilling processes, respectively (Higashi et al. 1994). Exposure levels were <0.3 f/mL in 70% of the workplaces in 1985 and 98% of workplaces in 1992. Concentrations in a new, well-controlled plant were <0.1 f/mL. Bulgarian workers engaged in the production of asbestos gaskets and filter materials at two plants were exposed to 0.04–0.38 and 0.04–0.43 f/mL of asbestos (Strokova et al. 1998).

As part of an international epidemiological study of cancer incidence and mortality among workers in the pulp and paper industry, the International Agency for Research on Cancer (IARC) coordinated a study involving researchers in 15 countries in gathering exposure measurements taken between 1956 and 1993 for nonproduction departments in the industry from previously unpublished studies (Teschke et al. 1999). The results are shown in Table 6-5. Exposure to asbestos was found in three areas: maintenance, construction, cleaning; storage, yard, loading, shipping; and steam and power generation with 16, 50, and 0% of exposures in these departments exceeding 0.2 f/mL.

Building materials used in older buildings such as insulation, dry wall, roofing, and flooring often contain asbestos. Occupational exposure to asbestos during asbestos abatement work is an area of concern. Lange and Thomulka (2000a, 2000b, 2000c) and Lange et al. (1996) collected both area and personal samples during various abatement projects and their results suggest that occupational levels were low with no value exceeding the OSHA PEL (see Table 6-6). In general, abatement of boiler and pipe insulation produced the highest airborne fiber levels and abatement of floor tile and mastic produced the lowest. Personal samples, which had higher concentration levels than area samples, are suggested to be

Table 6-5. Exposure to Airborne Asbestos in Nonproduction Departments of the Pulp and Paper Industry[a]

Department	Number of mills	Number of samples	Mean (f/cc)	Median (f/cc)	Maximum (f/cc)	Type	Percent less than LOD	LOD (f/cc)	Percent greater than TLV[a]
Maintenance, construction, cleaning	12	31	0.081	0.004	0.5	TWA	42	0.001	16
Storage, loading, shipping	4	26	7.2	0.18	28	TWA	19	0.010	50
Steam and power generation	6	16	0.013	0	0.1	TWA	56	0.005	0

Source: Teschke et al. 1999

[a]TLV (1995-6) = 0.2 f/cc

LOD = limit of detection; TLV = threshold limit value; TWA = time-weighted average

Table 6-6. Exposure to Airborne Asbestos During Asbestos Abatement[a]

Material abated	Number of samples	Concentration range (f/mL)	Arithmetic mean (SD) (f/mL)	Geometric mean (GSD) (f/mL)	Type[b]	Reference
Roofing material (wet method)	12[c]	0.0047–0.0752	0.015 (0.014)	0.011 (2.53)	Personal (non-TWA)	Lange and Thomulka 2000b
	17	<0.0006–0.0162	0.006 (0.006)	0.004 (2.82)	Area (non-TWA)	
Floor tile and mastic	10[c]	<0.008–0.094	0.022 (0.017)	0.015 (2.54)	Personal (non-TWA)	Lange and Thomulka 2000a
	13[c]	<0.002–0.067	0.010 (0.008)	0.006 (2.73)	Area (non-TWA)	
Dry wall[d]	25[c]	0.12–3.16	0.76 (0.57)	0.59.(1.94)	Personal (TWA)	Lange and Thomulka 2000c
Floor tile and mastic	23	0.01–0.08	0.04 (0.04)	0.03 (1.71)	Personal (TWA)	Lange and Thomulka 2000c
Pipe/boiler in a crawl space	102	0.005–1.542	0.202	0.149 (2.33)	Area	Lange et al. 1996
Pipe/boiler in a crawl space[e]	42	0.005–0.998	0.192	0.097 (3.17)	Area	
Pipe/boiler in a crawl space[e]	42	0.005–0.957	0.187	0.089 (2.75)	Personal	
Ceiling tile removal in mini-containment	11	0.005–0.331	0.043	0.019 (2.09)	Area	
Ceiling tile removal in mini-containment	9	0.005–0.154	0.022	0.007 (3.38)	Personal	
Transite removal	41	0.005–0.278	0.077	0.048 (3.50)	Personal	

Table 6-6. Exposure to Airborne Asbestos During Asbestos Abatement[a] *(continued)*

Material abated	Number of samples	Concentration range (f/mL)	Arithmetic mean (SD) (f/mL)	Geometric mean (GSD) (f/mL)	Type[b]	Reference
Floor tile and mastic (solvent method) removal	14	0.005–0.010	0.005	0.005	Area	
Mastic removal (blast method)	4	0.005–0.005	0.005	0.005	Area	

[a]Analysis by TEM.
[b]8-Hour TWA concentrations assume exposure only during sample periods. TWA levels refer to mean concentrations.
[c]One outlier excluded from calculation of means and standard deviations.
[d]Respirators are required for dry wall abatement.

GSD = geometric standard deviation; SD = standard deviation; TEM = transmission electron microscopy; TWA = time-weighted average

the best measure of occupational exposure. Higher exposure levels occur during dry wall abatement, but respirators are required for this type of abatement work.

Workers involved in custodial and maintenance and repair work in asbestos-containing buildings may be exposed to elevated asbestos levels in the workplace. The results of some recent studies in this area appear in Table 6-7. In all cases, the 8-hour TWA exposures for personal sampling were below the OSHA PEL of 0.1 f/mL for fibers above 5 μm. Mlynarek et al. (1996) found that the highest 8-hour TWA exposure occurred during ceiling tile replacement followed by high efficiency particulate air (HEPA) vacuuming or wet wiping of dust and debris. In their study of asbestos exposure of maintenance personnel in five buildings who worked above the ceiling in proximity to spray-applied fireproofing, Corn et al. (1994) found that less than a maximum of 5% of a worker's total working time was spent in such activity. Exposures were below the OSHA PEL with only simple protective measures employed such as HEPA vacuuming and wetting down of surfaces. Exposure would have been reduced substantially more by the use of respirators for the relatively short period of time maintenance personnel spent above the ceiling. Routine floor tile maintenance procedures such as spray-buffing, wet-stripping, and ultra high speed burnishing can result in elevated levels of airborne asbestos. TEM analysis showed that over 98% of the asbestos structures were below 5 μm in length and would not be detected or counted by PCM (Kominsky et al. 1998a, 1998b). Only in the case of ultra high speed burnishing was the OSHA PEL exceeded. However, this was due to the generation of nonasbestos particles during the burnishing process and therefore do not reflect actual asbestos exposure. This example underscores the limitations of PCM in interpreting workplace exposure.

The geometric mean asbestos body and crocidolite fiber content in 90 former workers in the Wittenoon crocodiolite industry in Western Australia were 17.5 asbestos bodies/g wet tissue and 183 TEM f/μg dry tissue, respectively (de Klerk et al. 1996). The geometric mean intensity of exposure, duration of exposure, and cumulative exposure were 20 f/mL, 395 days, and 20.9 f-yr/mL, respectively. The fiber concentration in the lung was correlated to the intensity and duration of exposure.

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 3.7 Children's Susceptibility.

Table 6-7. Exposure to Airborne Asbestos During Building Maintenance or Repair[a]

Material abated	Number of samples	Concentration range[b] (f/mL)	Arithmetic mean (SD) (f/mL)	TWA mean (Max) (f/mL)	Type[b]	Reference
Ceiling removal/installation	6	0.000–0.035	0.0149		Personal	Corn 1994; Corn et al. 1994
Ceiling removal/installation	18	0.001–0.044	0.0112		Area	
Electrical/plumbing	10	0.002–0.216	0.0619		Personal	
Electrical/plumbing	4	0.004–0.054	0.0308		Area	
HVAC work	8	0.000–0.077	0.0202		Personal	
HVAC work	23	0.001–0.024	0.0068		Area	
Miscellaneous work	4	0.000–0.031	0.0082		Personal	
Miscellaneous work	9	0.000–0.083	0.0108		Area	
Removal/encapsulation	4	0.015–0.115	0.0614		Personal	
Removal/encapsulation	10	0.003–0.019	0.0109		Area	
Run cable	33	0.001–0.228	0.0167		Personal	
Run cable	33	0.000–0.086	0.0080		Area	
ACM debris cleanup	9	0.012–0.36	0.074	0.0077 (0.028)	Personal	Mlynarek et al. 1996
Bulk sample collection	31	0.0030–0.17	0.034	0.0042 (0.024)	Personal	
Cable pull	37	0.011-0.20	0.048	0.013 (0.037)	Personal	
Ceiling tile replacement	67	0.030-3.5	0.35	0.030 (0.21)	Personal	
Ceiling tile replacement	18	0.0020–0.056	0.011	0.0027 (0.0088)	Area	

Table 6-7. Exposure to Airborne Asbestos During Building Maintenance or Repair[a] *(continued)*

Material abated	Number of samples	Concentration range[b] (f/mL)	Arithmetic mean (SD) (f/mL)	TWA mean (Max) (f/mL)	Type[b]	Reference
Electrical installation	14	0.010–0.11	0.037	0.011 (0.026)	Personal	
Electrical repair	24	0.003–0.052	0.020	0.0091 (0.027)	Personal	
Fluorescent lamp replacement	78	0.0054–0.065	0.025	0.0059 (0.018)	Personal	
Fluorescent lamp replacement	55	0.0039–0.0067	0.0067	0.0006 (0.0014)	Area	
HEPA vacuum/wet wiping dust/debris	17	0.029–0.304	0.098	0.026 (0.073)	Personal	
HEPA vacuum/wet wiping dust/debris	19	0.0023–0.027	0.0068	0.0031 (0.0074)	Area	
Wet wipe cleaning	25	0.018–0.048	0.031	0.0092 (0.024)	Personal	
Office environment	10	0.0016–0.057	0.0091	0.0032 (0.025)	Area	
TOTAL (range)	302	0.0030–3.5	0.020–0.35	0.0042–0.030 (0.018–0.21)	Personal	
TOTAL (range)	102	0.0016–0.062	0.0067–0.027	0.0006–0.0032 (0.0014–0.025)	Area	
Spay-buffing tile (poor)	5	0.008–0.015	0.012		Personal	Kominsky et al 1998a
Spay-buffing tile (medium)	5	0.003–0.008	0.006		Personal	
Spay-buffing tile (good)	5	0.015–0.030	0.019		Personal	
Wet-stripping tile (medium)	5	0.006–0.016	0.010		Personal	
Wet-stripping tile (good)	5	0.004–0.010	0.006		Personal	

Table 6-7. Exposure to Airborne Asbestos During Building Maintenance or Repair[a] *(continued)*

Material abated	Number of samples	Concentration range[b] (f/mL)	Arithmetic mean (SD) (f/mL)	TWA mean (Max) (f/mL)	Type[b]	Reference
Spay-buffing tile (poor)	5	0.046–0.081[c]	0.059[c]		Personal	
Spay-buffing tile (medium)	5	0.001–0.032[c]	0.014[c]		Personal	
Spay-buffing tile (good)	5	0.004–0.046[c]	0.024[c]		Personal	
Wet-stripping tile (medium)	5	0.055–2.58[c]	0.978[c]		Personal	
Wet-stripping tile (good)	5	0.010–0.128[c]	0.041[c]		Personal	
UHS burnishing tile (poor)	5	0.046–0.081[c]	0.024[c]		Personal	Kominsky et al 1998b
UHS burnishing tile (good)	5	0.004–0.046[c]	0.017[c]		Personal	
Wet-stripping tile (poor)	5	0.055–2.58[c]	0.019[c]		Personal	
Wet-stripping tile (good)	5	0.010–0.128[c]	0.015[c]		Personal	
UHS burnishing tile (poor)	5	0.872–1.692		0.133–0.275[d]	Personal	
UHS burnishing tile (good)	4	0.670–1.016		0.113–0.145[d]	Personal	
Wet-stripping tile (poor)	8	0.004–0.018		0.001–0.004[d]	Personal	
Wet-stripping tile (good)	8	0.006–0.014		0.001–0.003[d]	Personal	

[a]Analysis by PCM, NIOSH method 7400, unless otherwise indicated.
[b]8-Hour TWA concentrations assume exposure only during sample periods. TWA levels refer to mean concentrations.
[c]Analysis by TEM.
[d]Range of individual measurements, exceedance of OSHA PEL (0.1 f/mL) due to nonasbestos-containing powder generated during the burnishing operation.

ACM = asbestos-containing material; HEPA = high efficiency particulate air; HVAC = Heating, Ventilation and Air Conditioning; NIOSH = National Institute of Occupational Safety and Health; OSHA = Occupational Safety and Health Administration; PCM = phase contrast microscopy; PEL = permissible exposure limit; SD = standard deviation; TEM = transmission electron microscopy; TWA = time-weighted average

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).

Children may be exposed to asbestos in the same ways that adults are exposed outside the workplace– from asbestos in air especially near emission sources or in buildings with deteriorating asbestos-containing material. Differences in breathing patterns, airflow velocity, and airway geometry between adults and children can result in age-related differences in deposition of inhaled particles in the respiratory tract (Phalen et al. 1985). Deposition of particles in various regions of the respiratory tract in children may be higher or lower than in adults depending on particle size, but for particles with diameters <1 μm, fractional deposition in the alveolar, tracheobronchial, and nasopharyngeal regions in 2-year-old children has been estimated to be about 1.5 times higher than in adults (Xu and Yu 1986). This information may be relevant to inhalation exposure to asbestos fibers, but direct information regarding age-related differences in deposition of inhaled fibers was not located. Studies that have been conducted on asbestos levels in schools have stressed the low fiber counts in the air even when the buildings contained asbestos-containing material (Mossman et al. 1990a). As mentioned in Section 6.4.4, the release of asbestos fibers from ACM is sporadic and episodic, and human activity and traffic may facilitate release of asbestos fibers and stir up asbestos-containing dust. Monitoring of buildings are frequently performed at night or on weekends may therefore underestimate human exposure to asbestos in the buildings. Historically, children have been exposed to asbestos while playing near mining or processing facilities using materials containing asbestos, or from contact with asbestos-laden clothing of family members employed in asbestos-related industries. Although studies quantifying this type of exposure of children were not located, its existence is known based on reports of the development of asbestos-related respiratory diseases in adults who were "paraoccupationally " exposed as children, but had no occupational exposure to asbestos during adulthood (Anderson et al. 1976; Inase et al. 1991; Magee et al. 1986; Voisin et al. 1994; Wagner et al. 1960). Children may also be exposed from drinking water containing asbestos fibers or from ingesting asbestos-containing dust or soil. Asbestos fibers are not expected to undergo significant transformation in soil, and it is well documented that young children

ingest more soil than adults. Studies that examined levels of childhood exposure to asbestos through soil ingestion, however, were not located.

A few small studies have assessed the lung asbestos fiber content of children. In one, a small number of asbestos fibers were found in 10 of 41 infants aged 1–27 months (Haque and Kanz 1988). In another (Case et al. 1988), asbestos fiber levels in 10 of 15 children under the age of 19 were as high those seen in older, presumably more exposed, age groups; however, all but 2 of the children were over the age of 15 and could have been exposed in jobs. A survey of the lung fiber content of 60 American children aged 8–15 years who died between 1983 and 1987 was conducted by TEM to assess fiber burdens and exposure in children (Case et al. 1994). The preliminary results indicate that asbestos bodies and lung fiber concentrations were one to two orders of magnitude lower than found by the same laboratory in a study of a sample of general population adults. Asbestos bodies were absent in 57 of the children and below 100 asbestos bodies/g in 2 more, both of whom were rural residents. Thirty-eight percent of the subjects had 1 or more long (>5 μm) asbestos fibers. Thirty-three percent of the subjects had long chrysotile fibers and 5% or less contained long amphibole fibers. Short chrysotile fibers were present in twice as many subjects as the long fibers (63 vs. 33%). Short tremolite fibers were observed in 37 subjects. The geometric mean asbestos fiber concentration for the 60 subjects was 0.10×10^6 f/g dry lung tissue.

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

The people most likely to have high exposure to asbestos are workers who come into contact with asbestos while on the job. This includes people involved in the mining of asbestos and asbestos-containing minerals and manufacture of asbestos-containing products, and also people who install, service, remove, or use these products. The presence of asbestiform minerals is widespread in mining areas, and people employed in the mining and processing of other ores may therefore be exposed to asbestos (Rogers et al. 1997). Workers engaged in the demolition of buildings with asbestos-containing materials are also potentially exposed. Although recent regulations have resulted in a marked decrease in airborne exposure levels in the workplace, the currently acceptable upper limit in workplace air (0.1 f/mL) is still considerably higher than levels found outside the workplace (usually <0.001 f/mL). In the past, workers may have carried asbestos home on their clothing or in their hair, resulting in exposure of family members (Anderson et al. 1979; Case and Sebastien 1989). However, this is not likely to be of concern at the present.

People who live near an asbestos-related industry or near an asbestos-containing waste site may encounter elevated levels of asbestos in air and accumulate it in their lungs (Case 1991; Case and Sebastien 1987, 1989). People may also be exposed to asbestos from a variety of asbestos-containing products, from poorly performed asbestos removal, or from living or working in a building with deteriorating asbestos insulation. Working in a building with asbestos-containing material that is in good condition has not been shown to result in significantly elevated levels of asbestos in air (HEI 1991).

Some people may also be exposed to elevated levels of asbestos in drinking water, particularly where there are widespread natural deposits of asbestos (e.g., San Francisco Bay area), disposal of asbestos-containing ore tailings (e.g., Duluth, Minnesota), or the use of asbestos-containing cement pipes in drinking water distribution systems with low pH and low hardness (Craun et al. 1977; Kanarek et al. 1981; Webber et al. 1989).

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 asbestos is available. Where adequate information is not available, ATSDR, in conjunction with the National Toxicology Program (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 asbestos.

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.

6.8.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of asbestos are well characterized (see Chapter 4), and there does not appear to be a need for further research in this area.

Production, Import/Export, Use, Release, and Disposal. Asbestos is widely used by humans in a variety of products, and exposures are likely from a number of sources. Extensive data are available on current production, import, and use of asbestos (U.S. Bureau of Mines 1992). Releases to the environment may occur either to air or to soil and water, with releases to air being of greatest health concern. Waste friable asbestos is regulated as a hazardous substance, so disposal is permitted only in authorized waste sites. Methods of handling friable asbestos are prescribed to minimize dust release. However, data are lacking on the amount of asbestos disposed in waste sites, and on the location and status of these sites.

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. TRI, which contains this information for 1999, became available in 2001. This database is updated yearly and provides a list of industrial facilities producing, processing, and using friable asbestos and their emissions.

Environmental Fate. Asbestos fibers are fundamentally rather inert and are not considered to undergo transport or degradative processes in the environment analogous to organic pollutants. Additional studies on the behavior of fibers in water (processes such as change in metal ion and hydroxyl ion composition, adsorption to organic materials, flocculation and precipitation, etc.) would be helpful in evaluating water-based transport of fibers, as well as in improving methods for removal of fibers from water. Transport of fibers in air is governed by processes and forces which apply to all particulate matter (EPA 1977, 1979c), and these processes are reasonably well understood.

Bioavailability from Environmental Media. Asbestos fibers are insoluble and are not absorbed in the usual sense after inhalation, oral, or dermal exposure. Most exposures occur either to fibers in air or water, so the effect of matrices such as soil or food are largely unknown. It is possible that adsorption of fibers onto other dust particles could influence the location of deposition in the lung, and might even influence the cellular response to the fibers. Research to determine if this occurs and is of biological significance would be helpful.

Food Chain Bioaccumulation. No data were located on asbestos levels in the tissues of edible organisms. However, it is not expected that either aquatic or terrestrial organisms will accumulate a significant number of fibers in their flesh. Consequently, food chain bioaccumulation or biomagnification does not appear to be of concern.

Exposure Levels in Environmental Media. There have been extensive surveys of asbestos levels in water and air (both outside air and inside air) (Chesson et al. 1990; EPA 1979b, 1991b, 1992c; HEI 1991, 1992; Howe et al. 1989; IARC 1977; Kanarek et al. 1980, 1981; NRC 1984; Spengler et al. 1989). These studies have revealed that wide ranges of asbestos levels may be encountered, indicating that human exposures can only be estimated on a site-specific basis. By converting exposures levels from TEM f/mL to PCM f/mL using a global conversion factor, the benefit of increased sensitivity of TEM and its ability to identify fiber type is diminished. However, further studies on the sources of the fibers and key determinants of exposure level would be valuable. It is especially important that further studies of asbestos levels in environmental media investigate and report on the size distribution of the fibers, because this is important in evaluating the resultant risk. Few data exist on asbestos levels in soil, especially near waste sites. Reliable and recent monitoring data for the levels of asbestos in contaminated media at hazardous waste sites and in soil at mining and other sites with naturally elevated levels of asbestos are needed so that the information obtained on levels of asbestos in the environment can be used in combination with the known body burdens to assess the potential risk of adverse health effects in populations living in these areas. Also, techniques for estimating air levels of asbestos from soil concentrations and activity scenarios would enable screening level estimations of asbestos exposure in advance of activities or disturbances occurring at contaminated sites, without extensive air monitoring.

Several key factors have been recently identified by the European Respiratory Society Working Group regarding the analysis of mineral fibers in biological samples (De Vuyst et al. 1998). These include adequate sampling, comparable analytical procedures and expression of results, and the use of well-defined reference populations. It is important to obtain agreement on guidelines for these types of studies and work to get them adopted by investigators.

Exposure Levels in Humans. The best available methods to measure human exposure levels involve measuring retained fibers in lung tissue (Case 1994; Churg 1982; Churg and Warnock 1981; Churg and Wright 1994; Dufrense et al. 1995, 1996a, 1996b; Dodson et al. 1999; Gylseth et al. 1985; Sebastien et al. 1989; Wagner et al. 1986). Uses of concentrations of asbestos bodies and uncoated fibers in bronchoalveolar lavage and sputum samples as biomarkers of exposure also have been examined in several studies, but these approaches have not been fully developed as quantitative indicators of exposure (see Section 3.8.1). Fibers can also be detected in urine and feces (Cook and Olson 1979; Finn and Hallenback 1984), but these methods would likely reflect only recent exposures (within the last several days) and not the cumulative tissue burden. As discussed in Section 3.12, efforts to develop a noninvasive method for measuring fiber levels in tissue (especially in the lung) would be particularly

valuable in assessing human exposure to asbestos. Future studies of asbestos fiber concentrations in samples of biopsied or autopsied lung tissue from residents living near waste sites or other sites known to contain elevated levels of asbestos also would be helpful in estimating the magnitude of nonoccupational exposure associated with these sites.

Exposures of Children. Only a few small studies have assessed the lung asbestos fiber content of children (Case et al. 1988, 1994). Preliminary results from the most comprehensive of these studies indicate that asbestos bodies and lung fiber concentrations in children are one to two orders of magnitude lower than those found in adults. More data are needed on the levels of asbestos in children, and attempts should be made when these data are acquired to link the body burden with possible sources of exposure (e.g., residing in places with naturally elevated soil concentrations, in areas with mining or hazardous waste sites, or in housing with crumbling asbestos).

Children may be exposed to asbestos in the same ways that adults are exposed outside the workplace, from asbestos in the air especially near emission sources or in buildings with deteriorating asbestos-containing material. Children may also be exposed from drinking water containing asbestos fibers or from ingesting asbestos-containing dust or soil. However, there are factors, such as breathing rate and lung physiology, that may affect the deposition of fibers in lung tissue of children, and these factors need to be explored. These factors would be age-related, and may affect where and to what extent fibers are deposited. Just as children are exposed to asbestos in the same way as nonoccupationally-exposed adults, there are no childhood-specific means to decrease 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 asbestos 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 substance.

Many industries and researchers interested in studying the health effects of asbestos in exposed workers maintain registries of individuals who were exposed to asbestos on the job.

6.8.2 Ongoing Studies

The Federal Research in Progress (FEDRIP 2001) 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.

No information was located regarding ongoing studies on the stability and migration of asbestos in the environment. The EPA and many state and local agencies are continuing to make measurements of asbestos levels in air and in water, in order to identify locations where significant health concerns may be warranted.

M.B. Schenker of Institute of Toxicology, University of California Davis; in Davis, California is leading a multidisciplinary study supported by National Cancer Institute (NCI). This study will examine whether environmental asbestos deposits in California are associated with increased rates of mesothelioma. The study will address geological occurrence of asbestos and potential human exposure based on population patterns and known occupational exposure, and epidemiological characteristics of the disease in the state. The project will plan a case-control study to rigorously test the hypothesis that mesothelioma in California is independently associated with environmental asbestos exposure.