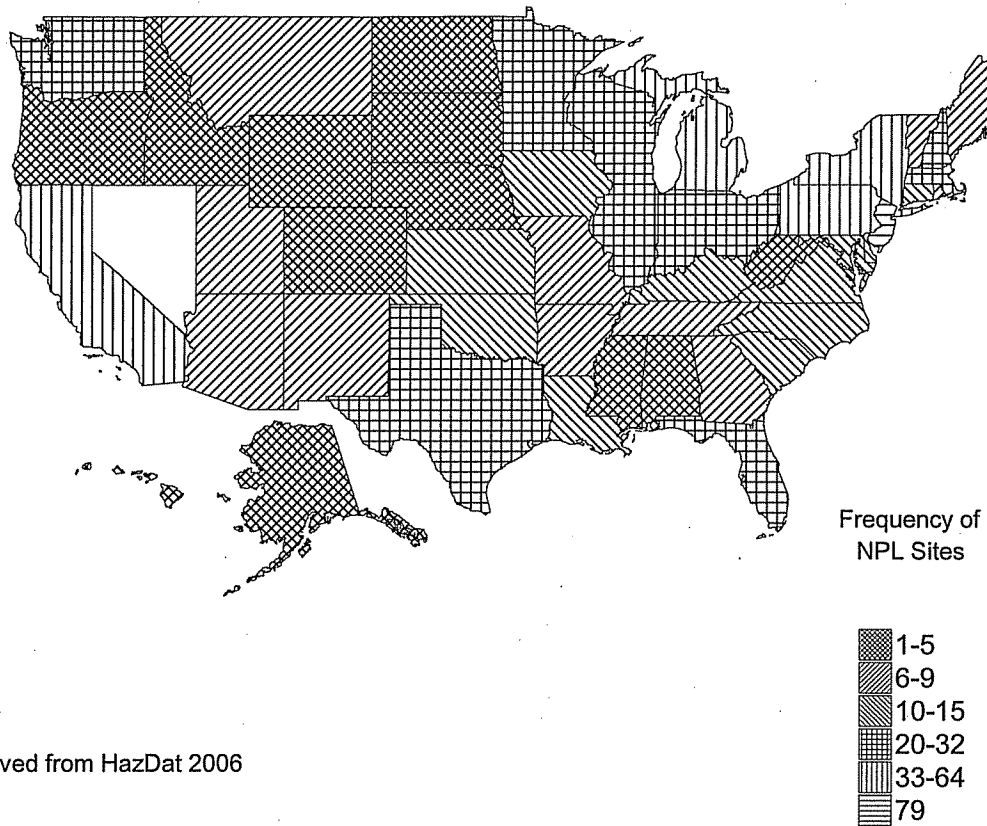# 6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

Xylene has been identified in at least 840 of the 1,684 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2006). However, the number of sites evaluated for xylene is not known. The frequency of these sites can be seen in Figure 6-1. Of these sites, 835 are located within the United States, 2 are located in the Commonwealth of Puerto Rico (not shown), 1 is located in Guam (not shown), and 2 are located on the Virgin Islands (not shown).

Xylenes are released to the atmosphere primarily as fugitive emissions from industrial sources (e.g., petroleum refineries, chemical plants), in automobile exhaust, and through volatilization from their use as solvents. Discharges into waterways and spills on land result primarily from use, storage, and transport of petroleum products and waste disposal. When xylenes are released to soil or surface water, they are expected to volatilize into the atmosphere. However, based on the mobility of these substances in soil, xylenes may also leach into groundwater, where they may persist for several months.

Xylene is rapidly transformed in the troposphere where photooxidation by hydroxyl radicals is the dominant process. Xylene is stable to hydrolysis and oxidation in the aquatic environment, but is expected to undergo biodegradation. However, based on the volatility of xylene, biotransformation of this substance in surface waters is not expected to compete with its evaporation into the air. Xylene is also expected to volatilize from soil surfaces. Biodegradation is an important process in subsurface soils and groundwater where volatilization is hindered. Xylene is not expected to adsorb strongly to soil; however, soil adsorption increases as organic matter content increases. Xylene has been found to bioaccumulate to very modest levels (e.g., bioconcentration factors of <100), and food-chain biomagnification has not been observed.

As is expected based on the partitioning and environmental fate of xylenes, these substances are primarily detected in air. Typical xylene concentrations range from 1 to 30 ppb in outdoor air and from 1 to 10 ppb in indoor air (see note at the end of Table 4-2). According to groundwater surveys conducted in the United States, xylenes are generally detected in <5% of groundwater samples. However, xylene concentrations in contaminated groundwater have been reported as high as 10,000 ppb. Little data are available reporting the concentrations of xylene in soil or surface water. Less than 6% of drinking water samples collected during U.S. drinking water surveys contained xylenes. Mean concentrations in positive

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

Frequency of
NPL Sites

1-5
6-9
10-15
20-32
33-64
79

Derived from HazDat 2006

samples were typically <2 ppb. Xylene has been detected in a variety of foods with typical concentrations ranging from 1 to 100 ppb.

Because individual xylene isomers are used in large amounts in industrial settings, people who work at or live near these locations may receive a higher exposure to one xylene isomer compared to the other isomers. However, since xylenes are present as a mixture in gasoline and in the solvent components of commonly used commercial products (paint, etc.), exposure of the general population is expected to be primarily to xylenes as a mixture, and not to the separate xylene isomers.

Xylene or its metabolites have been detected in human urine, blood, and expired air samples among members of the general population. Human exposure to xylene is believed to occur via inhalation of indoor and workplace air, inhalation of automobile exhaust, ingestion of contaminated drinking water, smoking, and inhalation and dermal absorption of solvents containing xylene.

When analyzing biological and environmental samples for xylene, it is difficult to separate the *m-* and *p*-isomers. Therefore, the concentrations of these two isomers are typically reported together as a sum (*m-/p*-xylene).

6.2   RELEASES TO THE ENVIRONMENT

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

6.2.1   Air

Estimated releases of mixed xylenes, *m*-xylene, *o*-xylene, and *p*-xylene to the atmosphere were
34.8 million pounds (16,000 metric tons), 0.5 million pounds (240 metric tons), 0.6 million pounds
(290 metric tons), and 1.4 million pounds (640 metric tons), respectively, to the atmosphere from 2,794,
58, 67, and 39 domestic manufacturing and processing facilities, respectively, in 2004. These releases
accounted for about 91, 93, 95, and 98% of the estimated total environmental releases of mixed xylenes,
m-xylene, *o*-xylene, and *p*-xylene, respectively, from facilities required to report to the TRI (TRI04 2006).
These releases are summarized in Tables 6 1, 6-2, 6-3, and 6-4, respectively.

Xylene has been identified in air samples collected at 143 of the 840 NPL hazardous waste sites where it
was detected in some environmental media (HazDat 2006).

Most annual releases of xylene are refinery losses into the atmosphere during the production,
transportation, and processing of petroleum. Other significant sources of xylene emissions are from the
use of solvents, as a component of automobile exhaust gases, evaporation of gasoline into the air during
its transportation and distribution, and releases from the chemical industry (Merian and Zander 1982).
Based on vapor pressures of 6–8 mm Hg (AIChE 1996; Chao et al. 1983; Lewis 2000), volatilization
from soil or surface water is also expected to be an important pathway for xylenes to enter the
atmosphere.

Releases of xylenes are associated with outgassing from landfills where disposal of industrial, hazardous,
and mixed municipal wastes occur. In Finland during 1989–1990, all three xylene isomers were detected
in gases released from closed municipal landfills at average concentrations of 0.86, 3.6, and 1.2 mg/m^3
(0.20, 0.83, and 0.28 ppm) for the *o*-, *m*-, and *p*-isomers, respectively (Assmuth and Kalevi 1992).
Concentrations of all of the xylene isomers in off-gases from an active landfill were 30–35 times higher.
In 1987–1988, air emissions of mixed xylene from facilities in the Houston, Texas, ship channel
industrial area were 551 tons per year (LaGrone 1991). The emissions resulted in an ambient
concentration in this area of 1.6 parts per billion volume (ppbv). The mean concentrations of *o*-xylene
and *m*-/*p*-xylene in landfill gas from the Fresh Kills Municipal Solid-waste Landfill in New York City
(Staten Island) were 2.17 and 5.97 ppmv, respectively (Eklund et al. 1998).

Eitzer (1995) measured volatile organic compound (VOC) emissions at eight municipal solid waste
compositing facilities. Respective mean *p*-xylene and *m*-/*o*-xylene concentrations were 1 and 2 μg/m^3

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Xylene (Mixed)[a]

							Reported amounts released in pounds per year[b]		
								Total release	
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
AK	10	22,415	41	0	820	0	23,268	7	23,275
AL	76	2,051,596	190	50	27,628	12,182	2,078,986	12,660	2,091,646
AR	35	571,748	46	0	74	0	571,794	74	571,868
AZ	27	87,092	0	0	5,901	768	87,097	6,664	93,761
CA	155	504,919	266	204	28,895	8,789	529,014	14,059	543,074
CO	19	70,584	0	0	10	479	70,584	489	71,073
CT	20	18,978	3	0	3	6,759	18,981	6,762	25,743
DE	9	93,557	0	0	51	0	93,557	51	93,608
FL	67	457,196	29	0	1	549	457,225	550	457,775
GA	67	1,070,406	252	0	589	755	1,071,198	805	1,072,003
GU	3	4,407	1	0	0	1,417	4,408	1,417	5,825
HI	11	25,708	43	0	1,710	2,795	25,758	4,498	30,256
IA	62	883,083	0	0	0	0	883,083	0	883,083
ID	4	39,534	No data	0	0	0	39,534	0	39,534
IL	134	1,287,226	296	0	6,483	6,504	1,288,763	11,746	1,300,509
IN	165	2,964,117	469	0	11,642	2,469	2,973,971	4,726	2,978,698
KS	52	773,525	146	293	1,033	50	774,006	1,041	775,047
KY	82	1,159,382	484	0	138,771	25,662	1,160,156	164,143	1,324,299
LA	80	1,096,942	710	27,957	13,236	7,374	1,127,021	19,199	1,146,219
MA	43	68,132	152	0	139	24,187	68,284	24,326	92,610
MD	23	102,410	266	0	139	250	102,677	388	103,065
ME	8	14,187	80	0	0	1,820	14,266	1,820	16,086
MI	137	2,768,110	27	0	49,160	155,142	2,777,445	194,994	2,972,439
MN	45	655,287	30	0	597	70	655,354	630	655,984
MO	77	1,797,940	0	0	510	1,748	1,797,940	2,258	1,800,198
MP	2	587	0	0	0	10	587	10	597
MS	47	1,056,657	50	0	1,826	0	1,058,407	126	1,058,533
MT	8	41,341	5	0	75	5,600	41,357	5,664	47,021
NC	62	609,558	0	0	558	4,296	609,558	4,854	614,412
ND	5	60,533	1	4	13	0	60,534	17	60,551
NE	19	231,469	No data	0	26,437	510	231,469	26,947	258,416
NH	6	32,052	No data	0	0	500	32,052	500	32,552
NJ	77	262,906	1,454	0	20,425	6,810	270,720	20,876	291,596
NM	13	71,564	5	25	230	5,468	71,824	5,468	77,292
NV	9	3,149	No data	0	902,695	0	905,844	0	905,844
NY	76	278,303	366	0	1,492	7,499	278,675	8,985	287,660

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Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Xylene (Mixed)[a]

State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	Total release On-site[j]	Total release Off-site[k]	Total release On- and off-site
OH	184	2,367,513	90	2,114	226,194	7,205	2,370,589	232,528	2,603,117
OK	37	471,134	47	109	560	50	471,566	333	471,899
OR	25	252,626	1,001	0	1,038	20,770	254,416	21,019	275,435
PA	147	1,080,111	725	0	11,167	18,372	1,080,857	29,517	1,110,375
PR	16	45,826	2	0	0	6	45,828	6	45,834
RI	9	8,395	6	0	0	7,305	8,401	7,305	15,706
SC	40	1,028,025	627	0	3,172	14,124	1,029,472	16,476	1,045,948
SD	16	399,993	No data	0	0	0	399,993	0	399,993
TN	86	1,918,718	80	0	1,137	9,962	1,918,799	11,098	1,929,897
TX	271	3,517,712	18,881	1,098,590	27,896	75,766	4,517,614	221,231	4,738,845
UT	23	135,919	1,000	0	1,051	2,141	137,169	2,942	140,111
VA	58	886,351	255	0	575	5	886,856	330	887,185
VI	3	49,114	0	0	1,089	0	49,114	1,089	50,203
VT	1	1,880	No data	0	0	0	1,880	0	1,880
WA	30	175,968	4	0	596	137	176,299	405	176,705
WI	80	830,359	5	0	25,478	1,665	855,764	1,743	857,507
WV	25	396,903	418	0	4,524	65	397,321	4,589	401,910
WY	8	25,986	0	0	69	0	26,055	0	26,055
Total	2,794	34,829,134	28,554	1,129,345	1,545,689	448,034	36,883,391	1,097,365	37,980,757

[a]The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b]Data in TRI are maximum amounts released by each facility.
[c]Post office state abbreviations are used.
[d]Number of reporting facilities.
[e]The sum of fugitive and point source releases are included in releases to air by a given facility.
[f]Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g]Class I wells, Class II-V wells, and underground injection.
[h]Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other on-site landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i]Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k]Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI04 2006 (Data are from 2004)

Table 6-2. Releases to the Environment from Facilities that Produce, Process, or Use *m*-Xylene[a]

State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
AL	1	201,000	22,000	0	250	0	223,250	0	223,250
AR	1	1,137	No data	0	5	0	1,137	5	1,142
CA	1	0	No data	No data	0	No data	No data	0	0
FL	1	4,505	No data	0	0	0	4,505	0	4,505
GA	4	38,421	No data	0	0	0	38,421	0	38,421
IA	3	14,891	No data	0	0	0	14,891	0	14,891
IL	2	6,271	4	0	173	0	6,276	173	6,449
IN	4	2,835	No data	0	0	0	2,835	0	2,835
KS	1	39,870	No data	0	0	0	39,870	0	39,870
KY	2	2,535	No data	0	0	0	2,535	0	2,535
LA	2	1,463	0	0	213	0	1,463	213	1,676
MO	1	933	0	0	0	0	933	0	933
MS	1	30,100	25	0	1,006	0	30,126	1,005	31,131
NE	2	11,265	No data	0	0	0	11,265	0	11,265
NJ	1	0	No data	No data	0	No data	No data	0	0
NM	2	190	No data	0	0	0	190	0	190
NY	1	920	No data	0	0	0	920	0	920
OK	1	500	1	0	0	0	501	0	501
PA	1	0	No data	No data	0	No data	No data	0	0
PR	1	11,530	0	0	0	0	11,530	0	11,530
SC	2	33,508	No data	0	0	0	33,508	0	33,508
TN	1	500	No data	0	0	0	500	0	500
TX	21	118,647	2,149	10,190	2,569	1,397	132,711	2,242	134,953
UT	1	0	No data	No data	0	No data	No data	0	0
Total	58	521,021	24,180	10,190	4,216	1,397	557,366	3,638	561,004

Reported amounts released in pounds per year[b] — Total release (On- and off-site columns)

[a]The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b]Data in TRI are maximum amounts released by each facility.
[c]Post office state abbreviations are used.
[d]Number of reporting facilities.
[e]The sum of fugitive and point source releases are included in releases to air by a given facility.
[f]Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g]Class I wells, Class II-V wells, and underground injection.
[h]Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other on-site landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i]Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k]Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI04 2006 (Data are from 2004)

Table 6-3. Releases to the Environment from Facilities that Produce, Process, or Use *o*-Xylene[a]

| | | Reported amounts released in pounds per year[b] | | | | | Total release | | |
| | | | | | | | | | On- and |
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	off-site
AL	4	224,186	9,500	0	252	0	233,938	0	233,938
AR	2	29,007	0	82	5	0	29,089	5	29,094
CA	2	114	0	0	0	0	114	0	114
FL	1	0	No data	0	0	No data	No data	0	0
GA	4	598	No data	0	3	0	598	3	601
IA	2	2,247	No data	0	0	0	2,247	0	2,247
IL	3	110,203	4	0	0	0	110,207	0	110,207
IN	1	424	No data	0	0	0	424	0	424
KS	2	17,966	No data	0	0	0	17,966	0	17,966
KY	1	0	No data	0	0	No data	No data	0	0
LA	2	2,739	0	0	2	0	2,739	2	2,741
MD	1	0	No data	0	0	0	0	0	0
MO	2	5,161	5	0	5	0	5,171	0	5,171
MS	1	16,400	25	0	503	0	16,425	503	16,928
NC	2	3,383	18	0	0	0	3,401	0	3,401
ND	1	0	No data	0	0	No data	No data	0	0
NE	2	1,144	No data	0	0	0	1,144	0	1,144
NJ	3	509	No data	0	0	0	509	0	509
NY	2	45,231	No data	0	0	0	45,231	0	45,231
PA	2	0	No data	0	0	No data	No data	0	0
PR	2	4,658	0	0	0	0	4,658	0	4,658
SC	1	12	No data	0	0	0	12	0	12
TN	2	16,509	No data	0	0	0	16,509	0	16,509
TX	20	162,940	1	25,174	1,096	614	189,107	718	189,825
UT	1	0	No data	0	0	No data	No data	0	0

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Table 6-3. Releases to the Environment from Facilities that Produce, Process, or Use *o*-Xylene[a]

State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	Total release On-site[j]	Off-site[k]	On- and off-site
WI	1	1,452	0	0	0	0	1,452	0	1,452
Total	67	644,883	9,553	25,256	1,866	614	680,941	1,231	682,172

[a]The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b]Data in TRI are maximum amounts released by each facility.
[c]Post office state abbreviations are used.
[d]Number of reporting facilities.
[e]The sum of fugitive and point source releases are included in releases to air by a given facility.
[f]Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g]Class I wells, Class II-V wells, and underground injection.
[h]Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other on-site landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i]Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k]Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI04 2006 (Data are from 2004)

Table 6-4. Releases to the Environment from Facilities that Produce, Process, or Use *p*-Xylene[a]

State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Total release		
						On-site[j]	Off-site[k]	On- and off-site
AL	1	380,000	360	0	4,150	380,610	3,900	384,510
AR	2	354	0	0	5	354	5	359
CA	1	12,862	No data	0	0	12,862	0	12,862
GA	1	11,410	No data	0	0	11,410	0	11,410
IA	2	487	No data	0	0	487	0	487
IN	1	2,496	No data	0	0	2,496	0	2,496
KS	1	8,284	No data	0	0	8,284	0	8,284
KY	1	0	No data	No data	0	No data	0	0
LA	1	0	No data	0	0	0	0	0
MS	1	123,000	25	0	503	123,025	503	123,528
NC	3	1,032	No data	0	0	1,032	0	1,032
NE	1	423,442	268	0	2,550	423,710	2,550	426,260
PA	1	0	No data	No data	0	No data	0	0
PR	1	18,338	0	0	0	18,338	0	18,338
SC	3	276,970	0	0	0	276,970	0	276,970
TN	2	24,482	No data	0	0	24,482	0	24,482
TX	15	136,545	2,144	10,539	1,724	150,479	473	150,952
UT	1	0	No data	No data	0	No data	0	0
Total	39	1,419,702	2,797	10,539	8,932	1,434,539	7,431	1,441,970

[a]The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b]Data in TRI are maximum amounts released by each facility.
[c]Post office state abbreviations are used.
[d]Number of reporting facilities.
[e]The sum of fugitive and point source releases are included in releases to air by a given facility.
[f]Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g]Class I wells, Class II-V wells, and underground injection.
[h]Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other on-site landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i]Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k]Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI04 2006 (Data are from 2004)

(0.23 and 0.46 ppb) in background air; 910 and 2,600 µg/m^3 (209 and 600 ppb) in tipping air; 1,600 and

3,700 µg/m^3 (370 and 850 ppb) in shredder air; 110 and 250 µg/m^3 (25 and 58 ppb) in indoor air; 250 and

420 µg/m^3 (56 and 97 ppb) in digester air; 250 and 520 µg/m^3 (58 and 120 ppb) in fresh compost air;

76 and 86 µg/m^3 (18 and 20 ppb) in mid-aged compost air; 31 and 55 µg/m^3 (7.1 and 13 ppb) in old

compost air; and 4 and 6 µg/m^3 (0.92 and 1.4 ppb) in curing compost air.

The mean concentration of xylene in the post combustion region of a German incineration plant (prior to

any emission reduction) was 7.881 µg/m^3 (1.816 ppb) (Zimmermann et al. 2001). Jay and Stieglitz

(1995) reported xylene concentrations of 7.77 and 1.79 µg/m^3 (1.79 and 0.412 ppb) in the emissions of a

municipal waste incineration plant at an unspecified location in Germany. Schauer et al. (2001) reported

emissions of *o*-xylene and *m*-/*p*-xylene during pine wood burning of 18.1 and 60.0 mg per kg of wood

burned, respectively.

o-Xylene was identified in the volatile emissions of a waste water treatment plant in Broward County,

Florida with an emission rate of approximately 16 mg/s (1,400 g/day) (Tansel and Eyma 1999). The

volatile emissions of xylenes measured in five municipal waste water treatment plants in Ontario, Canada

were 770, 129, 213, 408, and 0.16 g/day (Quigley and Corsi 1995). The volatile emissions of total

xylenes from four publicly owned treatment works servicing the Los Angeles, California area were 3,683,

215, 294, and 72 kg/year (Mayer et al. 1994)

Xylenes have been detected among other VOCs in the emissions of newly built homes (Hodgson et al.

2000; Zabiegala et al. 1999). The geometric mean (range) concentrations of *m*-/*p*-xylene in the indoor air

of four manufactured houses and seven site built houses in the eastern and southeastern United States

were 1.0 ppb (0.5–2.7 ppb) and 3.9 ppb (1.4–11.5 ppb), respectively (Hodgson et al. 2000). The

geometric mean (range) emission rates of *m*-/*p*-xylene from these houses were 3.2 µg/m^2-hour (<1.5–

9.1 µg/m^2-hour) and 9.5 µg/m^2-hour (<4.1–24.2 µg/m^2-hour), respectively. Brown et al. (1994) reported

weighted average geometric mean and 98th percentile *m*-/*p*-xylene concentrations of 280 and 2,700 µg/m^3

(65 and 620 ppb), respectively, in seven new dwellings, 25 and 240 µg/m^3 (5.8 and 55 ppb), respectively,

in four new office buildings, and 9 and 85 µg/m^3 (2 and 20 ppb), respectively, in one new school building.

The concentration of *m*-/*p*-xylene in volatiles released from a tufted textile floor covering with styrene-

butadiene rubber backing ranged from 85.1 to 155 ng/L (19.6–35.7 ppt) (Sollinger et al. 1994).

o-Xylene and *m*-/*p*-xylene emission rates from diesel-powered medium duty trucks have been measured

as 830 and 2,330 µg/km (0.83 and 2.33 mg/km), respectively (Schauer et al. 1999). Schauer et al. (2002)

reported tailpipe *o*-xylene and *m*-/*p*-xylene emission rates of 5,410 and 14,300 µg/km (5.41 and
14.3 mg/km), respectively, for catalyst-equipped gasoline-powered vehicles and 562,000 and
1,720,000 µg/km (562 and 1,720 mg/km), respectively, for noncatalyst-equipped gasoline-powered
vehicles. Mean *o*-xylene and *m*-/*p*-xylene tail pipe emission rates from cars that use a catalyst were
0.0042–0.0110 and 0.0054–0.0270 g/km (4.2–11 and 5.4–27 mg/km), respectively, compared to mean
emission rates of 0.0330 and 0.0868 g/km (33 and 86.8 mg/km), respectively, from a car that did not use a
catalyst (Chan et al. 1995). These authors reported mean *o*-xylene and tail pipe emission rates of
approximately 0.010 g/km (10 mg/km) from noncatalyst motorcycle engines and 0.016 g/km (37 mg/km)
from a catalyst motorcycle engine. Mean *m*-/*p*-xylene tail pipe emission rates were approximately
0.028 g/km (28 mg/km) from the noncatalyst motorcycle engines and 0.037 g/km (37 mg/km) from the
catalyst motorcycle engine. Gabele (1997) reported that *o*-xylene and *m*-/*p*-xylene made up 1.58 and
4.55%, respectively, of total organic emissions in the exhaust of 10 four-stroke lawnmower engines.

o-Xylene and *m*-/*p*-xylene emission values measured in the Craeybeckx tunnel in Antwerp, Belgium were
0.148 and 0.307 g/kg carbon, respectively, under highway conditions and 0.216 and 0.442 g/kg carbon,
respectively, under congested conditions (De Fré et al. 1994). Average concentrations in the tunnel air
were 17 µg/m^3 (3.9 ppb) for *o*-xylene and 34 µg/m^3 (7.8 ppb) for *m*-/*p*-xylene, compared to background
concentrations of 1.0 µg/m^3 (0.23 ppb) for *o*-xylene and 2.4 µg/m^3 (0.55 ppb) for *m*-/*p*-xylene. The
authors estimated total yearly vehicle emissions in Belgium of 824 metric tons/year (1.82 million
pounds/year) for *o*-xylene and 1,690 metric tons/year (3.72 million pounds/year) for *m*-/*p*-xylene based on
the congested traffic emissions data. Vehicle emission rates measured in the Los Angeles roadway tunnel
in 1993 were 200 mg/L of consumed fuel for *o*-xylene and 557 mg/L of consumed fuel for *m*-/*p*-xylene
(Fraser et al. 1998b). Lawryk and Weisel (1996) measured mean *o*-xylene and *m*-/*p*-xylene in vehicle
concentrations of 20.7 and 52.9 µg/m^3 (4.77 and 12.2 ppb), respectively, in the Lincoln Tunnel and
12.5 and 31.4 µg/m^3 (2.88 and 7.47 ppb), respectively, on the New Jersey Turnpike.

6.2.2   Water

Estimated releases of mixed xylenes, *m*-xylene, *o*-xylene, and *p*-xylene to surface water were
29,000 pounds (13 metric tons), 24,000 pounds (11 metric tons), 10,000 pounds (4.3 metric tons), and
3,000 pounds (1.3 metric tons), respectively, to the atmosphere from 2,794, 58, 67, and 39 domestic
manufacturing and processing facilities, respectively, in 2004. These releases accounted for <0.1, 4.3,
1.4, and <0.1% of the estimated total environmental releases of mixed xylenes, *m*-xylene, *o*-xylene, and

p-xylene, respectively, from facilities required to report to the TRI (TRI04 2006). These releases are summarized in Tables 6-1, 6-2, 6-3, and 6-4.

Xylene has been identified in groundwater and surface water samples collected at 556 and 150 of the 840 NPL hazardous waste sites, respectively, where it was detected (HazDat 2006).

Xylenes may be introduced into groundwater by fuel oil, gasoline, or solvent spills, infiltration of polluted surface waters, leaking underground petroleum storage tanks, or leaching from disposed wastes (Giger and Schaffner 1981).

The mean concentrations of xylenes in three groundwater monitoring wells at a Shell Oil service station site in San Diego, California were 0.39, 1.23, and 19.35 mg/L (ppm) (Odermatt 1994). Groundwater extract from an oil spill site in northern Virginia contained xylene at a concentration of 2.8 ppm (Mushrush et al. 1994).

A total xylene concentration (concentration includes ethylbenzene) of 1.2 ppb was detected in effluent from containment ponds in the containment area of an oil spill that accumulated along the banks of the Atigun River, Alaska (Lysyj et al. 1980). Treated effluents from offshore oil drilling platforms in the Gulf of Mexico contained an average concentration of 0.3 mg/L (ppm) (concentration includes ethylbenzene) (Lysyj et al. 1980).

The mean influent concentrations of *o*-xylene and *m*-/*p*-xylene upstream of the Metropolitan Wastewater Treatment Plant of St. Paul, Minnesota were 4.09 and 9.03 μg/L (ppb), respectively, in grab samples and 4.04 and 2.64 μg/L (ppb), respectively, in composite samples (Balogh et al. 1998). Final effluent from a Los Angeles County waste-water treatment plant, sampled between November 1980 and August 1981, contained *o*-xylene and *p*-xylene at concentrations of 40 and 30 μg/L (ppb), respectively (Gossett et al. 1983).

All three xylenes have been detected in the leachate from landfills at concentrations ranging from 10 to 4,400 μg/L (ppb) for hazardous waste landfills and from 3.7 to 38 μg/L (ppb) for domestic landfills (Först et al. 1989a, 1989b). Roy (1994) reported a concentration range of 2.5–320 μg/L (ppb) for xylenes in municipal landfill leachate. The concentration of xylenes detected in 6 of 13 landfills sampled in Minnesota ranged from 1.3 to 950 μg/L (ppb) (Roy 1994). The concentration of *o*-xylene and *m*-/*p*-xylene in groundwater samples collected at the Orange County Landfill in central Florida range

from 0.04 to 38.78 µg/L (ppb) and from 0.10 to 3.18 µg/L (ppb), respectively (Chen and Zolteck 1995).

The concentration of *o*-xylene and *m*-/*p*-xylene in surface water samples at this site ranged from 0.07 to

0.09 µg/L (ppb) and from 0.07 to 0.10 µg/L (ppb), respectively.

Xylenes are also released to waterways through the use of gasoline powered outboard boat engines

(Gabele 2000; Juttner 1994). The rates of release of *o*-xylene and *m*-/*p*-xylene to water by an unleaded

gasoline powered four-stroke outboard motor were 3.7 and 7.1 mg/minute, respectively (Juttner 1994).

The aqueous emission rates of xylenes from a two-stroke outboard engine and a four-stroke outboard

engine range from 0.27 to 0.86 g/kW-hour (0.075–0.24 kg/kJ) and from 0.07 to 0.09 g/kW-hour (0.019–

0.025 kg/kJ), respectively (Gabele 2000).

6.2.3   Soil

Estimated releases of mixed xylenes, *m*-xylene, *o*-xylene, and *p*-xylene to soil were 1.5 million pounds

(700 metric tons), 4,200 pounds (1.9 metric tons), 2,900 pounds (1.3 metric tons), and 8,900 pounds

(4.0 metric tons), respectively, to the atmosphere from 2,794, 58, 67, and 39 domestic manufacturing and

processing facilities, respectively in 2004. These releases accounted for 4, 0.8, 0.4, and 0.6% of the

estimated total environmental releases of mixed xylenes, *m*-xylene, *o*-xylene, and *p*-xylene, respectively,

from facilities required to report to the TRI (TRI04 2006).

An additional 1.1 million pounds (510 metric tons) of mixed xylenes, 10,000 pounds (4.6 metric tons) of

m-xylene, 25,000 pounds (11.4 metric tons) of *o*-xylene, and 11,000 (4.8 metric tons) of *p*-xylene,

constituting about 3, 1.8, 3.7, and 0.7%, respectively of the total environmental emissions, were released

via underground injection (TRI04 2006). These releases are summarized in Tables 6-1, 6-2, 6-3, and 6-4.

Xylene has been identified in soil and sediment samples collected at 469 and 139 of the 840 NPL

hazardous waste sites, respectively, where it was detected (HazDat 2006).

No quantitative information was available in the literature regarding total releases of xylene to soil.

Atmospheric xylene may reach soils either by wet deposition by precipitation or through dry deposition of

material adsorbed to particulate matter in air. Xylene may also reach soils from the introduction of man-

made wastes (e.g., landfills) or as a result of accidental releases (e.g., spills).

Xylene was detected in only 4 out of 30 sediment samples collected adjacent to combined sewer overflow outfalls along the lower Passaic River in New Jersey at concentrations of 15, 7, 6, and 5 µg/kg (ppb) (Iannuzzi et al. 1997).

6.3   ENVIRONMENTAL FATE

The environmental fate (transport, partitioning, transformation, and degradation) is expected to be similar for each of the xylene isomers based on the similarities of their physical and chemical properties.

6.3.1   Transport and Partitioning

Based on Henry's law constants of 0.005–0.007 atm-m^3/mol (Foster et al. 1994; Sanemasa et al. 1982), volatilization is expected to be the dominant transport mechanism for xylenes in surface water. The half-life associated with the volatilization of *o*-xylene from surface waters at a depth of 1 meter is reported to be 5.6 hours (Mackay and Leinonen 1975). This value will vary in accordance with turbulence and water depth. Once xylenes enter the atmosphere, they undergo rapid photooxidation such that washout and long-range atmospheric transport are not expected to be important processes.

Soil organic carbon sorption coefficient (K_{oc}) values ranging from 25.4 to 540 indicate that xylenes are mobile in soil and will not adsorb strongly to organic matter, although adsorption does increase with increasing organic matter (Green et al. 1981; Kango and Quinn 1989; Nathwani and Phillips 1977; Seip et al. 1986; Swann et al. 1983). Based on the Henry's law constants and vapor pressures (6.6–8.8 mm Hg) (AIChE 1996; Chao et al. 1983; Lewis 2000), xylenes that are released to soil are expected to volatilize if near the surface. However, the mobility of xylenes in soil indicates that these substances may also leach into groundwater, especially when volatilization is hindered as is the case with underground releases from gasoline storage tanks.

When xylene was spilled at an application depth of 7.2 cm (2.9 inches) or less on loam-textured soil at moisture contents ranging from 0.15 to 0.26 kg/kg, 1–4% volatilized, 0.5–35% leached, 50–85% degraded, and 6–12% remained after about 80 days in the soil (Aurelius and Brown 1987). Most of the observed volatilization occurred immediately after application. A greater percentage of xylene initially evaporated when it was applied to the wet soil compared to the dry soil. However, after the initial retention in the dry soil, there was less moisture to entrap the subsurface soil and prevent it from later volatilizing or degrading. The xylene that remained in the wet soil after the initial evaporation was then blocked by the moisture and was less able to volatilize or degrade. Therefore, xylene is expected to

evaporate more rapidly when spilled onto wet soil than when spilled onto dry soil; however, removal is expected to be more complete in the dry soil after the initial retention period.

Xylene moves through unsaturated (drier) soil faster than water and other polar solvents (Amoozegar et al. 1986; Barbee and Brown 1986). For example, diffusion coefficients of approximately 0.02 and 0.005 cm^2/second were measured in dry and wet (12–15%) cores taken from the first natural barriers at the Los Alamos National Laboratory chemical waste site (Fuentes et al. 1991). Additional field data suggesting that concentrated organics may leach 10–1,000 times faster than water in unsaturated soil were provided by Griffin et al. (1984). This increased conductivity is probably due to cracks in the soil through which the organics move rapidly (Aurelius and Brown 1987).

Measured log octanol-water partition coefficient (log K_{ow}) values are 2.77, 3.15, and 3.20 for *o*-, *p*-, and *m*-xylene, respectively (Chiou et al. 1982; Gherini et al. 1989). The rapid oxidation of xylene isomers to their corresponding polar metabolites seems to preclude bioconcentration in higher animal systems and, therefore, bioaccumulation up the food chain is unlikely (NRC 1980). Bioconcentration factors (BCFs) for *o*-, *m*-, and *p*-xylenes have been estimated to be 45, 105, and 95, respectively (EPA 1985a). Bioconcentration of xylene has been observed in shrimp (*Pandalus platyceros*) (Sanborn and Malins 1980), manila clams (*Tapes semidecussata*) (Nunes and Benville 1979), and eels (*Anguilla japonica*) (Ogata and Miyake 1978). A bioconcentration factor of 6 has been reported for tissue uptake in clams throughout an 8-day exposure to *o*-, *m*-, and *p*-xylenes (Nunes and Benville 1979), and bioconcentration factors of 21.4, 23.6, and 23.6 have been reported for eels exposed to 50 ppm of *o*-, *m*-, and *p*-xylenes, respectively (Ogata and Miyake 1978). Tissue levels reached a steady state after 10 days. The green alga *Selenastrum capricornutum* has bioconcentration factors of 257, 251, and 218 for *p*-, *m*-, and *o*-xylenes, respectively (Herman et al. 1991). Bioconcentration has been predicted for all isomers of xylene because of their tendency to partition into the octanol phase of the octanol-water system (EPA 1978). Scientists generally regard BCFs below 20 as indicative of little or no bioconcentration, 20–100 as equivocal, and <1,000 as indicative of modest bioconcentration.

6.3.2   Transformation and Degradation

6.3.2.1   Air

Xylene is transformed in the atmosphere by photooxidation. Based on experimental reaction rate constants of 13.7×10^{-12}–23.6×10^{-12} cm^3/molecule-sec (Atkinson 1989; Kwok and Atkinson 1995), the calculated half-life of xylenes in air is 8–14 hours using a hydroxyl radical concentration of

5.00×10^5 molecules/cm^3 and a 12-hour day (Atkinson 1990). The transformation of xylene by reaction with hydroxyl radicals prevails over that of reaction with ozone (half-life 3–78 years) and nitrate radicals (half-life 80–220 days) (Atkinson and Carter 1984; Atkinson et al. 1982, 1984, 1991; ECETOC 1986; Fox et al. 1984; Mill 1980; Roberts et al. 1984). Direct photolysis is not expected because xylene does not significantly absorb light at wavelengths >290 nm (Jori et al. 1986). Major photodegradation products formed by the cleavage of the aromatic ring in the presence of nitric oxide are: *o*-tolualdehyde, methylglyoxal, 4-nitro-*o*-xylene, and 2,3-dimethylphenol for *o*-xylene; 2,6-dimethylphenol, 2,4-dimethylphenol, methylglyoxal, and *m*-tolualdehyde for *m*-xylene; and *p*-tolualdehyde and 2,5-dimethylphenol for *p*-xylene (Atkinson et al. 1991; Gery et al. 1987). Glyoxal and methylglyoxal may form approximately 30–50% of the photooxidation products (Tuazon et al. 1986). *o*-Xylene also forms formaldehyde, acetaldehyde, biacetyl nitrate, and peroxyacetylnitrate (Bandow and Washida 1985; Darnall et al. 1979; Shepson et al. 1984; Takagi et al. 1980). The products of photoreaction with hydroxyl radicals are ultimately degraded to carbon dioxide and water after absorption in the hydrosphere (Guisti et al. 1974).

6.3.2.2 Water

The primary removal process for xylene in surface water is expected to be volatilization. Xylenes are not expected to undergo hydrolysis, and biodegradation is not fast enough to be a competing process (Rathbun 1998). However, biodegradation is expected to an important removal process for xylenes in groundwater since volatilization is hindered under these conditions (Rathbun 1998).

Data describing the degradation of xylenes in surface waters are limited. The first-order degradation-rate coefficients for *o*-xylene and *m*-/*p*-xylene in a strip-pit pond formed as a result of coal-mining operations were 3.6 and 6.5 day^{-1}, respectively, after amendment with nutrients (Bouwer 1989; Rathbun 1998). These rate coefficients correspond to half-lives of approximately 4.6 and 2.6 hours, respectively. Clapp et al. (1994) observed the biodegradation of priority pollutants in waste water treated in both an activated sludge reactor and a biological aerated filter reactor. Influent concentrations were 1.929 μg/L (ppb) for *o*-xylene and 5.53 μg/L (ppb) for *m*-/*p*-xylene, while effluent and percent removal concentrations were <1.2 μg/L (ppb) and >38%, respectively, for *o*-xylene and <1.2 μg/L (ppb) and >78%, respectively, for *m*-/*p*-xylene in both types of reactors.

The majority of xylene biodegradation studies have examined the fate of this substance in groundwater. During a field experiment conducted at Base Borden in Ontario, Canada, xylenes were degraded to 50%

of initial concentrations (1,080–1,290 µg/L (ppb)) in a shallow sand aquifer in approximately 20–40 days (Barker 1987). The authors reported similar results in aerobic laboratory biodegradation tests. Biodegradation of xylenes is expected to be slower under anaerobic conditions. The aerobic biodegradation half-lives of *o*-, *m*-, and *p*-xylene in an unconfined, uncontaminated aquifer after injection with 100% PS6 gasoline were 116, 70, and 100 days, respectively (API 1994). The gasoline was injected above a landfill leachate zone. Although biodegradation of petroleum hydrocarbons (including xylene) spilled in northern Alaska was observed, the authors concluded that this process is likely to be limited by a short annual thaw season (Braddock and McCarthy 1996).

The half-life of xylenes measured in groundwater from an anaerobic aquifer in Seal Beach, California was approximately 25 days (Beller et al. 1995). Xylene degradation metabolites observed by these authors included the methylated homologs of benzylsuccinic acid, benzylfumaric acid, and E-phenylitaconate (Beller 2000; Beller et al. 1995). *o*-Xylene was anaerobically degraded by approximately 75–100% 30 days in groundwater after it was injected into contaminated aquifers (Reusser et al. 2002). Detection of methylbenzylsuccinic acid in the same wells following injection was additional evidence of xylene biodegradation. Between 92 and 95% of xylene released from a gasoline spill at an underground storage tank site was degraded over a distance of 80 m from the spill location (Kao and Wang 2001). The major removal process was biodegradation under iron-reducing conditions. Thierrin et al. (1995) measured a half-life of 125–170 days for xylenes under anoxic groundwater conditions. The first-order anaerobic biodegradation rate constants for *o*-, *m*-, and *p*-xylene were 0.028–0.11, 0.026–0.10, and 0.017– 0.067 week^{-1} (corrected for dilution), respectively, in an underground gasoline storage tank spill plume at the Sleeping Bear Dunes National Lakeshore in Michigan. These rate constants correspond to half-lives of 7–25 weeks for *o*-xylene, 7–27 weeks for *m*-xylene, and 10–41 weeks for *p*-xylene (Wilson et al. 1994). Hunt et al. (1997) did not observe anaerobic biodegradation of xylenes at Sleeping Bear Dunes National Lakeshore and reported that this process may be hindered by the presence of acetate and other non-BTEX organic carbon. These authors did observe anaerobic biodegradation of xylenes in groundwater at a site near Rocky Point, North Carolina. Weidemeier et al. (1995a) concluded that BTEX was biodegraded both aerobically and anaerobically at two U.S. air force bases (AFB) (Hill AFB and Patrick AFB) with sulfite reduction being the primary removal mechanism at Hill AFB and methanogenesis being the primary removal mechanism at Patrick AFB. Greater than 99% of xylene at the Hill AFB site was degraded after traveling 305 m downgradient from the contamination source. Only 38% of xylene (34% *o*-xylene, 60% *m*-xylene, and 21% *p*-xylene) at the Patrick AFB site was degraded after traveling 98 m downgradient from the contamination source. Differences in the degradation rates

and half-lives reported in these studies are most likely due to differences in study conditions such as temperature, presence of oxygen, and presence of electron acceptors.

6.3.2.3   Sediment and Soil

If xylene is released to soil, the dominant removal process is expected to be volatilization. However, in situations where volatilization is hindered, biodegradation is expected to be an important fate process.

o-Xylene in vials containing unsaturated soil was biodegraded within 5 days after a lag period of 10 days (English and Loehr 1991). However, subsequent additions of *o*-xylene to the soil were degraded without a lag period. The half-life after the sixth addition to the soil was less than 3 hours. *o*- and *p*-Xylene applied to a soil microcosm at 3 μL/g (2.6 mg/g) were aerobically degraded in less than 25 days (Tsao et al. 1998). CO_2 production measured during the experiment ranged from approximately 35–65%. *p*-Xylene, at an initial concentration of 45 ppm, was completely degraded in natural potting soil microcosm in less than 27 days at 20 °C (Eriksson et al. 1999). It was not degraded at 6 °C.

Elshahed et al. (2001) reported that xylenes were degraded anaerobically in an aquifer microflora laboratory test under sulfate-reducing conditions, but not under methanogenic conditions. *m*-Xylene was completely degraded in less than 25 days under sulfate-reducing conditions. The authors proposed that the successive metabolites involved in the ultimate anaerobic degradation of xylenes are methylbenzyl-succinic acid, toluic acid, phthalic acid, and benzoic acid (finally degraded to carbon dioxide).

The first-order biodegradation rate constants for xylene calculated from data collected at a gasoline spill site in Beaufort, South Carolina ranged from 0.10 to 0.31 d^{-1} near the water table (Lahvis et al. 1999). These rates correspond to half-lives of 2–7 days. Sovik et al. (2002) calculated first-order biodegradation rate constants of 0.1–0.11 d^{-1} for xylene applied to a lysimeter trench at the Gardermoen delta north of Oslo, Norway. These rates correspond to half-lives of 6–7 days.

Total VOCs (including xylene) added to sewage sludge-amended fields were reduced to a concentration similar to that in control fields within 36 days in a plowed plot and within 8 days in a pasture plot (Wilson and Jones 1996; Wilson et al. 1997). The half-lives calculated for *o*-xylene and *m*-/*p*-xylene were 7.6 and 5.8 days, respectively, in the plowed plot and 0.7 and 0.3 days, respectively, in the pasture plot. During a laboratory soil study conducted by these authors, 92.6% of the total VOC concentration was lost after 65 days from an unsterilized treatment compared to 88.1% loss from a sterilized treatment. This indicates

that abiotic factors, such as volatilization, are primarily responsible for this degradation, with
biodegradation accounting for approximately 5% of the loss.

6.4   LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

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

6.4.1   Air

Since one of the largest sources of xylene release into the atmosphere is auto emissions, atmospheric
concentrations are related to urbanization. Ambient air concentrations of xylene in industrial and urban
areas of the United States have been reported to range from 0.003 to 0.38 mg/m^3 (1–88 ppb) (Merian and
Zander 1982). Median *o*-xylene concentrations calculated from a compilation of atmospheric data on
organic chemicals were 0.41 μg/m^3 (0.094 ppb) in rural/remote areas (114 observations), 5.2 μg/m^3
(1.2 ppb) in urban/suburban areas (1,885 observations), and 3.5 μg/m^3 (0.81 ppb) in source-dominated
areas (183 observations) (EPA 1983). The median concentrations for the combined *m*- and *p*-isomers
were 0.38 μg/m^3 (0.088 ppb) in rural/remote areas (115 observations), 12 μg/m^3 (2.8 ppb) in
urban/suburban areas (1,911 observations), and 7.4 μg/m^3 (1.7 ppb) in source-dominated areas
(186 observations) (EPA 1983). Air samples in highly industrialized areas of Illinois (Chicago and East
St. Louis) between 1986 and 1990 had mean concentrations of 3.9–16 μg/m^3 (0.90–3.7 ppb) (for *m*- and
p-xylene combined) and 2.9–3.3 μg/m^3 (0.67–0.76 ppb) (for *o*-xylene and styrene combined). Levels in
rural areas of Illinois were 1.2 μg/m^3 (0.28 ppb) (for *m*- and *p*-xylene combined) and 1.1 μg/m^3 (0.25 ppb)
(for *o*-xylene and styrene combined). Paints (including automobile paint), chemical plants, and vehicle
exhaust were the major sources of these chemicals (Sweet and Vermette 1992). Concentrations of
xylenes measured in outdoor air at various locations are listed in Table 6-5. Based on these data, typical
xylene concentrations in outdoor air range from 1 to 30 ppb.

Air samples collected at 12 cities around the United States between 1979 and 1984 contained average
concentrations of 1.0–10.2 ppb for *m*-/*p*-xylene and 0.3–4.2 ppb for *o*-xylene (Singh et al. 1985). In

Table 6-5. Xylene Concentrations in Outdoor Air

Location	Type of value	Concentration (ppb)			Reference
		o-Xylene	*m-/p*-Xylene	Total xylenes[a]	
Urban					
Urban/suburban United States	Median	1.2	2.8	4	EPA 1983
Industrial/Urban United States	Range	—	—	1–88[b]	Merian and Zander 1982
Urban 12 U.S. cities	Mean	0.3–4.2	1.0–10.2	—	Singh et al. 1985
39 U.S. cities	Range	0.9–79	1.3–338	7.2[c]	EPA 1989
39 U.S. cities	Median	8.0	20.0	28.0	Mohamed et al. 2002
9 major U.S. cities	Median	0.3–3.1	0.7–8.6	—	Mohamed et al. 2002
Chicago, East St. Louis	Mean	0.67–0.76[d]	0.9–3.7	—	Sweet and Vermette 1992
Los Angeles	Range	4–13	11–45	—	Grosjean and Fung 1984
Las Vegas	Range	0–1.1	0–0.46	—	Tran et al. 2000
Phoenix	Mean	1.07	2.92	3.99	Zielinska et al. 1998
Tucson	Mean	0.46	1.21	1.67	Zielinska et al. 1998
Columbus, Ohio	Mean	0.31	0.82	1.1	Spicer et al. 1996
Rural					
Rural United States	Median	0.094	0.088	0.18	EPA 1983
Rural Illinois	Mean	0.25[d]	0.28	0.53[d]	Sweet and Vermette 1992
Rural Arizona	Mean	0.30, 0.43	0.82, 1.13	1.12, 1.56	Zielinska et al. 1998
Mixed Locations					
25 sites in Minnesota	Mean	0.18	1.18[e]	1.36	Pratt et al. 2000
Southern California	Mean	1.7	4.5	6.2	Fraser et al. 2000
Approximately 100 U.S. locations	Median	0.51	1.96[e]	0.51	EPA 1993; Kelly et al. 1994
Remote					
Remote Arizona	Mean	0.02	0.03	0.05	Zielinska et al. 1998
North Atlantic	Mean	0.003	0.0068[e]	0.0098	Eichmann et al. 1979
Indian Ocean	Mean	0.00021	0.00028[e]	0.00049	Eichmann et al. 1980
Pacific Ocean	Range	0.01–0.77	<0.05–0.31	—	Greenberg and Zimmerman 1984

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Table 6-5. Xylene Concentrations in Outdoor Air

Location	Type of value	Concentration (ppb)			Reference
		o-Xylene	*m-/p*-Xylene	Total xylenes[a]	
Brazilian Rainforest	Range	—	—	<0.05–0.12[b]	Greenberg and Zimmerman 1984

[a]Unless otherwise indicated, total xylene concentrations listed here are the sum of the *o*-xylene and *m-/p*-xylene concentrations.
[b]Range of total xylenes reported in source
[c]Median total xylenes concentration reported in source
[d]Includes styrene
[e]Sum of *m*- and *p*-xylene concentrations (reported separately in source)

1981, atmospheric concentrations of *m-*/*p*-xylene and *o*-xylene, measured at a downtown Los Angeles location, were 11–45 and 4–13 ppbv, respectively (Grosjean and Fung 1984). Between 1984 and 1986, ambient air monitoring was conducted in 39 cities nationwide. All three isomers of xylene were detected in all cities at a median concentration of 7.2 ppb (range, 1.3–338 ppb for *m-*/*p*-xylene and 0.9–79 ppb for *o*-xylene) (EPA 1989). In 1990, *o*-xylene was measured at 4.2–6.9 μg/m^3 (0.97–1.6 ppb) in ambient outdoor air in Atlanta, Georgia (EPA 1991a).

o-Xylene and *m-*/*p*-xylene were detected in ambient air at Las Vegas, Nevada at concentrations of 0– 4.6 and 0–2.0 μg/m^3 (0–1.1 and 0–0.46 ppb), respectively (Tran et al. 2000). Trost et al. (1997) reported urban air concentrations of *o*-xylene and *m-*/*p*-xylene of 0.5 and 1.2 ppbv, respectively, in Boston, Massachusetts, 0.5 and 0.9 ppbv, respectively, in Chicago, Illinois, 1.1 and 2.9 ppbv, respectively, in Los Angeles, California, and 18 and 38 ppbv, respectively, in Houston, Texas. Mean concentrations of *o*-xylene and *m-*/*p*-xylene were 1.07 and 2.92 ppbv, respectively, in urban air from Phoenix, Arizona, 0.46 and 1.21 ppbv, respectively, in urban air from Tucson, Arizona, 0.30 and 0.82 ppbv, respectively, in rural air from Payson, Arizona, 0.43 and 1.13 ppbv, respectively, in rural air from Casa Grande, Arizona, and 0.02 and 0.03 ppbv, respectively in remote mountain top air near Hillside, Arizona (Zielinska et al. 1998). The mean (maximum) concentrations of *o*-xylene and *m-*/*p*-xylene in 142 air samples collected in the Columbus, Ohio area were 0.31 ppb (1.22 ppb) and 0.82 ppb (3.88 ppb), respectively (Spicer et al. 1996). Concentrations of xylenes in snow samples collected in Denver, Colorado during February, 1995 were <10, 86, 47, 32, and 38 ng/L (Bruce and McMahon 1996). Mohamed et al. (2002) reported median *o*-xylene and *m-*/*p*-xylene concentrations of 8.0 and 20.0 ppb, respectively, measured in the air of 39 U.S. cities. Median *o*-xylene and *m-*/*p*-xylene concentrations reported for nine major U.S. cities were 0.3– 3.1 and 0.7–8.6 ppb, respectively.

The mean and median concentrations of xylenes in air samples collected at 25 sites across Minnesota were 0.79 and 0.5 μg/m^3 (0.18 and 0.12 ppb), respectively, for *o*-xylene, 2.94 and 1.87 μg/m^3 (0.686 and 0.43 ppb), respectively, for *m*-xylene, and 2.11 and 1.36 μg/m^3 (0.49 and 0.31 ppb), respectively, for *p*-xylene (Pratt et al. 2000). The observed ambient mean concentrations of *o*-xylene and *m-*/*p*-xylene in Southern California based on data from Los Angeles, Azusa, and Claremont, California were 7.3 and 19.6 μg/m^3 (1.7 and 4.5 ppb), respectively (Fraser et al. 2000). EPA (1993) and Kelly et al. (1994) reported the ambient air concentrations of *o*-, *m*-, and *p*-xylene that were measured in 104, 98, and 102 U.S. locations, respectively. Median concentrations were 2.2 μg/m^3 (0.51 ppb) in 8,542 samples for *o*-xylene, 4.2 μg/m^3 (0.97 ppb) in 8,431 samples for *m*-xylene, and 4.3 μg/m^3 (0.99 ppb) in 3,597 samples for *p*-xylene.

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Mean concentrations of *o*-xylene and *m*-/*p*-xylene measured in vehicle tunnels were 61.79 and 148.04 ppb carbon, respectively, in the Caldecott tunnel of San Francisco, California, 17 and 34 μg/m³ (3.9 and 7.8 ppb), respectively, in the Craeybeckx tunnel in Antwerp, Belgium, 39.6 and 69.8 μg/m³ (9.12 and 16.1 ppb), respectively, in the Zefun tunnel of Taipei, Taiwan, and 74.4 and 104.0 μg/m³ (17.1 and 24.0 ppb) respectively, in the Lishin motorcycle tunnel of Taipei, Taiwan (De Fré et al. 1994; Hsieh et al. 1999; Zielinska and Fung 1994).

Mean in-vehicle concentrations of *o*-xylene and *m*-/*p*-xylene reported by Leung and Harrison (1999) for several locations in the United States were 2.5 and 2.7 ppb, respectively, in Birmingham, Alabama, 1.7 and 4.8 ppb, respectively, during the winter in Boston, Massachusetts, 2.6 and 7.1 ppb, respectively, during the summer in Raleigh, North Carolina, and 2.1 and 5.5 ppb, respectively, during the winter in New Jersey. The mean and range of xylene concentrations measured in the cabins of automobiles with gasoline engines in Germany were 6.2 and 1.4–22.6 μg/m³ (1.4 and 0.3–5.2 ppb), respectively, for *o*-xylene and 19.1 and 3.9–66.3 μg/m³ (4.4 and 0.9–15 ppb), respectively, for *m*-/*p*-xylene (Ilgen et al. 2001c). The mean and range of xylene concentrations in the cabins of automobiles with diesel engines were 2.7 and 1.0–5.9 μg/m³ (0.6 and 0.2–1.4 ppb), respectively, for *o*-xylene and 7.9 and 3.2–15.2 μg/m³ (1.8 and 0.7–3.5 ppb), respectively, for *m*-/*p*-xylene. Mean in-vehicle concentrations during suburban New Jersey-New York City commutes were 10.1 μg/m³ (2.33 ppb) for *o*-xylene and 22.5 μg/m³ (5.18 ppb) for *m*-/*p*-xylene with high ventilation and 14.5 μg/m³ (3.34 ppb) for *o*-xylene and 34.6 μg/m³ (7.97 ppb) for *m*-/*p*-xylene with low ventilation. The mean (range) xylene concentration measured in the air inside patrol cars was 4.5 ppb (1.4–12.1 ppb) compared to a concentration of 1.0 ppb (0.04–2.4 ppb) in air at an ambient site and 1.0 ppb (0.4–1.9 ppb) in roadside air (Riediker et al. 2003).

Chan et al. (1994) reported the concentrations of VOCs that commuters were exposed to in Taipei, Taiwan during the spring of 1992. The mean, median, and maximum concentrations of *o*-xylene were 95, 90, and 265 μg/m³ (22, 21, and 61 ppb), respectively, in the bus, 161, 140, and 405 μg/m³ (37, 32, and 93 ppb), respectively, in the car, and 244, 225, and 467 μg/m³ (56, 52, and 108 ppb), respectively, on a motorcycle. The mean, median, and maximum concentrations of *m*-/*p*-xylene were 149, 141, and 480 μg/m³ (34, 32, and 111 ppb), respectively, in the bus, 240, 212, and 479 μg/m³ (55, 49, and 110 ppb), respectively, in the car, and 362, 350, and 698 μg/m³ (83, 81, and 161 ppb), respectively, on a motorcycle.

Jo and Choi (1996) reported higher concentrations of xylenes in urban vehicles compared to suburban vehicles during commutes in Korea. Mean, median, and maximum concentrations of *o*-xylene were 22.8, 17.7, and 90.1 μg/m³ (5.2, 4.1, and 21 ppb), respectively, in urban automobiles and 16.6, 12.4 and

65.6 μg/m^3 (3.8, 2.9, and 15 ppb), respectively, in urban buses. Mean, median, and maximum concentrations of m-/p-xylene were 28.9, 23.2, and 82.7 μg/m^3 (6.7, 5.3, and 19 ppb), respectively, in urban automobiles and 23.1, 16.3, and 64.3 μg/m^3 (5.3, 3.8, and 15 ppb), respectively, in urban buses. Mean, median, and maximum concentrations of o-xylene were 13.1, 11.0, and 33.9 μg/m^3 (3.0, 2.5, and 7.8 ppb), respectively, in suburban automobiles and 9.5, 7.5, and 36.4 μg/m^3 (2.2, 1.7, and 8.4 ppb), respectively, in suburban buses. Mean, median, and maximum concentrations of m-/p-xylene were 18.6, 14.9, and 47.0 μg/m^3 (4.3, 3.4, and 11 ppb), respectively, in suburban automobiles and 12.5, 9.8, and 34.2 μg/m^3 (2.9, 2.3, and 7.9 ppb), respectively, in urban buses.

Xylene has also been detected in remote locations. Average background levels of o-, m-, and p-xylene, measured over the North Atlantic in 1977, were 13, 21, and 9.2 ng/m^3 (0.003, 0.0048, and 0.002 ppb), respectively (Eichmann et al. 1979). Similar measurements over the Indian Ocean gave average concentrations of 0.9, 1.1, and 0.15 ng/m^3 (0.21, 0.25, and 0.03 ppt), respectively (Eichmann et al. 1980), while over the Pacific Ocean, concentrations ranged from below the detection limit (0.05 ppbv) to 0.31 ppbv for m- and p-xylene and from 0.01 to 0.77 ppbv for o-xylene (Greenberg and Zimmerman 1984). All three xylene isomers were detected in the air of the Brazilian rainforest in 1979–1980, at concentrations ranging from below the detection limit (0.05 ppbv) to 0.12 ppbv (Greenberg and Zimmerman 1984). The concentrations of o-xylene and the combination of m- and p-xylene measured in Antarctic snow collected near the coast of the Ross Sea ranged from 1 to 80 ng/L and from 8 to 198 ng/L, respectively (Desideri et al. 1994, 1998). It is unlikely that xylenes were carried to these locations by long-range atmospheric transport since the half-life of these substances in air is 8–14 hours. One explanation given for the presence of xylenes in the remote oceanic locations was that they were being released in marine aerosols from contaminated ocean water (Desideri et al. 1994, 1998; Eichmann et al. 1979, 1980). However, sources of this marine contamination were not identified.

Recent studies have indicated that xylene is also a common but low contaminant of indoor air both at home and in the workplace. Xylene concentrations measured in indoor air are listed in Table 6-6. Based on these data, the concentrations of xylene in indoor air typically range from 1 to 10 ppb.

Concentrations of m- and p-xylene measured in homes at 15 locations in the United States ranged from 10 to 47 μg/m^3 (2.3–10.8 ppb) (Seifert and Abraham 1982). Similar results were reported during a 1981 study of the correlation between breath concentration and personal and outdoor air concentrations of 350 New Jersey residents (Wallace et al. 1986). The weighted median indoor air concentrations of o-xylene and the combined m- and p-xylene isomers were 4.9 and 14 μg/m^3 (1.1 and 3.2 ppb),

Table 6-6. Xylene Concentrations in Indoor Air

Location	Type of value	Concentration (ppb)			Reference
		o-Xylene	m-/p-Xylene	Total xylenes[a]	
U.S. Locations					
15 homes	Range	—	2.3–10.8	—	Seifert and Abraham 1982
Homes of 350 New Jersey residents	Median	1.1	3.2	4.3	Wallace et al. 1986
Homes of 36 students in New York City					Kinney et al. 2002
Summer	Mean	0.52	1.48	2.0	
Winter (30 students)	Mean	0.77	2.40	3.2	
Library of Congress in Washington, DC	Mean	0.7	1.7[b]	2.4[b]	NIOSH 1990a
50 "normal" houses	Median	0.41	1.3[b]	1.71[b]	Kostiainen 1995
7 "sick" houses	Median	0.77	2.2[b]	2.97[b]	Kostiainen 1995
"Sick" building	Range	0.99–1.6	2.8–5.1	—	Weschler et al. 1990
Office buildings in United States					Shields et al. 1996
50 telecommunications offices	Geometric mean	0.65[c]	0.99	1.64[c]	
9 data centers	Geometric mean	1.1[c]	1.5	2.6[c]	
11 administrative offices	Geometric mean	0.81[c]	1.11	1.92[c]	
Canadian homes					Fellin and Otson 1994
Winter (185 homes)	Mean	0.94	3.72[d]	4.66	
Spring (178 homes)	Mean	1.59	4.73[d]	6.32	
Summer (197 homes)	Mean	0.70	2.43[d]	3.13	
Fall (194 homes)	Mean	1.89	8.10[d]	9.99	
U.K. Indoor locations					Kim et al. 2001
64 homes	Mean	0.44	1.64[d]	2.08	
12 offices	Mean	0.41	1.08[d]	1.49	
6 restaurants, 6 pubs	Mean	1.4, 1.6	5.1, 5.7[d]	6.5, 7.3	
8 department stores, 6 cinemas, 3 perfume shops	Mean	0.81, 1.4, 0.55	2.81, 4.9, 1.91[d]	3.62, 6.3, 2.46	
6 libraries	Mean	0.76	2.81[d]	3.57	
8 labs	Mean	0.18	0.58[d]	0.76	

Table 6-6. Xylene Concentrations in Indoor Air

Location	Type of value	Concentration (ppb)			Reference
		o-Xylene	m-/p-Xylene	Total xylenes[a]	
German homes					Ilgen et al. 2001
Rural homes (summer)	Mean	0.16	0.744	0.904	
Rural homes (winter)	Mean	0.36	1.1	1.46	
Urban homes (summer)	Mean	0.36	1.09	1.45	
Urban homes (winter)	Mean	0.64	1.91	2.55	

[a]Unless otherwise indicated, total xylene concentrations listed here are the sum of the o-xylene and m-/p-xylene concentrations.
[b]Does not include m-xylene concentration because it was not reported in the source.
[c]Includes styrene
[d]Sum of m- and p-xylene concentrations (reported separately in source)

respectively. Breath concentrations showed significant correlation with personal air concentrations but only weak correlation with outdoor air concentrations. Concentrations in indoor air were usually higher than in outdoor air, indicating that the source of the xylene was building materials or household products (e.g., cleaning agents) (Wallace et al. 1986, 1987b). However, in areas where heavy automotive traffic has increased outdoor xylene concentrations, ventilating homes by leaving windows open may actually result in additional increases in indoor xylene levels (Hung and Liao 1991). That indoor sources of xylene contribute significantly to the levels of these chemicals in interior spaces was also demonstrated in an indoor air monitoring study conducted in February and March 1989 on the premises of the Library of Congress in Washington, DC. *p*-Xylene and *o*-xylene were present at mean levels of 7.2 μg/m^3 (1.7 ppb) and 3.2 μg/m^3 (0.7 ppb) in indoor air and 3.2 μg/m^3 (0.7 ppb) and 1.2 μg/m^3 (0.3 ppb) in outdoor air, respectively (NIOSH 1990a).

Analysis of a building with "sick building syndrome" in the summer of 1987 showed significant differences in the concentrations of xylenes in indoor and outdoor air. Combined *m*- and *p*-xylene concentrations were 12–22 μg/m^3 (2.8–5.1 ppb) and 3.9 μg/m^3 (0.9 ppb) for indoor and outdoor air, respectively, while *o*-xylene concentrations were 4.3–6.8 μg/m^3 (0.99–1.6 ppb) for indoor air and 2.8 μg/m^3 (0.64 ppb) for outdoor air. Higher levels of the xylenes were detected during autumn for indoor but not outdoor samples. Potential sources were tobacco smoke and other consumer products including carpet adhesive (Weschler et al. 1990). Kostianen (1995) measured the concentrations of VOCs in the indoor air of 50 "normal" houses and 38 "sick" houses. Median concentrations of *o*-xylene and *p*-xylene in the "normal" houses were 1.8 and 5.77 μg/m^3 (0.41 and 1.3 ppb), respectively. Concentrations were only provided for 7 of the 38 "sick" houses. *o*-Xylene concentrations in these houses ranged from 1.74 to 1,100 μg/m^3 (0.40–253 ppb) with median and geometric mean values of 3.35 and 8.74 μg/m^3 (0.77 and 2.01 ppb), respectively. *p*-Xylene concentrations ranged from 5.46 to 2,240 μg/m^3 (1.26–516 ppb) with median and geometric mean values of 9.53 and 23.9 μg/m^3 (2.20 and 5.51 ppb), respectively.

Ilgen et al. (2001b) measured geometric mean *o*-xylene and *m*-/*p*-xylene concentrations of 0.68 and 3.23 μg/m^3 (0.16 and 0.744 ppb), respectively, in German rural homes and 1.56 and 4.74 μg/m^3 (0.36 and 1.09 ppb), respectively, in German urban homes during the summer. Winter *o*-xylene and *m*-/*p*-xylene concentrations were 1.57 and 4.97 μg/m^3 (0.36 and 1.1 ppb), respectively, in the rural homes, and 2.78 and 8.27 μg/m^3 (0.64 and 1.91 ppb), respectively, in the urban homes.

Fellin and Otson (1994) measured seasonal indoor air concentrations of VOCs in Canadian homes during 1991. The mean concentrations of *o*-, *m*-, and *p*-xylene were 4.09, 11.21, and 4.96 μg/m^3 (0.94, 2.58, and

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1.14 ppb), respectively, in 185 homes during the winter, 6.89, 13.17, and 7.38 μg/m^3 (1.59, 3.03, and 1.70 ppb), respectively, in 178 homes during the spring, 3.03, 6.81, and 3.73 μg/m^3 (0.698, 1.57, and 0.86 ppb), respectively, in 197 homes during the summer, and 8.19, 26.03, and 9.12 μg/m^3 (1.89, 6.00, and 2.10 ppb), respectively, in 194 homes during the fall.

Graham et al. (2004) studied the effect of vehicle emission infiltration from an attached garage on the concentrations of VOCs in house air. The median levels of xylenes measured in 15 Canadian homes before and after running a warm vehicle in the garage during the afternoon were 18 and 34.5 ng/L, respectively. Median levels in these houses before and after running the vehicles following a cold start in the morning were 22.1 and 47.8 ng/L, respectively. Median concentrations of xylenes measured in the garage were 274 ng/L after running the vehicles in the afternoon and 1,001 ng/L after running the vehicles in the morning.

The mean concentrations of *o*-xylene and *m*-/*p*-xylene were 1.52 and 4.46 μg/m^3 (0.350 and 1.03 ppb), respectively, in the home outdoor air and 3.36 and 10.4 μg/m^3 (0.774 and 2.40 ppb), respectively, in the home indoor air of 36 students from west central Harlem in New York City during the winter (Kinney et al. 2002). *o*-Xylene and *m*-/*p*-xylene concentrations during the summer were 2.00 and 5.77 μg/m^3 (0.461 and 1.33 ppb) respectively, in the home outdoor air and 2.27 and 6.44 μg/m^3 (0.523 and 1.48 ppb), respectively, in the home indoor air of 30 students from this area. Mean *o*-xylene and *m*-/*p*-xylene concentrations measured in the personal air of the students were 2.24 and 6.71 μg/m^3 (0.516 and 1.55 ppb), respectively, during the winter and 3.93 and 10.9 μg/m^3 (0.906 and 2.51 ppb), respectively, during the summer.

Jo et al. (2003) did not observe a large difference in xylene indoor air concentrations at high apartment floors compared to the air at low floors. In contrast, the concentrations of other chemicals such as methyl tertiary butyl ether, toluene, and benzene were higher in the air at the lower floors. Median *o*-xylene and *m*-/*p*-xylene concentrations were 4.6 and 13.1 μg/m^3 (1.1 and 3.02 ppb), respectively, in air from low floors compared to 4.8 and 14.2 μg/m^3 (1.1 and 3.27 ppb), respectively, in air from high floors. The type of ventilation used in the apartment buildings was not indicated.

Ilgen et al. (2001b) reported that xylene concentrations in the indoor air of homes dramatically increased after redecoration, painting, and varnishing. Elevated *o*-xylene and *m*-/*p*-xylene levels attributed to these activities ranged from 11.2 to 103.8 μg/m^3 (2.6–23.9 ppb) and from 28.5 to 352.4 μg/m^3 (6.6–81 ppb), respectively, compared to normal levels ranging from 0.7 to 1.4 μg/m^3 (0.16–0.32 ppb) and from 2.6 to

5.9 µg/m³ (0.60–1.4 ppb), respectively. Leung and Harrison (1998) reported xylene concentrations measured in various microenvironments. Values were highest in the painted room and traffic tunnel microenvironments with mean *o*-xylene concentrations of 9.0 and 5.1 ppb, respectively, and mean *m*-/*p*-xylene concentrations of 24.6 and 22.7 ppb, respectively.

In the United Kingdom, Kim et al. (2001) measured xylene concentrations in the air of 64 homes, 12 offices, 6 restaurants, 6 pubs, 8 department stores, 6 cinemas, 3 perfume shops, 6 libraries, and 8 labs. Mean concentrations at these locations were 0.8–6.9 µg/m³ (0.18–1.6 ppb) for *o*-xylene, 1.9–18.3 µg/m³ (0.44–4.2 ppb) for *m*-xylene, and 0.6–6.5 µg/m³ (0.14–1.5 ppb) for *p*-xylene. Mean concentrations reported for each location are listed in Table 6-6. These authors also measured xylene in the air of 12 train stations, 12 coach stations, 12 trafficked roads, 18 trains, 18 busses, and 35 cars. Xylene levels were highest in the cars, with mean concentrations of 54.2, 127.2, and 52.5 µg/m³ (12.4, 29.3, and 12.1 ppb) for *o*-, *m*-, and *p*-xylene, respectively. Mean concentrations at the other locations were 3.5–13.2 µg/m³ (0.81–3 ppb) for *o*-xylene, 10.1–32.3 µg/m³ (2.3–7.4 ppb) for *m*-xylene, and 3.5–11.6 µg/m³ (0.81–2.7 ppb) for *p*-xylene.

Shields et al. (1996) measured the VOC concentrations in the air of 70 outdoor locations, 50 telecommunications offices, 11 administrative offices, and 9 data centers throughout the United States. The geometric mean concentrations of *m*-/*p*-xylene at these locations were 2.7, 4.3, 4.6, and 6.7 µg/m³ (0.62, 0.99, 1.1, and 1.5 ppb), respectively. The geometric mean concentrations of *o*-xylene (reported in combination with styrene) at these locations were 1.4, 2.8, 3.5, and 4.8 µg/m³ (0.32, 0.65, 0.81, and 1.1 ppb) respectively. The concentration of *o*-xylene and *m*-/*p*-xylene measured in the air of three photocopy centers ranged from 0.5 to 16.8 ppb and from 0.7 to 9.4 ppb, respectively (Stefaniak et al. 2000). The concentrations of xylene in 22 air samples collected from nonproduction departments of 6 pulp, paper, and paper product mills ranged from <1 to 82 ppm with mean and median concentrations of 23 and 17 ppm, respectively (Teschke et al. 1999).

6.4.2   Water

Limited monitoring data are available on ambient concentrations of xylenes in surface waters. In view of the rapid volatilization of xylenes, their presence in surface waters is unlikely to be significant. Surface waters generally contain average xylene concentrations of <1 ppb total xylenes except in areas where there are fuel processing activities, such as petroleum refining (ECETOC 1986; Otson et al. 1982b; Sauer

et al. 1978). Typical surface water concentrations range from not detected to 2 µg/L (ppb) (Otson et al. 1982b; Sauer et al. 1978).

According to 1999–2005 nationwide U.S monitoring data from the STORET database, mixed xylenes were detected in 1,252 out of 9,189 water samples with a median (range) concentration of 5.5 µg/L (ppb) (0.05–75,000 µg/L [ppb]) (EPA 2005h). *o*-Xylene was detected in 414 out of 3,623 STORET water samples with a median (range) concentration of 0.32 µg/L (ppb) (0.001–2,400 µg/L [ppb]). *m*-Xylene was detected in 76 out of 532 STORET water samples with a median (range) concentration of 0.5 µg/L (ppb) (0.02–2.18 µg/L [ppb]). *p*-Xylene was detected in 73 out of 526 STORET water samples with a median (range) concentration of 0.5 µg/L (ppb) (0.01–2 µg/L [ppb]). *m-/p*-Xylene was detected in 358 out of 3,147 STORET water samples with a median (range) concentration of 0.53 µg/L (ppb) (0.004–4,300 µg/L [ppb]).

The concentrations of *o*-xylene measured in estuarine water from Humber, Tyne, Wear, and Tweed, United Kingdom were all <10 ng/L (ppt); however, *o*-xylene was detected at Tees, United Kingdom at concentrations up to 1,340 ng/L (ppt) (Dewulf and Van Langenhove 1997). This high concentration of *o*-xylene was attributed to the use of this isomer as an intermediate in the production of phthalic anhydride. Concentrations of *o*-xylene and the combination of *m*- and *p*-xylene in estuarine water from Sheldt, Netherlands/Belgium were 21.0 and 23.0 ng/L (ppt), respectively. Mixed xylenes have been detected in estuarine water from Brazos, United States at concentrations ranging from 1 to 56 ng/L (ppt). Xylenes have been detected in beach, bay, shelf sea, and coastal waters in locations around the world. *o*-Xylene concentrations were 1.8–42 ng/L (ppt) at Vineyard Sound, United States, 210 ng/L (ppt) at La Pineda, Spain, 0.3–10.1 ng/L (ppt) at the Gulf of Mexico, 4.0 ng/L (ppt) at Vilanova/Sitges, Spain, 6.1 ng/L (ppt) at Barcelona, Spain, <1–13 ng/L (ppt) at the Campeche Shelf, <10–35 ng/L (ppt) at the North Sea, and 9.8–11.9 ng/L (ppt) at the Belgian Continental Shelf. The concentrations of *m-/p*-xylene at these locations were 2.5–66, 34, 27–24.4, 72, 15, 22–59, <10–50, and 11.0–15.1 ng/L (ppt), respectively. The concentration of *o*-xylene was <10 ng/L (ppt) in water samples from five coastal locations in the United Kingdom.

Xylenes were detected in stormwater samples collected from basins around the state of North Carolina at mean, median, and maximum concentrations of 0.15, 0.08, and 2.37 µg/L (ppb), respectively, for *o*-xylene and 0.14, 0.09, and 1.62 µg/L (ppb), respectively, for *m-/p*-xylene (Borden et al. 2002). Concentrations of detected xylene in 592 stormwater samples from 16 cities and metropolitan areas across

the United States ranged from 0.2 to 15 µg/L (ppb) with a median concentration of 0.4 µg/L (ppb)
(percent detected not reported) (Delzer et al. 1997).

Data on the occurrence of xylene in public drinking water supplies are available from several federal,
regional, and state surveys (EPA 1985a). In most cases, <6% of the groundwater and surface water
systems sampled contained detectable levels of xylenes (EPA 1985a). Typical xylene concentrations (all
isomers) ranged from 0.2 to 9.9 µg/L (ppb) with mean concentrations of <2 µg/L (ppb) (EPA 1985a;
Keith et al. 1976; Williams et al. 1982). The Unregulated Contaminant Information System (URCIS)
database round 1 contains public water system contaminant data for a 24-state cross-section (EPA 2001a).
o-Xylene was detected in 2.41% of 1,450 surface water public water systems and 1.69% of 12,638
groundwater public water systems. *m*-Xylene was detected in 2.12% of 1,276 surface water public water
systems and 1.47% of 10,145 groundwater public water systems. *p*-Xylene was detected in 2.36% of
1,230 surface water public water systems and 1.49% of 8,956 groundwater public water systems. Total
xylenes were detected in 10.75% of 670 surface water public water systems and 2.51% of 8,841
groundwater public water systems. The 99th percentile concentrations of *o*-, *m*-, *p*-, and total xylenes for
the round 1 data were <5.0, <4.0, <5.0, and 0.6 µg/L (ppb), respectively. The California EPA Office of
Drinking Water quality-monitoring database contains drinking water contaminant data for both surface
water and groundwater sources throughout the state of California (Storm 1994). According to these data,
xylene has been detected in 23 out of 11,589 California public drinking water sources (0.2%) with mean
and median detected concentrations of 22.91 and 3.80 µg/L (ppb), respectively.

The migration of petroleum products from leaking underground storage tanks and pipelines poses a
groundwater contamination problem. Gasoline-contaminated groundwater in Los Angeles contained
levels of xylenes as high as 153 µg/L (ppb) (Karlson and Frankenberger 1989). Contaminated
groundwater from a New Jersey industrial site contained xylenes at a concentration of 3.68 mg/L (ppm)
(Adey et al. 1996).

The concentration of *o*-xylene in groundwater collected from a sampling well at a crude oil spill site in
north central Minnesota was 269 µg/L (ppb) (Eganhouse et al. 1996). The concentrations of total xylenes
detected in the leachate plume of a closed landfill in Norman, Oklahoma were 0–1 µg/L (ppb)
(Eganhouse et al. 2001). The concentration of xylenes measured in groundwater from a hydrocarbon-
contaminated site in Southern California was 1,010 µg/L (ppb) (Kent and Spycher 1994). The
concentrations of *m*-xylene and the combination of *o*- and *p*-xylene measured at the Biscayne Aquifer
Superfund site study area were 20 and 23 µg/L (ppb), respectively (Canter and Sabatini 1994).

Seventeen out of 338 water samples collected from four sites in Iowa using drain tiles, observations wells, or lysimeters contained xylene with a mean concentration of 3.0 µg/L (ppb) and a maximum concentration of 5 µg/L (ppb) (Wang et al. 1995). Xylenes were detected above a minimum detection limit of 0.2 µg/L (ppb) in approximately 15% of groundwater samples collected from 30 wells located throughout the Denver, Colorado area with a maximum concentration of 33 µg/L (ppb) (Bruce and McMahon 1996). During the National Water Quality Assessment Program of the U.S. Geological Survey, mixed xylenes were detected above a reporting level of 0.2 µg/L (ppb) in 2.2% (9 of 406) of urban wells with median and maximum detected concentrations of approximately 2 and 50 µg/L (ppb), respectively (Kolpin et al. 1997; Squillace et al. 1999). Mixed xylenes were detected above 0.2 µg/L (ppb) in 0.9% (23 of 2,542) of rural wells with median and maximum detected concentrations of approximately 0.5 and 200 µg/L (ppb), respectively. Concentrations of xylenes measured in groundwater are listed in Table 6-7.

Concentrations of *o*-xylene and the combination of *m*- and *p*-xylene in Antarctic pack ice located at the coast of the Ross Sea range from 10 to 20 ng/L (ppt) and from 29 to 54 ng/L (ppt), respectively (Desideri et al. 1998).

6.4.3   Sediment and Soil

Although several investigators (Aurelius and Brown 1987; Barbee and Brown 1986; Griffin et al. 1984) refer to leaching of xylene from waste disposal sites as a source of xylene levels in groundwater samples, little data are available on actual measurements of xylene in soil. The rapid volatilization of this chemical makes its presence in surface soils unlikely. According to 1999–2005 nationwide U.S. monitoring data from the STORET database, mixed xylene was detected in 90 out of 528 soil samples with a median (range) concentration of 0.038 mg/kg (0.001–190 mg/kg) (EPA 2005h).

The concentrations of *o*-xylene and *m*-/*p*-xylene ranged from <0.05 to 3.2 ng/g (ppb) (mean 0.89 ng/g [ppb]) and from 0.08 to 5.2 ng/g (ppb) (mean 1.4 ng/g [ppb]) in sediment samples collected from seven rivers and a port located in the Niigata Perfecture, Japan (Kawata et al. 1997). The concentration of xylenes measured in an aquifer matrix from a hydrocarbon-contaminated site in Southern California was 5,300 µg/kg (ppb), respectively (Kent and Spycher 1994). According to 1999–2005 nationwide U.S. monitoring data from the STORET database, mixed xylene was detected in 14 out of 165 sediment samples with a median (range) concentration of 0.087 mg/kg (0.001–41 mg/kg) (EPA 2005h).

Table 6-7. Xylene Concentrations in Groundwater[a]

Location	Percent detected	Positive concentration (ppb)			Reference
		Mean	Median	Maximum	
General surveys					
4 sites in Iowa	5	3.0	—	10,000	Wang et al. 1995
30 wells around Denver, Colorado	15	—	—	33	Bruce and McMahon 1996
406 urban U.S. wells	2.2	—	2.0	50	Squllace et al. 1999
2,542 rural U.S. wells	0.9	—	0.5	200	Squllace et al. 1999
Individual contaminated sites					
Los Angeles site (gasoline contamination)	—	—	—	153	Karlson and Frankenberger 1989
New Jersey industrial site	—	3,680[b]	—	—	Adey et al. 1996
Minnesota crude oil spill site	—	269[c]	—	—	Eganhouse et al. 1996
Leachate from closed Oklahoma landfill	—	—	—	1	Eganhouse et al. 2001
Southern California site	—	1,010[b]	—	—	Kent and Spycher 1994
Biscayne Aquifer Superfund site	—	43[d]	—	—	Canter and Sabatini 1994

[a]Reported in sources as concentrations of xylene unless otherwise specified
[b]Value reported by source as single concentration of xylenes at that site
[c]Value reported by source as single concentration of *o*-xylene at that site (*m*- and *p*-xylene not reported)
[d]Value is the sum of reported single *o*- and *p*-xylene concentrations at that site (*m*-xylene not reported)

6.4.4   Other Environmental Media

Xylene has been detected in cigarette smoke, consumer products, and some foods. The gas phase delivery of *p*-xylene in ultra-low tar delivery cigarette smoke ranges from <0.01 to 8 µg/cigarette, while the ranges for *m*- and *o*-xylene are <0.01–20 and <0.005–10 µg/cigarette, respectively (Higgins et al. 1983). Data were not located for regular strength or unfiltered cigarettes. The 1,095 household products surveyed by the Consumer Product Safety Commission (Fishbein 1985) contained an average of 9.5% mixed xylene. The largest number of products containing mixed xylene were household aerosols and paints, varnishes, shellac, and rust preventatives. The concentrations of *o*-xylene measured in interior alkyd primer and three interior alkyd enamel paints were 1.39, 4.91, 5.48, and 6.92 mg/g (1,390, 4,910, 5,480, and 6,920 ppm) (Fortmann et al. 1998). The concentrations of *p*-xylene in these paints were 0.23, 0.73, 1.45, and 1.36 mg/g (230, 730, 1,450, and 1,360 ppm).

Xylene has been detected in distillates of rainbow trout and in carp tissue samples from three rivers not known to be contaminated (Hiatt 1983). The estimated tissue concentrations of *m*- and *p*-xylene in rainbow trout and carp were 0.05 and 0.12 mg/kg (ppm), respectively (Hiatt 1983).

Eggs, whether stored or used fresh, contained detectable levels of all three xylene isomers when scrambled (Matiella and Hsieh 1991). The polystyrene packing case in which some of the eggs had been stored also contained detectable levels of the xylene. Actual concentrations of *o*-, *m*-, and *p*-xylene were 4.0, 7.0, and 3.0 ng/g (ppb), respectively, in supermarket eggs packed in polystyrene, 3.0. 8.0, and 2.7 ng/g (ppb), respectively, in fresh eggs not stored, and 2.0, 3.0, and 1.3 ng/g (ppb), respectively, in fresh eggs stored in polystyrene for 2 weeks.

o-Xylene was detected above 3.72 ppb in 32 of 234 table-ready food items analyzed during a Total Diet Study conducted by the FDA with an average concentration of 8.15 ppb (range 3.72–23.5 ppb) (Heikes et al. 1995). *m*-/*p*-Xylene was detected in 64 out of the 234 food items with an average concentration of 64 ppb (range 6.20–114 ppb). The concentrations of *o*-xylene in sandwich cookies, margarine, butter, and cake doughnuts measured during this study were 6.31, 21.7, 12.5, and 23.5 ppb, respectively. The concentrations of *m*- and *p*-xylene together in these foods were 12.9, 114, 54.8, and 35.0 ppb, respectively.

The mean and range of *m*-/*p*-xylene concentrations were 0.24 and 0.01–0.75 ng/mL, respectively, in 19 whole milk samples, 0.08 and 0.02–0.33 ng/mL, respectively, in eight 2% milk samples, and 0.27 and

0.01–0.56 ng/mL, respectively, in five 1% milk samples collected in Las Vegas, Nevada (Hiatt and Pia 2004). The mean and range of *o*-xylene concentrations were 0.18 and 0.01–0.62 ng/mL, respectively, in the whole milk samples, 0.08 and 0.02–0.29 ng/mL, respectively, in the 2% milk samples, and 0.21 and 0.01–0.40 ng/mL, respectively, in the 1% milk samples.

Both *o*- and *m*-xylene were detected in the aroma concentrates of cured beef (Ramarathnam et al. 1991) as well as in the volatile fraction of raw beef (King et al. 1993). Only *o*-xylene was detected in cured chicken. None of the xylene isomers were detected in the uncured meat samples. *o*-, *m*-, and *p*-Xylene have been detected in the headspace of frankfurter sausages at unspecified concentrations (Chevance and Farmer 1999). Ho et al. (1983) identified *o*-xylene as a volatile flavor compound in fried bacon. *o*-Xylene has also been identified in the volatiles of fried chicken (Tang et al. 1983). Wu and Liou (1992) measured reported *o*-, *m*-, and *p*-xylene concentrations of 1.85, 0.99, and 0.72 ppb, respectively, in duck meat, 14.91, 4.29, and 5.97 ppb, respectively, in duck fat, 1.90, 9.61, and 10.64 ppb, respectively, in Cantonese style roasted duck, and 10.29, 18.09, and 21.23 ppb, respectively, in Cantonese style duck gravy.

The concentrations of *o*-, *m*-, and *p*-xylene were measured to be 132 ng/g (ppb), not detected, and 79.4 ng/g (ppb), respectively, in Korean anchovy; 102 ng/g (ppb), 378 ng/g (ppb), and not detected, respectively in Korean big eyed herring; not detected, 124 ng/g (ppb), and not detected, respectively, in Korean hair tail viscera; and 58.6, 99.9, and 39.0 ng/g (ppb), respectively in Korean Shrimp pastes (Cha and Cadwallader 1995). Chung (1999) reported measured *o*-, *m*-, and *p*-xylene concentrations of 31.4, 53.8, and 36.0 μg/kg (ppb), respectively, in the leg meat of crabs (*C. feriatus*), 23.6, 40.1, and 2.8 μg/kg (ppb), respectively, in the body meat of the crabs, and 199.7, 329.4, and 234.6 μg/kg (ppb), respectively, in the carapace meat of the crabs. Misharina and Golovnya (1992) also detected xylenes among the volatile components of shrimp and crabmeat. *o*- and *m*-Xylene have been identified in the volatiles of cooked mussels (Leguen et al. 2000).

Xylene (unspecified isomers) has been identified as a volatile component of Beaufort cheese from the French Alps (Dumont and Adda 1978). *o*-, *m*-, and *p*-Xylene have been identified as volatile components of Idaho Russet Burbank baked potatoes, chickpea (Cicer *arietinum* L.) seed, and peaches (Coleman et al. 1981, Rembold et al. 1989, Takeoka et al. 1988). *o*-Xylene was detected in dry beans, split peas, and lentils at mean concentrations of 9 ppb (0–25 ppb), 8 ppb, and 3 ppb, respectively (Lovegren et al. 1979). Jenkins et al. (2004) found little difference in the mean concentrations of total xylenes in hazelnuts that had been previously treated with xylene compared to control hazelnuts that had not been treated (0.65–

1.43 ng/g [ppb] compared to 1.49 ng/g [ppb]). *o*-, *m*-, and *p*-xylene have all been detected in the volatiles

of roasted filberts (Kinlin et al. 1972). The concentration of *p*-xylene in three apricots and two plums

ranged from not detected to 2 μg/kg (ppb) while concentrations of this substance ranged from not detected

to 9 μg/kg (ppb) in their interspecific hybrid progeny (Gomez et al. 1993).

6.5   GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Because individual xylene isomers are used in large amounts in industrial settings, people who work at or

live near these locations may receive a higher exposure to one xylene isomer compared to the other

isomers. However, since xylenes are present as a mixture in gasoline and in the solvent components of

commonly used commercial products (paint, coatings, etc.), exposure of the general population is

expected to be primarily to xylenes as a mixture, and not to the separate xylene isomers.

The California Total Exposure Assessment Methodology (TEAM) Study conducted in 1984 in Los

Angeles County (an urban area) and Contra Costa County (a rural area) monitored volatile organic

compounds in ambient (outdoor) air, personal air, and breath samples for 188 people (Wallace et al.

1988). (Personal air is defined as air samples which were collected using a sampling vest worn by the

participant with the pump and collection cartridge placed close to the breathing level.) In Los Angeles,

all three xylene isomers were detected in each air type; higher levels were measured during the winter for

all air types and all xylene isomers compared with summer levels. Average concentrations (in $μg/m^3$

[ppb]) are listed in Table 6-8.

Smoking was determined to be the major determinant for the presence of xylene in breath and personal

air, with concentrations in the breath of smokers more than double those of nonsmokers. Auto-related

situations, such as pumping gasoline and exposure to exhaust, as well as type of employment also

contributed significantly to increased concentrations of xylene in breath and personal air (Wallace et al.

1988). A second TEAM study in 1987, of the same Los Angeles families, showed similar trends in

relative concentrations of xylene in personal, indoor, and outdoor air (Wallace et al. 1991). Again,

outdoor concentrations were lower than indoor concentrations which, in turn, were lower than personal air

samples. Mean xylene concentrations (in $μg/m^3$ [ppb]) are listed in Table 6-9.

Studies by Ashley et al. (1995) and Wallace et al. (1987a) supported the argument that xylene exposure is

greater for individuals who smoke cigarettes. The reported mean (median) concentrations of *o*-xylene

and *m*-/*p*-xylene were 0.13 ng/mL (0.086 ng/mL) and 0.41 ng/mL (0.19 ng/mL), respectively, in the blood

Table 6-8. Average Personal Air, Outdoor Air, and Breath Concentrations Measured During the 1984 TEAM Study

Location	Sample type	*m-/p*-Xylene (ppb)	*o*-Xylene (ppb)
Los Angeles	Personal air	28 (6.5)	13 (3.0)
(February)	Outdoor air	24 (5.5)	11 (2.5)
	Breath	3.5 (0.8)	1.0 (0.2)
Los Angeles	Personal air	24 (5.5)	7.2 (1.7)
(June)	Outdoor air	9.4 (2.2)	2.7 (0.6)
	Breath	2.8 (0.6)	0.7 (0.2)
Contra Costa	Personal air	11 (2.5)	4.4 (1.0)
(June)	Outdoor air	2.2 (0.5)	0.7 (0.2)
	Breath	2.5 (0.6)	0.6 (0.1)

TEAM Study = The California Total Exposure Assessment Methodology Study

Source: Wallace et al. 1988

Table 6-9. Average Personal Air, Indoor Air, Outdoor Air, and Breath Concentrations from the 1987 TEAM Study

Date	Sample type	*m-/p*-Xylene (ppb)	*o*-Xylene (ppb)
February	Personal air	43 (9.9)	16 (3.7)
	Indoor	30 (6.9)	12 (2.8)
	Outdoor	18 (4.2)	6.5 (1.5)
	Breath (median value)	2.5 (0.6)	0.8 (0.2)
July	Personal air	27 (6.2)	9.2 (2.1)
	Indoor	12 (2.8)	4.3 (1.0)
	Outdoor	7.4 (1.7)	2.8 (0.6)
	Breath (median value)	0.7 (0.2)	0.25 (0.1)

TEAM Study = The California Total Exposure Assessment Methodology Study

Source: Wallace et al. 1991

of 126 nonsmokers and 0.18 ng/mL (0.14 ng/mL) and 0.53 mg/mL (0.42 mg/mL), respectively, in the

blood of 42 smokers (Ashley et al. 1995). The unweighted geometric mean concentrations of *o*-xylene

and *m*-/*p*-xylene were 1.55 and 5.5 μg/m^3, respectively, in the breath of 200 smokers in New Jersey and

California compared to 0.8 and 2.1 μg/m^3, respectively, in the breath of 322 nonsmokers from these

locations (Wallace et al. 1987a). The unweighted geometric mean daytime personal air exposures of

o-xylene and *m*-/*p*-xylene were 7.8 and 22 μg/m^3, respectively, for the smokers and 6.5 and 16 μg/m^3,

respectively, for the nonsmokers. The weighted geometric mean overnight indoor air concentrations of

o- and *m*-/*p*-xylene were 5.5 and 14.9 μg/m^3, respectively, in the homes of the smokers and 4.9 μg/m^3 and

13.4 μg/m^3, respectively, in the homes of the nonsmokers. Heavner et al. (1995, 1996), however, came to

a different conclusion, reporting that there was no significant difference between xylene exposure in

smoking and nonsmoking homes. Median exposures reported for *o*-, *m*-, and *p*-xylene were 1.51, 3.61,

and 1.11 μg day/m^3, respectively, at the homes of 15 smokers and 1.63, 3.22, and 1.12 μg day/m^3,

respectively, at the homes of 35 nonsmokers. It should be noted, however, that Heavner et al. (1995,

1996) studied a relatively small subject population (49 subjects) compared to Ashley et al. (1995)

(168 subjects) and Wallace et al. (1987a) (522 subjects).

Individuals are expected to be exposed to xylenes by breathing the air inside homes and buildings since

these substances are commonly found in indoor air. Exposure may also arise from ingestion of

contaminated drinking water. Common activities identified with increased potential exposure include

pumping gasoline, visiting service stations, traveling in a car, painting, scale model building, pesticide

use, and smoking (Wallace et al. 1986, 1987b).

Blood levels of *o*-xylene and *m*-/*p*-xylene were 0.080 and 0.32 μg/L, respectively, in 86 commuters from

Mexico City, 0.082 and 0.24 μg/L, respectively, in 14 commuters from Stamford, Connecticut, 0.20 and

0.44 μg/L, respectively, in 26 commuters from Fairbanks, Alaska, 0.045 and 0.14 μg/L, respectively, in

19 commuters from Albany, New York, and 0.094 and 0.16 μg/L, respectively (Lemire et al. 2004).

Jo and Moon (1999) studied the exposure of South Korean housewives who live near roadside service

stations to VOCs. For housewives who lived within 30 m of a service station, mean *o*-, *m*-, and *p*-xylene

concentrations were 9.8, 7.0, and 12.7 μg/m^3 (2.3, 1.6, and 2.9 ppb), respectively, in indoor air, 6.0, 4.1,

and 8.8 μg/m^3 (1.4, 0.9, and 2.0 ppb), respectively, in outdoor air, and 3.3, 3.4, and 2.4 μg/m^3 (0.8, 0.8,

and 0.6 ppb), respectively, in breath samples. For housewives who lived 60–100 m from a service

station, mean *o*-, *m*-, and *p*-xylene concentrations were 12.2, 8.5, and 15.5 μg/m^3 (2.8, 2.0, and 3.6 ppb),

respectively, in indoor air, 3.7, 2.3, and 5.7 μg/m^3 (0.9, 0.5, and 1.3 ppb), respectively, in outdoor air, and

4.1, 4.0, and 3.2 µg/m^3 (0.9, 0.9, and 0.7 ppb), respectively, in breath samples. The mean and range of concentration of xylenes that 25 individuals were exposed to while riding or operating an open sleigh snowmobile were 2.00 and <0.05–13.0 mg/m^3 (0.5 and <0.1–3.0 ppb), respectively (Eriksson et al. 2003).

Of 237 consumer products tested for *m*-xylene and 221 products tested for *o*- and *p*-xylene, 101 products contained *m*-xylene and 93 products contained *o*- and *p*-xylene at concentrations >0.1% weight (EPA 1991b; Sack et al. 1992). The concentrations and percentage of positive detects are listed in Table 6-10.

Based on the estimates of EPA (1983) of median atmospheric concentrations of (see Section 6.4.1) and assuming inhalation of 23 m^3/day by a 70-kg adult, the daily *o*-xylene intakes from air for adults exposed to the median levels in rural, urban, and source-dominated areas would be 0.0001, 0.0017, and 0.0012 mg/kg/day, respectively. The median *m*- and *p*-xylene intakes would be 0.0001, 0.0039, and 0.0024 mg/kg/day, respectively (EPA 1985a). Assuming a typical ambient air xylene concentration of 4.0 ppb, the average daily intake of xylene from air is estimated to be 353 µg (HSDB 2007).

General population exposure to xylene can also occur through dermal contact with the many consumer products containing xylene, including cleaning solvents, insecticides, lacquers, paint thinners and removers, and pesticides (EPA 1985a; Fishbein 1985; Gleason et al. 1969). Dermal absorption is reported to be minor following exposure to xylene vapor but may be significant following contact with the liquid (EPA 1985a). The percutaneous absorption rate of *m*-xylene in humans is approximately 2 µg/cm^2/minute through the skin of the hands (Engstrom et al. 1977).

Assuming a maximum concentration of total xylenes (*m*-, *o*-, and *p*-xylene) (1.5 mg/L) and a daily intake of 2 L of drinking water, the adult maximum daily intake for total xylenes through consumption of drinking water is estimated to be 3 mg/day or 0.04 mg/kg/day (EPA 1985a).

Mean and median concentrations of *o*-xylene detected in 711 blood samples from participants in the Third National Health and Nutrition Examination Survey (NHANES III) were 0.14 and 0.11 ppb, respectively (Ashley et al. 1994, 1996). *m*- and *p*-Xylene were detected together in 649 blood samples with mean and median concentrations of 0.37 and 0.19 ppb, respectively. *o*- and *p*-Xylene blood levels of 0.094 and 0.16 µg/L (ppb), respectively, were reported for the nonsmoking subset (546 individuals) of participants in NHANES III (Lemire et al. 2004).

Table 6-10. Concentrations of Xylene in Consumer Products

Product	m-Xylene		o-/p-Xylene	
	Percent detected	Concentration of xylene	Percent detected	Concentration of xylene
Automotive products	26.7	10.6	10.0	31.0
Household cleaners, polishers	33.3	1.4	0.0	0.0
Paint-related products	60.3	4.2	58.2	2.8
Fabric and leather treatments	0.0	0.0	33.3	0.1
Oils, greases, and lubricants	9.3	0.2	11.9	0.2
Adhesive-related products	9.1	0.2	9.1	0.2

Source: Sack et al. 1992

The mean and range of xylene concentrations measured in whole blood specimens collected from
250 hospital patients were 5.2 and 0.5–160 ppm (5,200 and 500–160,000 ppb), respectively (Antoine et
al. 1986). Mean and median concentrations of *m*-xylene measured in blood samples of 25 individuals
living in Italy (including both smokers and non smokers) were 719 and 457 ng/L (0.719 and 0.457 ppb),
respectively (Perbellini et al. 2002). Mean and median *m*-xylene concentrations in the urine of these
individuals were 106 and 96 ng/L (0.106 and 0.096 ppb), respectively. The mean and range of xylene
concentrations in the blood of the occupants of approximately 57 rural homes in northern Germany were
229 and 71–1,113 ng/L (0.229 and 0.071–1.113 ppb), respectively, with corresponding indoor air
concentrations of 9.29 and 3.64–54.64 ng/L (2.1 and 0.8–12.5 ppb) (Ilgen et al. 2001a). The mean and
range of xylene concentrations in the blood of the occupants of approximately 57 urban homes in northern
Germany were 262 and 89–1,301 ng/L (0.262 and 0.089–1.301 ppb), respectively, with corresponding
indoor air concentrations of 9.29 and 1.84–87.79 ng/L (2.1 and 0.4–20.2 ppb), respectively.

Xylenes were detected in eight milk samples collected from mothers at hospitals in Bayonne, New Jersey;
Jersey City, New Jersey; Pittsburgh, Pennsylvania; Baton Rouge, Louisiana; and Charleston, West
Virginia (EPA 1980a). Concentrations in these samples were not reported.

Occupational exposure to mixed xylenes may occur during their production as well as their end use as
industrial solvents. Occupational exposures result from inhalation or dermal exposure and are usually
associated with process, storage, or fugitive emissions at petroleum chemical, paint, and plastics plants
(Bratveit et al. 2004; Fishbein 1985, 1988). Average daily intake of xylenes from individual occupational
exposure sources has not been estimated. Results of a study of solvent exposures in 1981 involving
eighty-nine workers in seven plants of three companies applying paints and glues, primarily by spraying,
showed that most solvent spraying activities surveyed showed only low-to-moderate exposures to xylene
relative to the TLV in the presence of ordinary general room ventilation (Whitehead et al. 1984). The
TWA concentrations of xylene for high-aromatic spraying in booths (3.5 ppm), solvent wiping (0.7 ppm),
and paint mixing (3.7 ppm) were well below the TLV for xylene (100 ppm) (Whitehead et al. 1984).

The ranges of concentrations of *o*-xylene and *m*-/*p*-xylene were 65–1,900 µg/m^3 (15–440 ppb) and 180–
5,800 µg/m^3 (41–1,300 ppb), respectively, in the personal air of 24 service station attendants, 2.0–
44 µg/m^3 (0.5–10 ppb) and 71–120 µg/m^3 (16–28 ppb), respectively, in the personal air of 6 street
vendors, and 16–28 µg/m^3 (3.7–6.5 ppb) and 44–80 µg/m^3 (10–18 ppb), respectively, in the personal air
of 7 office workers in Mexico City during their work shifts (Romieu et al. 1999). Mean (range)
concentrations of *o*-xylene and *m*-/*p*-xylene in the blood of the service station attendants were 0.39 (0.16–

1.2 µg/L) and 1.4 (0.50–4.7) µg/L (ppb), respectively, at the beginning of the work shift and 0.45 (0.15–6.3) and 1.3 (0.36–16) µg/L (ppb), respectively, at the end of the work shift. Mean (range) concentrations of *o*-xylene and *m*-/*p*-xylene in the blood of the street vendors were 0.18 (0.13–0.30) and 0.75 (0.41–1.1) µg/L (ppb), respectively, at the beginning of the work shift and 0.15 (0.083–0.20) and 0.53 (0.25–0.70) µg/L (ppb), respectively, at the end of the work shift. Mean (range) concentrations of *o*-xylene and *m*-/*p*-xylene in the blood of the street vendors were 0.15 (0.081–0.31) and 0.55 (0.37–0.81) µg/L (ppb), respectively, at the beginning of the work shift and 0.10 (0.073–0.21) and 0.39 (0.19–0.73) µg/L (ppb), respectively, at the end of the work shift.

The ranges of concentrations of xylenes detected in the perimeter air, pump air, and breathing zone air were <0.001–0.066 ppm (<1.0–66 ppb) at two full service stations in New Jersey, 0.001–0.014 ppm (1.0–4.0 ppb) at three self-serve service stations in New York, and <0.001–0.281 ppm (<1.0–281 ppb) at five self-serve service stations in Connecticut (API 1994).

The American Petroleum Institute (API 1995) studied the exposure of service station attendants and mechanics to fuel components at six stations in New York, three stations in Minnesota, four stations in Arizona, and three stations in Oregon in 1994. During the wintertime, xylene was detected above 0.01–0.30 ppm in only 1 of the 59 short-term exposure cases involving attendants. It was not detected above the detection limit (0.01–0.03 ppm) in 51 long-term exposure cases involving attendants. Xylene was detected above 0.09–0.15 ppm in 7 of 44 short term winter exposure cases involving mechanics with a median (range) concentration of 1 ppm (1–6.4 ppm). It was detected above 0.01–0.02 ppm in 3 out of 44 long-term exposure cases involving mechanics with a median (range) concentration of 1 ppm (1–2.2 ppm). During the summertime, xylene was detected above 0.09–0.16 ppm in 44 of the 60 short-term exposure cases involving attendants with a median (range) concentration of 0.15 ppm (0.09–7.70 ppm). It was detected above 0.01–0.06 ppm in 52 out of 54 long-term exposure cases involving attendants with a median (range) concentration of 0.05 ppm (0.01–0.83 ppm). Xylene was detected above 0.08–0.16 ppm in 18 of 44 short term summer exposure cases involving mechanics with a median (range) concentration of 0.15 ppm (0.08–30.0 ppm). It was detected above 0.01–0.02 ppm in 35 out of 42 long-term exposure cases involving mechanics with a median (range) concentration of 0.1 ppm (0.01–1.60 ppm).

During a study of exposure to gasoline components during loading and delivery, the mean exposure of tanker drivers to xylene was measured to be 0.8–4 mg/m³ (Hakkola and Saarinen 1996).

The mean (median, range) concentrations of xylene in the blood of thirteen workers occupied in the production of paints containing xylene and 10 workers occupied in paint spraying were 380 μg/L (403 μg/L, 63–715 μg/L) and 130 μg/L (74 μg/L, 49–308 μg/L), respectively, after an 8-hour work shift (Kramer et al. 1999). The mean (median, range) concentrations of xylene in the air during the shifts were 29 μg/L (30 μg/L, 5–58 μg/L) for the production workers and 8 μg/L (7 μg/L, 3–21 μg/L) for the spraying workers. The mean (median, range) concentrations of the methylhippuric acid metabolites in urine were 1,221 mg/L (1,168 mg/L, 194–2,333 mg/L) for the production workers and 485 mg/L (397 mg/L, 65–1,633 mg/L) for the spraying workers. Moen and Hollund (2000) measured xylene concentrations ranging from 0.2 to 0.8 ppm in the air of six car painting garages. Vincent et al. (1994) reported that the mean (range) concentrations of xylenes in personal air during painting operations in an aeronautical workshop were 30.9 mg/m^3 (14.3–46.5 mg/m^3) after day 1, 87.0 mg/m^3 (38.7–160.0 mg/m^3) after day 2, and 122.2 mg/m^3 (68.3–167.0 mg/m^3) after day 3.

o-Xylene and *m*-/*p*-xylene concentrations in the inhaled air were 5.3 and 15.9 μg/m^3, respectively, in the inhaled air of individuals who spent less than 3 hours/day in workshops and warehouses compared to 30.4 and 114 μg/m^3, respectively, for individuals who spent more than 3 hours/day in these places (Hoffmann et al. 2000). The concentrations of *o*-xylene and *m*-/*p*-xylene were 5.4 and 16.2 μg/m^3, respectively, in the inhaled air of individuals who work where no paints or lacquers are used, 12.7 and 38.4 μg/m^3, respectively, in the inhaled air of individuals who work where paints or lacquers are used occasionally, and 41.8 and 171 μg/m^3, respectively, in the inhaled air of individuals who work where paints or lacquers are used frequently.

Holz et al. (1995) reported that exposure of workers at a styrene plant to air concentrations of 6.0–44.1 μg/m^3 for *o*-xylene and 5.6–64.0 μg/m^3 for *m*- and *p*-xylene together did not result in increased breath concentrations compared to non-exposed individuals. *o*-Xylene and *m*- and *p*-xylene concentrations were 3.4 and 3.7 μg/m^3, respectively, in the breath of exposed workers after their shift compared to 3.5 and 4.0 μg/m^3, respectively, in the breath of non-exposed controls. The differences in mean concentrations of the metabolites *o*-methyl hippuric acid and *m*- and *p*-methyl hippuric acid together in the urine of workers before their shift to mean concentrations in their urine after their shift were 0.6 and 8.1 mg/g creatinine, respectively, for the exposed workers and 0.2 and 2 mg/g creatinine, respectively, for the non-exposed controls.

Pedersen and Higgins (1995) reported the vapor concentrations of xylenes that individuals were exposed to while taking part in various activities. Measured vapor concentrations of xylenes were 10.83 ppm

during varnishing and sealing household wooden doors, 0.92 ppm during activity in a paint mixing booth, 0.069 ppm during automotive break and rotor cleaning, 0.04 ppm during emptying/cleaning a fuel oil holding tank, 0.21 ppm during activity in a printing shop, 1.680 ppm during cleaning firearms, 2.264 ppm during refinishing furniture, and below the detection limit (not specified) during activity in a beauty salon, application of hairspray, activities in an autorepair shop, and activity in a traffic sign painting shop. The concentrations of xylenes measured in various work areas were 0.124 ppm in a paint booth mixing room, 1.100 ppm in a household remodeling bathroom, 0.102 ppm in a household paint stripping room, and below the detection limit (not specified) in a wooden door staining room, a traffic sign painting room, and a traffic sign stripping room.

The average concentrations of xylene vapors that 60 material handling personnel and 51 laboratory personnel were exposed to while working at treatment, storage, and disposal facilities were 1.61 and 0.16 ppm, respectively (Pedersen and Higgins 1995). The average work area vapor concentration at these facilities was 0.47 ppm.

The concentrations of xylene in the exhaled breath of shipyard workers commonly exposed to organic solvents ranged from <1 to 10.6 ppm (Katsuyama et al. 1998). The mean (range) concentrations of the metabolite methylhippuric acid in the urine of these workers were 0.09 g/g creatinine (0.02–0.40 g/g creatinine) before their work shift and 0.22 g/g creatinine (0.02–1.41 g/g creatinine) after their work shift.

The mean concentrations of *o*-xylene and *m*-/*p*-xylene in the breath of four dry cleaning workers ranged from 4.5 to 9.0 and from 7.6 to 17.7 $\mu g/m^3$ (1.0–2.1 and 1.8–4.1 ppb), respectively compared to mean concentrations of 3.7 and 6.5 $\mu g/m^3$ (0.9 and 1.5 ppb), respectively, in the breath of their housewives (Jo and Kim 2001). Mean air concentrations measured inside different dry cleaning stores ranged from 16.6 to 85.2 $\mu g/m^3$ (3.8–19.6 ppb) for *o*-xylene and from 33.8 to 161 $\mu g/m^3$ (7.8–37.0 ppb) for *m*-/*p*-xylene.

The National Occupational Exposure Survey (NOES), conducted by NIOSH from 1980 to 1983, indicated that 1,106,789 workers, including 211,806 women, in 74,063 plants were potentially exposed to mixed xylene in the workplace in 1980 (NIOSH 1990c). An estimated 5,596 workers (including 1,314 women) in 331 plants, 16,863 workers (including 1,194 women) in 1,610 plants, and 1,160 workers (including 545 women) in 178 plants were potentially exposed to *o*-, *m*-, and *p*-xylene, respectively. The largest numbers of workers exposed to mixed xylene were employed in the machinery (except electrical), special trade contractors, fabricated metal products, and health services industries (as assemblers, janitors,

cleaners, painting and paint-spraying machine operators, and automobile mechanics). The largest

numbers of workers exposed to *o*-xylene were employed in the chemical and allied products industry (as

machine operators [not specified], chemical technicians, production inspectors, checkers, and examiners).

The largest numbers of workers exposed to *m*-xylene were employed in the electric, gas, and sanitary

services and business services industries (as electrical power installers and repairers, supervisors,

plumbers, pipe fitters, steam fitters, order clerks, and chemists [except biochemists]). The largest

numbers of exposed workers exposed to *p*-xylene were employed in the health services industries (as

clinical laboratory technologists and technicians). These estimates were derived from observations of the

actual use of mixed xylene and the individual xylene isomers and the use of trade name products known

to contain xylene (see Table 6-11 for percentage breakdown).

The NOES database does not contain information on the frequency, level, or duration of exposure of

workers to any of the chemicals listed therein. The survey only provides estimates of workers potentially

exposed to the chemicals.

6.6   EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from

adults in susceptibility to hazardous substances are discussed in Section 3.7, Children's Susceptibility.

Children are not small adults. A child's exposure may differ from an adult's exposure in many ways.

Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a

larger skin surface in proportion to their body volume. A child's diet often differs from that of adults.

The developing human's source of nutrition changes with age: from placental nourishment to breast milk

or formula to the diet of older children who eat more of certain types of foods than adults. A child's

behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths,

sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children

also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Children are expected to be exposed to xylenes by the same routes that affect adults. Since xylenes have

a low affinity for adsorption onto soil and dust particles and a high volatilization rate, the risk of exposure

for small children from ingesting soil or dust is likely to be low.

Table 6-11. Percentage Breakdown of NIOSH Occupational Exposure Estimates from the NOES Database[a]

Chemical	NOES	
	Actual[b]	Trade name
o-Xylene	96%	4%
m-Xylene	23%	77%
p-Xylene	75%	25%
Total xylenes	19%	81%

[a]Derived from NIOSH 1976, 1990c
[b]Actual observations are surveyor observations in which the surveyor observed the use of the specific agent.

NIOSH = National Institute for Occupational Safety and Health; NOES = National Occupational Exposure Survey

6. POTENTIAL FOR HUMAN EXPOSURE

During the Minnesota Children's Pesticide Exposure Study (MCPES), xylene was detected in personal, indoor, and outdoor air samples collected from households with children (Adgate et al. 2004a). During the School Health Initiative: Environment, Learning, Disease (SHIELD) study, the concentrations of xylene were measured in the outdoor home air, indoor school air, indoor home air, and personal air of 113 children from two inner-city schools in Minneapolis, Minnesota (Adgate et al. 2004b). Mean and median exposure concentrations reported in these studies were below 7 $\mu g/cm^3$ for both *m-/p-* and *o*-xylene. The data are listed in Table 6-12.

Sexton et al. (2006) analyzed blood samples collected from 43 inner-city children 3–6 years of age living in Minneapolis, Minnesota. Mean, minimum, and maximum concentrations in 50 blood samples were 0.32, 0.09, and 1.40, ng/mL, respectively, for *m-/p*-xylene and 0.06, 0.02, and 0.22 ng/mL, respectively, for *o*-xylene.

During a study of the exposure of Danish children to benzene, toluene, and xylenes, the median concentration of xylenes was 18 $\mu g/m^3$ (4.1 ppb) in front door air samplers and 17 $\mu g/m^3$ (3.9 ppb) in personal air samplers of 56 children living in Copenhagen. Median concentrations for 40 Danish children living in rural areas were 2.6 $\mu g/m^3$ (0.6 ppb) in front door air samplers and 13 $\mu g/m^3$ (3.0 ppb) in personal air samplers (Raaschou-Nielsen et al. 1997). The authors concluded that riding in cars and activities involving exposure to gasoline vapors were factors contributing to the exposure of these children to xylenes.

Minoia et al. (1996) studied the exposure of school children living in three Italian towns with 50,000 inhabitants or less (Treviglio-Lombardy; Poggibonsi-Tuscany and Valenza-Piedmont) to xylenes. Mean indoor air concentrations within the children's homes in these three towns were 18.5, 24.1, and 11.7 $\mu g/m^3$ (4.3, 5.6, and 2.7 ppb), respectively, which correspond to mean inhaled doses of 92.5, 120.5, and 58.5 $\mu g/day$, respectively. Mean personal air concentrations (referred to as "indoor + outdoor") for children living in Treviglio, Poggibonsi, and Valenza were 20.2, 21.2, and 12.7 $\mu g/m^3$ (4.7, 4.9, and 2.9 ppb), respectively, which correspond to inhaled doses of 101.0, 106.0, and 63.5 $\mu g/day$, respectively. Mean concentrations of xylene measured in urine samples were 316 ng/L for 144 children living in Treviglio, 112 ng/L for 96 children living in Poggibonsi, and 123 ng/L for 139 children living in Valenza.

Table 6-12. Personal, Indoor, and Outdoor Air Exposures of Inner-city Children in Minneapolis, Minnesota to Xylenes[a]

Study	Type of sample	Number of samples[b]	m/p-Xylene (µg/m^3)[c]	o-Xylene (µg/m^3)[d]
MCPES[e]				
	Personal	73	6.3	2.5
	Home Indoor	101[c]	5.1	2.2
	Home Outdoor	100[c]	0.5	1.5
SHIELD[f]				
	Winter			
	School outdoor	8	2.3	0.8
	School indoor	39	2.3	0.8
	Personal	93	3.7	1.2
	Home indoor	93	3.5	1.1
	Spring			
	School outdoor	10	2	0.7
	School indoor	47	1.2	0.4
	Personal	88	3.3	1.1
	Home indoor	88	2.9	1

[a]Data are from Adgate et al. 2004a, 2004b.
[b]Xylene isomers were detected in 100% of all samples unless otherwise specified.
[c]m/p-Xylene was detected above 0.5 µg/m^3 in 99% of the home outdoor samples.
[d]o-Xylene was detected above 0.3 µg/m^3 in 98% of the home indoor and home outdoor samples.
[e]Values reported for MCPES are mean concentrations.
[f]Values reported for SHIELD are median concentrations.

MCPES = Minnesota Children's Pesticide Exposure Study; SHIELD = School Health Initiative: Environment, Learning, Disease

6.7   POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Among persons not occupationally exposed to xylenes, the highest exposure levels result from smoking
and from contact with consumer products containing xylene (Wallace et al. 1988, 1991). Populations
living near chemical waste sites where xylene is improperly stored are also likely to be at risk of increased
exposure to xylene vapors via inhalation or dermal contact.

Workers in certain occupational groups appear to have the greatest potential for exposure to high
concentrations of xylenes. Based on the available case reports of xylene toxicity in humans, painters (or
paint industry workers) and laboratory workers appear to be most frequently affected (EPA 1985a). In
general, workers involved in the distillation and purification of xylene or employed in industries using
xylene as a raw material (e.g., gasoline component) may be at higher risk of exposure (EPA 1985a). The
use of xylene in improperly ventilated areas is often the cause for toxic levels of exposure, and increased
exposures or breath concentrations have been observed for wood processing plant workers, gas station
employees, metal workers, and furniture refinishers.

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 xylene is available. Where adequate information is not
available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research
designed to determine the health effects (and techniques for developing methods to determine such health
effects) of xylene.

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 xylene have been well studied, and reliable information is available. On this basis, further studies of the physical-chemical properties of xylene are not essential at the present time.

Production, Import/Export, Use, Release, and Disposal.   According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The TRI, which contains this information for 2004, became available in May of 2006. This database is updated yearly and should provide a list of industrial production facilities and emissions.

Potential for human exposure to xylene is expected to be quite high based on the high volume of production and the widespread domestic and industrial uses of xylene.

Recent estimates of xylene production capacity indicate that over 18 billion pounds of mixed xylene and over 13 billion pounds of xylene isomers may be produced in the United States each year (SRI 2006). Further information on the amounts of xylenes used in various products would be helpful in estimating human exposure to xylenes from consumer products.

Xylenes are widely used in industry as solvents and as precursors of other products (i.e., polyester). Data describing releases of xylenes to the environment (TRI04 2006) and the presence of xylenes in gasoline, paint products, insecticides, and cigarette smoke have been well documented (Wallace et al. 1991). Information on the occurrence of xylenes in food are available and have been included.

Because of its widespread use and release into the environment, xylene has been distributed to most environmental media. It has been detected in air (Wallace et al. 1991), surface water, sediments (Otson et al. 1982b), drinking water (EPA 1985a), and aquatic organisms (Hiatt 1983). Very little data are available that report actual levels of xylenes in soil. Information on the most recent distribution of xylene are needed to estimate exposure.

Incineration is the primary method for disposal of xylene, although information on the disposal methods is not detailed (HSDB 2007). Information on the amount of xylene disposed of by incineration as well as

the amount of xylene disposed of or abandoned at hazardous waste sites is important for estimating the potential human exposure. Criteria for the disposal of xylenes are currently subject to frequent revision.

Environmental Fate. The environmental fate of xylene has been well studied. Volatilization of xylene is the dominant fate process. Xylene released to surface water primarily volatilizes (Mackay and Leinonen 1975). Xylene also adsorbs to soils and sediments and leaches into groundwater (Gherini et al. 1989). Photooxidation appears to be the most important transformation process in the atmosphere and in surface soils (Anderson et al. 1991; Jori et al. 1986). Biodegradation is likely to be the only significant degradation process for xylene in subsurface soils and aquatic systems (EPA 1984a, 1985a; Haigler et al. 1992). Additional data on the partitioning of xylene released to soil and on longevity and the rates of biotransformation in soils and sediments, are important to further define potential pathways of human exposure.

Bioavailability from Environmental Media. Xylene is absorbed during inhalation (Morley et al. 1970), oral (Abu Al Ragheb et al. 1986; Ogata et al. 1979), and dermal contact (Riihimaki and Pfaffli 1978; Skowronski et al. 1990). Approximately 50% of the xylene that is inhaled is absorbed into the body (Riihimaki and Savolainen 1980; Wallen et al. 1985), while 90% of ingested xylene is absorbed (Bray et al. 1949). However, limited information was found in the available literature regarding the bioavailability of xylene from contaminated media such as soil (Turkall et al. 1992) and sediments to which the xylene is sorbed or from contaminated surface waters. This information is needed to estimate human exposure from contaminated environmental media.

Food Chain Bioaccumulation. Xylenes are bioconcentrated in aquatic organisms to a limited extent (Nunes and Benville 1979; Ogata and Miyake 1978). The degree of concentration is believed to be limited by the rapid metabolism and excretion of xylene from some aquatic species. However, additional data on the bioconcentration of xylene by aquatic organisms from contaminated surface waters and sediments would be useful. No information was found in the literature regarding the bioconcentration of xylene in plants or biomagnification of xylene among food chain trophic levels. Although bioconcentration has been predicted for all isomers of xylene because of their tendency to partition into the octanol phase of the octanol-water system, the rapid oxidation of xylene during metabolism seems to preclude bioconcentration in higher animal systems. Thus, biomagnification is not expected to be important for xylene. However, data on the bioaccumulation of xylene in commercially important fish and shellfish are needed since consumption of contaminated fish and shellfish may be a potential source of human exposure.

6. POTENTIAL FOR HUMAN EXPOSURE

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

Levels of xylene in air and groundwater have been determined (Kolpin et al. 1997; Squillace et al. 1999; EPA 1991a; Wallace et al. 1991). However, there are limited monitoring data on xylene levels in soil and surface waters (EPA 1985a). More monitoring data are needed to better characterize ambient concentrations of xylene in soils and surface water, particularly in the vicinity of hazardous waste sites and petroleum refineries.

The available data allow characterization of human exposure to xylene from most exposure pathways, particularly air (Wallace et al. 1988, 1991). Estimates of human intake of xylene from contaminated air and drinking water have been made based on background levels that have been recorded.

Exposure Levels in Humans.   Xylene has been detected in human blood, urine, and exhaled breath. However, exposure associated with living or working near hazardous waste sites and refineries has not been assessed. The most important human exposure sources, workplace and ambient air, are well understood (Fishbein 1985, 1988; Wallace et al. 1988, 1991). Additional monitoring programs involving analysis of human breath or urine are needed to assess the magnitude of exposures and in estimating the average daily dose associated with various sources, particularly for populations in the vicinity of hazardous waste sites.

Several sectors of the work force have the greatest levels of exposure to xylene. Total xylene exposure has been found to be greatest among those employed in the machinery (except electrical), special trade contracting, fabricated metal products, and health services industries (as assemblers, janitors and cleaners, painting and paint-spraying machine operators, and automobile mechanics) (EPA 1985a). More current information on occupational exposure are needed.

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

Exposures of Children.   Little data are available regarding exposures of children to xylene. Two foreign studies and three studies conducted in the United States have been located. The U.S. studies focus

primarily on children living in Minnesota. Additional data reporting the exposures of children living in other areas of the United States to xylenes would be helpful.

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 xylene were located. This substance is not currently one of the compounds for which a sub-registry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for sub-registries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance.

6.8.2   Ongoing Studies

The Federal Research in Progress (FEDRIP 2006) database and the Federal Research and Development (FED R&D 2005) database provide additional information obtainable from a few ongoing studies that may fill in some of the data needs identified in Section 6.8.1. These studies are summarized below.

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 be analyzing human blood samples for xylene 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.

Kate Scow (University of California Davis) is studying the relationship between microbial communities and the anaerobic biodegradation of contaminant mixtures in aquifer groundwater. Chemicals of focus will include toluene and xylene. This study will include both microcosm and field studies.

T.Y. Sylva and C.M. Kinoshita (University of Hawaii) is studying the application of bioremediation to hydrocarbon contaminated soils. Laboratory soil biodegradation studies will be performed on organic compounds commonly found in petroleum products (including xylene).

Alfred Spormann (Stanford University) is studying the microbial degradation of aromatic hydrocarbons under anaerobic conditions. Anaerobic biodegradation studies on BTEX compounds will be examined to gain additional knowledge of microbial metabolism and for evaluating and enhancing intrinsic bioremediation.