APPENDIX 7A
ADDITIONAL STUDIES OF ENVIRONMENTAL CONCENTRATIONS OF LEAD

This collection of studies is intended to extend and detail the general picture of lead concentrations in the environment and in proximity to identified major sources as portrayed in Chapter 7. The list is by no means all-inclusive, but is intended to be representative and to supplement the data cited in Chapter 7.

7.A.1 GENERAL AMBIENT AIR CONCENTRATIONS

7.A.1.1 "Seven-City Study"

A special lead study ("Seven-City Study") was conducted for 12-month periods between 1968 and 1971 in Cincinnati, Los Angeles, Philadelphia, Houston, New York City, Washington, D.C., and Chicago. Samples of ambient air were analyzed by atomic absorption spectroscopy. The monthly average lead concentrations obtained are summarized in Table C-1.

This study, specifically designed to measure ambient lead concentrations at a variety of sites within each of the cities, incorporated techniques that would provide the most precise measure of ambient lead concentrations available. A membrane filter was used instead of a glass filter, and the samples were collected continuously over 2 to 3 days rather than collected in biweekly 24-hour periods as in the NASN. The high annual average lead concentrations found in the Los Angeles area are largely attributable to heavy automotive emissions.

7.A.1.2 Birmingham, Alabama

During 1964 and 1965, seasonal levels of trace metals were determined from suspended particulate samples collected at 10 area sampling sites at Birmingham, Alabama, as a part of the Alabama Respiratory Disease and Air Pollution Study initiated in 1962. This monitoring study produced data representative of area source industrial pollution. Samples from each of the 10 sites were composited on a seasonal basis to give a total of 40 pooled samples. The lead data are summarized in Table C-2. The maximum seasonal

Table C-1. SUMMARY OF MONTHLY AVERAGE LEAD CONCENTRATIONS FOUND IN SEVEN-CITY STUDY[1]

City	Site type[a]	Months of data	Monthly concentration, $\mu g/m^3$		
			Min.	Max.	Avg.
Los Angeles	C	12	2.4	5.8	4.2
	C	12	2.6	6.8	4.5
	R	12	2.1	5.0	3.6
	R	12	2.7	5.4	3.8
	R	12	2.1	4.4	3.1
	R	12	1.4	3.9	2.5
	I	12	1.7	7.0	3.7
	C	12	2.5	7.6	4.8
Philadelphia	M	12	1.3	2.7	1.9
	C	12	1.2	2.6	1.8
	C	12	2.6	5.1	3.8
	I	12	1.5	3.0	2.2
	R	12	0.9	2.0	1.4
	M	12	0.6	1.7	1.1
	R	12	0.6	1.5	1.1
	R	12	1.1	2.6	1.7
	R	12	0.8	1.7	1.3
	R	12	0.7	1.6	1.0
Cincinnati	C	12	1.3	3.1	2.0
	R	12	0.8	2.6	1.5
	I	12	1.2	2.8	2.2
	P	12	0.5	1.2	0.9
	F	12	0.1	0.5	0.3
	F	12	0.2	0.5	0.3
Los Alamos	R	12	0.1	0.3	0.2
	C	12	0.1	0.3	0.2
Houston	R	12	0.7	2.7	1.2
	C	12	0.7	1.9	1.1
	C	12	1.2	3.2	2.2
	C	12	1.5	4.1	2.4
	M	12	1.0	2.2	1.3
	R	12	0.6	1.4	0.9
	R	12	0.6	1.2	0.8

(continued)

TABLE C-1. (continued)

City	Site type[a]	Months of data	Monthly concentration, $\mu g/m^3$		
			Min.	Max.	Avg.
Chicago	R	12	1.0	1.7	1.3
	M	12	1.1	1.7	1.4
	R	12	1.0	2.1	1.6
	M	12	1.3	2.2	1.8
	C	12	1.4	2.3	1.9
	R	12	1.2	2.2	1.6
	R	7	0.9	2.7	1.3
	M	12	1.1	2.1	1.6
	R	12	1.2	3.5	2.0
Washington	R	12	0.7	1.6	1.1
	C	7	1.2	2.2	1.7
	C	12	1.6	3.9	2.3
	R	12	1.4	2.8	1.8
	R	12	1.0	1.7	1.2
	F	12	0.9	1.6	1.1
	R	12	1.8	3.5	2.4
	R	12	0.8	1.8	1.1
New York	M	11	1.1	2.9	1.7
	M	12	1.4	2.6	2.1
	R	12	1.4	2.1	1.7
	R	12	1.3	2.2	1.7
	M	12	1.2	2.7	2.1
	R	12	0.8	1.9	1.4
	R	12	0.9	1.6	1.2
	R	12	0.9	1.4	1.2
	R	12	0.8	1.4	1.1

[a]C - Commercial; I - industrial; R - residential; M - mixed; F - farm; and P - park.

Table C-2. SEASONAL LEAD CONCENTRATIONS IN BIRMINGHAM, ALABAMA, AREA, 1964-1965
($\mu g/m^3$)

Place	Site	Seasonal average concentrations				Study period average concentration
		Spring	Summer	Fall	Winter	
Bessemer	1	0.9	0.7	1.1	0.6	0.8
Birmingham	3	0.7	1.4	1.7	1.4	1.3
Birmingham	4	3.2	2.8	2.3	3.5	3.0
Birmingham	5	1.2	1.6	1.8	0.8	1.4
Birmingham	7	1.2	1.4	1.3	1.8	1.4
Fairfield	1	0.6	0.5	0.6	0.3	0.5
Irondale	1	0.6	0.4	0.9	0.6	0.6
Mt. Brook	1	0.5	0.6	1.0	0.5	0.6
Tarrant	1	1.1	1.8	3.0	3.4	2.3
Vestavia	1	0.8	0.8	0.5	0.7	0.7

lead concentration (3.5 $\mu g/m^3$) occurred at Birmingham site 4 during the winter. Only two sites showed average concentrations > 2 $\mu g/m^3$ for the year, Birmingham site 4 (3.0 $\mu g/m^3$) and Tarrant (2.3 $\mu g/m^3$). These results are typical for a medium-sized industrialized urban area.

7.A.1.3 Kanawha Valley, West Virginia

A comprehensive air pollution study was conducted in the Kanawha River Valley in the vicinity of Charleston, West Virginia (Figure C-1), during 1964 and 1965. Twenty-four-hour samples of suspended particulate matter were collected at 14 strategically located sites. Samples from selected sites were composited on a seasonal basis (fall 1964, winter 1964 and 1965, and summer 1965) and the composites were analyzed for trace-metal content by the NASN emission spectrographic procedure. The data for lead are presented in Table C-3. Highest concentrations of suspended lead were found during the fall of 1964 at the St. Albans, Kanawha City, and Charleston sites.

Lead in "dustfall" measurements (settled particulates) for the same stations are also presented in Table C-3. The "dustfall" was collected by exposing wide-mouth jars for a period of 1 month; and then composite samples were analyzed. The highest average concentrations of settled lead occurred at the Smithers site (11.2 mg/m^2-mo), and at the South Charleston-East site (11.6 mg/m^2-mo).

The combustion of solid fuels (coal and coke) is the primary source of lead emissions in the Kanawha Valley. Additional sources are metallurgical operations, asphalt hot-mix production, and other industrial processes. In most cases, these sources have inadequate air pollution control equipment. The lead concentrations found are somewhat low when one considers the diversity of industrial activity and the meterological and topographic characteristics prevailing. The highest values found were associated with sampling sites adjacent to major traffic arteries, which demonstrates the contribution from mobile sources.

7.A.1.4 Study of Lead Deposition in 77 Cities (Hunt, W. F. et al., 1971)

Settled particulates were collected in 77 midwestern cities from September through December 1968. Within each city, sites were chosen to represent residential, commercial, and industrial areas. The lead content of the settled particulates was determined by atomic absorption spectrophotometry, and the depositions were expressed as mg/m^2-mo. The highest amounts found in

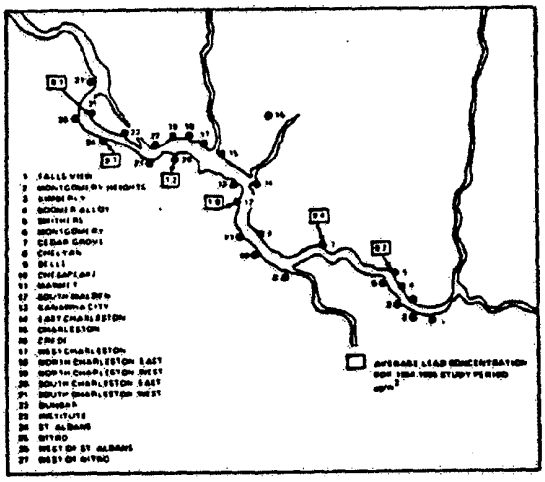

Figure C-1. Locations of fixed sampling stations in Kanawha River Valley.[3]

Figure C-1. Locations of fixed sampling stations in Kanawha River Valley (Faoro and McMullen, 1977).

Table C-3. LEAD DATA FROM KANAWHA VALLEY STUDY (Faoro and McMullen, 1977)

Sampling sites, location and no.	Lead in suspended particulates, $\mu g/m^3$					Lead in settled particulates, mg/m^2-mo, study period average
	Fall 1964	Winter 1964-1965	Spring 1965	Summer 1965	Study period average	
Falls View (1)	--	0.2	--	--	--	--
Smithers (5)	0.4	0.3	0.3	0.0	0.2	11.2
Montgomery (6)	--	0.6	--	--	--	6.7
Cedar Grove (7)	0.5	0.4	0.2	0.4	0.4	4.8
Marmet (11)	--	0.5	--	--	--	3.8
Kanawha City (13)	2.1	0.8	0.6	0.5	1.0	2.8
Charleston (15)	--	0.9	--	--	--	--
West Charleston (17)	--	0.7	--	--	--	--
North Charleston-W (19)	--	0.7	--	--	--	8.6
South Charleston-E (20)	2.7	0.6	0.6	1.0	1.2	11.6
Dunbar (22)	--	0.4	--	--	--	--
St. Albans (24)	1.3	0.9	0.3	0.4	0.7	3.0
Nitro (25)	1.0	1.4	0.2	0.3	0.7	3.4
Nitro-West (27)	--	0.1	--	--	--	--

residential, commercial, and industrial areas were in South Bend, Indiana (80 mg/m^2-mo in November); Nashville, Tennessee (346 mg/m^2-mo in October); and Omaha, Nebraska (137 mg/m^2-mo in November); respectively. Maximum readings by month occurred in Muncie, Indiana (industrial) (105 mg/m^2-mo in September); Nashville, Tennessee (commercial) (346 mg/m^2-mo in October); Omaha, Nebraska (industrial) (137 mg/m^2-mo in November; and Waterloo, Iowa (industrial) (94 mg/m^2-mo in December). The data are summarized in Table C-4.

Table C-4. DATA ON LEAD DEPOSITION IN 77 MIDWESTERN CITIES
(Hunt, W. F. et al., 1971)
(mg/m^2-mo)

Lead deposition		Lead deposition	
Area	Concentration, geometric mean	Month	Concentration, geometric mean
Residential	5.24	September	9.11
Commercial	9.80	October	8.71
Industrial	12.78	November	9.15
		December	8.06

7.A.2. POINT SOURCE EXPOSURES

7.A.2.1 Southern Solano County, California (Maga, J. A. et al., 1972)

The State of California Air Resources Board coordinated a joint study conducted by several state agencies between March 1970 and November 1971, to determine the cause of the death of a number of horses in the Benicia area from 1968 to 1970. Figure C-2 is a map of this area showing sampling site locations. The evidence strongly suggested that the horses died of lead poisoning that was caused by ingestion of lead deposited on pasture grass from a smelter plant at Selby, California. The ambient air concentrations of particulate lead were typical of those found in urban and suburban areas. It was concluded that horses in this area should not be allowed to subsist on pasture grass alone, but should receive supplemental feed. Tables C-5 and C-6 contain the data on suspended and deposited lead obtained during the study. Note that the fallout rates are on a daily basis.

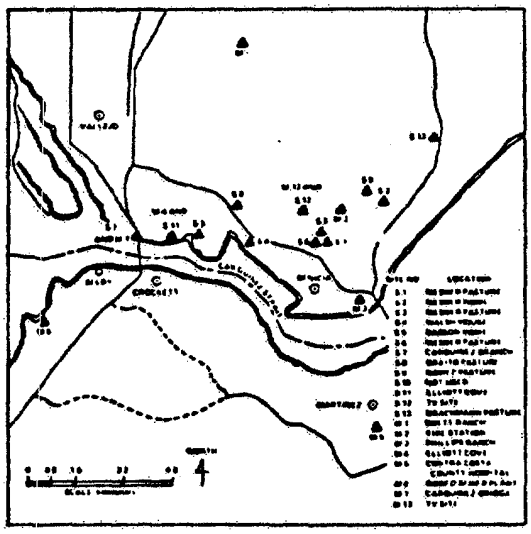

Figure C-2. Air sampling sites for Southern Solano County, California, study.[5]

Figure C-2. Air sampling sites for Southern Solano County, California, study.

Table C-5. LEAD CONCENTRATIONS IN AIR DETERMINED BY ANALYSIS OF SUSPENDED PARTICULATE, SOUTHERN SOLANO COUNTY, CALIFORNIA, March-May 1970 (Maga, J. A., et al., 1972)

Site	Distance from Selby,[a] km	Lead concentrations, $\mu g/m^3$		
		High	Low	Mean
Carquinez Bridge	1.9	8.45	0.35	3.49
Elliot Cove	3.0	0.93	0.27	0.52
Babson house	3.7	0.82	0.58	0.70
Braito dump	5.6	0.69	0.07	0.64
Walsh house	5.7	0.62	0.14	0.40
Braito TV transmitter site	7.7	1.07	0.25	0.59
Wesner pasture	7.8	0.56	0.40	0.42
Wesner pasture	8.0	0.66	0.11	0.38
Wesner pasture	8.3	0.51	0.03	0.27
Gomez pasture	10.0	0.28	0.03	0.11
Wesner house	10.2	0.22	0.02	0.14
San Francisco[b]	22.0	3.50	1.15	2.12
Fremont[b]	20.0	2.24	0.59	1.04
San Rafael[b]	19.2	2.04	0.41	1.14

[a]Location of suspected lead emissions source. See text.

[b]1969 data provided by Bay Area Air Pollution Control District.

TABLE C-6. TOTAL LEAD AND LEAD FALLOUT DETERMINED BY ANALYSIS OF DUSTFALL SAMPLES, SOUTHERN SOLANO COUNTY, CALIFORNIA, JUNE-SEPTEMBER 1970 (Maga, J. A. et al., 1972)

Site	Distance from Selby,[a] km	Sample period, days	Total solids, mg	Total lead, µg	Lead fallout, mg/m^2-day
Carquinez Bridge	1.9	30	49.2	1435	2.78
Braito dump	5.6	30	58.7	195	0.38
Braito TV transmitter site	7.7	60	101.7	520	0.50
Wesner pasture	8.0	31	370	185	0.35
Wesner pasture	8.0	31	162	155	0.29
Wesner pasture	8.0	31	171.4	195	0.37
Wesner pasture	8.0	31	109.8	255	0.48
Wesner pasture	8.0	31	351.7	210	0.39
Wesner pasture	8.0	31	220.2	4535	8.51
Wesner pasture	8.0	30	83.5	430	0.83
Wesner pasture	8.3	30	163.6	705	1.37
Gomez pasture	10.0	32	45.0	150	0.27
Drachman pasture	13.4	30	26.5	75	0.15

[a]Location of suspected lead emissions source. See text.

7.A.2.2 Omaha, Nebraska (McIntire, M. S. and Angle, C. R., 1972)

In April and May of 1968, a study of settled lead by the EPA Division of Health Effects Research showed central Omaha, Nebraska, to have the highest concentrations of deposited lead of 22 midwestern cities. Because automobile emissions should reflect the relatively low population density, the possibility of a significant contribution to air lead from other sources (two battery plants, one refinery) in the central city area was considered. Consequently, from May to November 1970, monitoring of air lead in Omaha was conducted at five sites: one industrial (I), one commercial (C), one mixed (M), and two residential (R). All samples were taken at 15 feet elevation, and all data were reported as the composited averages of 24-hour samples collected three times weekly. The monthly composite average of air lead concentrations at the sampling sites is shown in Figure C-3. Air lead levels in central Omaha at sites C and I were not only comparable with those of similar sites in Chicago, New York City, and Houston from the same months, as reported by EPA, but the maximum monthly mean at the industrial site (in July) exceeded the maximum monthly mean of all sites in these other cities.

7.A.2.3 El Paso, Texas

The El Paso, Texas study was initiated in 1971 as a result of the discovery of increased lead deposition in the vicinity of a local smelter whose emissions rose from 256 MT in 1969 to 463 MT in 1970. The El Paso City-County Health Department then began special ambient and soil sampling in addition to routine operation of their nine-station particulate sampling network. Particulate samples were collected with high-volume samplers over 24-hr periods and were then analyzed for lead by atomic absorption spectrophotometry. The results for 1971 from the nine-station network are given in Table C-7. Daily sampling at six selected sites in Smeltertown began in February 1972. Daily lead concentrations at four ground level sites ranged from 0.49 to 75 $\mu g/m^3$ and averaged 6.6 $\mu g/m^3$ over 86 days. Average concentrations of 3.6 and 6.5 $\mu g/m^3$ were found at two rooftop sites.

Soil lead concentrations were determined during March 1972 through June 1973 at 99 sites in the vicinity of the smelter. Results, shown in Figure C-4, indicate elevated soil lead levels near the plant (Landrigan and Baker, 1981). Some of this soil may find its way inside homes, for example tracked in by shoes. Table C-8 shows that the lead content of dust inside houses is greatest

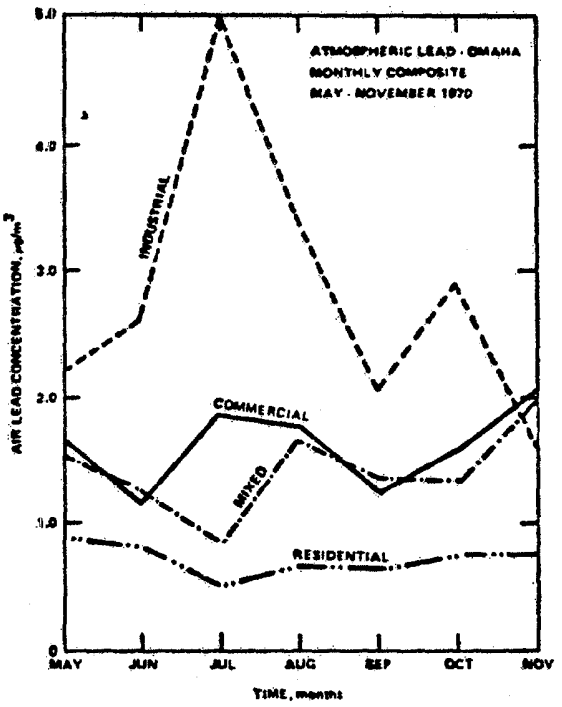

Figure C-3. Omaha, Nebraska study: mean monthly composite atmospheric lead at industrial, commercial, mixed, and two residential sites. Mean is that of representative 24-hour samples collected three times weekly. The autumnal peak at all but the industrial site parallels the usual Omaha pattern for particulates.[8]

Figure C-3. Omaha, Nebraska study: mean monthly composite atmospheric lead at industrial, commercial, mixed, and two residential sites. Mean is that of representative 24-hour samples collected three times weekly. The autumnal peak at all but the industrial site parallels the usual Omaha pattern for particulates. (Darrow and Schroeder, 1973)

TABLE C-7. LEAD CONCENTRATIONS IN SUSPENDED PARTICULATE AIR SAMPLES FROM EL PASO, TEXAS, 1971 (Henderson, J. J. and Hudson, P. A., 1972)

Location	Distance from smelter, km	No. of samples	Suspended atmospheric lead concentration, $\mu g/m^3$	
			Range	Average
Airport	12.8 E	84	0.38 to 5.82	0.96
Northeast	16 NE	73	0.12 to 3.68	0.76
Canutillo	15.2 NW	45	0.10 to 1.50	0.46
Shorty Way	8 NW	75	0.18 to 4.51	1.03
Tillman	4.8 SE	70	0.02 to 22.16	2.69
Ysleta	21.6 SE	71	0.18 to 4.81	1.39
Coronado	4.8 N	94	0.08 to 8.62	0.83
Kern	2.4 E	26	0.12 to 7.28	2.72
Executive	1.6 NE	65	0.26 to 6.67	1.16

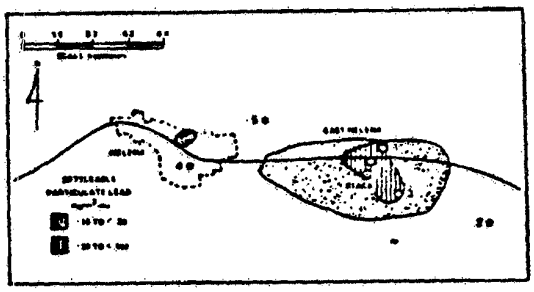

Figure C-4. Settleable particulate lead radial distribution from Helena Valley environmental pollution study.[9]

Figure C-4. Settleable particulate lead radial distribution from Helena Valley environmental pollution study. (PedCo-Environmental, Inc., 1977)

TABLE C-8. LEAD CONTENT OF HOUSEHOLD DUST IN EL PASO, TEXAS DURING JULY 1972 TO JUNE 1973

Distance from smelter (km)	No of samples	Lead content (ppm) Geometric mean	Range
0.0-1.6	53	22.191	2.800-103.750
1.7-3.2	219	2.124	100-84,000
3.3-6.4	209	1.552	100-29.384
>6.4	48	973	200-22.700

Source: Landrigan and Baker (1981).

for those dwellings nearest the smelter. Analysis of lead in 1600 paint samples in these houses showed that no gradient exists in the lead content of the paint relative to distance from the smelter.

7.A.2.4 Helena Valley, Montana (U.S. Environmental Protection Agency, 1972)

During the summer and fall of 1969, a source-oriented study of the Helena Valley, Montana, area (Figure C-4) was undertaken using dustfall bucket and high-volume sampling techniques. During this period, Helena residents were exposed to an average daily lead concentration of 0.1 $\mu g/m^3$, with maximum concentrations up to 0.7 $\mu g/m^3$. The residents of the East Helena area were exposed to an average daily concentration of 0.4 to 4.0 $\mu g/m^3$, depending upon proximity to the source, with maximum daily exposures up to 15 $\mu g/m^3$. Within a 1-mile radius of the East Helena smelter, settled particulate lead values ranged from 30 to 108 mg/m^2-mo. Table C-8 summarizes the dustfall and suspended particulate data acquired during this study, and Figure C-4 shows the deposition of lead (dustfall) in the area.

7.A.2.5 Southeast Missouri (Purushothaman, K., 1972)

Studies were carried out in 1971 in the Viburnum Trend or New Lead Belt in southeast Missouri to determine the magnitude and distribution of atmospheric pollutants from lead mining and smelting operations. This industrial district has become one of the world's largest lead-producing areas by mining

more than 392,277 MT of lead, or 75 percent of the entire U.S. lead production, during 1970. Settleable particulates were collected monthly at 10 locations in western Iron County shown in Figure C-5. Annual averages for each site are included in the figure; monthly maximum values are listed in Table C-9. Annual averages for suspended lead collected in Glover, Mo. (Site 43, southeastern Iron County), by high-volume sampler were 3.4 $\mu g/m^3$ (20 samples) in 1970, 5.3 $\mu g/m^3$ (32 samples) in 1971, and 5.6 $\mu g/m^3$ (28 samples) in 1972.

7.A.2.6 Two Smelter Study

The homes of workers of two secondary lead smelters in different geographical areas of the United States were studied by Rice et al. (1978). Paper towels were used to collect dust from surfaces in each house, following the method of Vostal et al. (1974). A total of 33 homes of smelter workers and 19 control homes located in the same or similar neighborhoods were investigated. The geometric mean lead levels on the towels were 79.3 µg (smelter workers) versus 28.8 µg (controls) in the first area, while in the second area mean values were 112 µg versus 9.7 µg. Also in the second area, settled dust above doorways was collected by brushing the dust into glassine envelopes for subsequent analysis. The geometric mean lead content of this dust in 15 workers' homes was 3300 ppm, compared with 1200 ppm in eight control homes. Curbside dust collected near each home in the second area had a geometric mean lead content of 1500 ppm, with no significant difference between worker and control homes. No significant difference was reported in the paint lead content between worker and control homes. The authors concluded that lead in dust carried home by these workers contributed to the lead content of dust in their homes, despite showering and changing clothes at the plant, and despite work clothes being laundered by the company. Storage of employee street clothes in dusty lockers, walking across lead-contaminated areas on the way home, and particulate settling on workers' cars in the parking lot may have been important factors. Based on measurement of zinc protoporphyrin levels in the blood of children in these homes, the authors also concluded that the greater lead levels in housedust contributed to increased child absorption of lead.

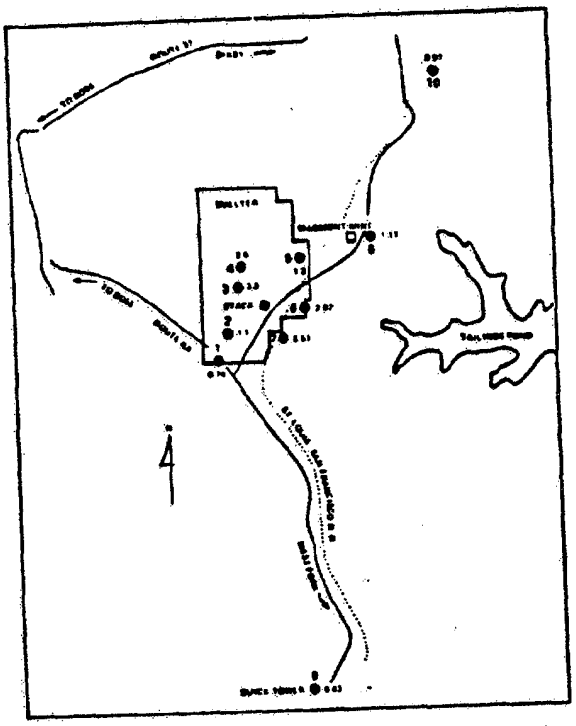

Figure C-5. Annual average of settleable particulate lead at sites near Missouri lead mine and smelter, g/m²/mo.[10]

Figure C-5. Annual average of settleable particulate lead at sites near Missouri lead mine and smelter, $g/m^2/mo$. (U.S. Environmental Protection Agency, 1977)

Table C-9. PEAK DEPOSITION RATES OF LEAD MEASURED IN SOUTHEAST MISSOURI (Purushothaman, K., 1972)

1971	Station no.	Wind direction	Distance, m	Lead deposition rate, $mg/m^2/mo$	Wind frequency, % prevailing direction
May-June	6	E	81	5.88	18(S), 12(WNW)
July	7	SSE	91	5.54	14(SSE), 13(S), 10(SSW)
August	10	NE	633	4.57	14(SSE), 11(S), 10(SSW)
September	7	SSE	91	7.76	22(S), 12(SSE), 12(SSW)
October	7	SSE	91	5.10	10(N), 10(W), 10(SE), 11(ESE)
November	3	WNW	61	2.01	26(S), 12(SSW), 10(WSW), 8(SSE)

7.A.2.7 Southern Vermont

Watson et al. (1978) investigated homes of employees of a lead storage battery plant in southern Vermont. Lead levels in household dust, drinking water, and paint were determined for 22 workers' homes and 22 control homes. The mean lead concentration in dust in the workers' homes was 2239 ppm, compared with 718 ppm in the control homes. Blood lead levels in the workers' children were greater than levels in the control children, and were significantly correlated with dust lead concentrations. No significant correlations were found between drinking water lead and blood lead, or between paint lead and blood lead. It is noteworthy that although 90 percent of the employees showered and changed clothes at the plant, 87 percent brought their work clothes home for laundering. The authors concluded that dust carried home by the workers contributed to increased lead absorption in their children.

7.A.2.8 North Carolina

Several cases of elevated environmental lead levels near point sources in North Carolina have been reported by Dolcourt et al. (1978; 1981). In the first instance, dust lead was measured in the homes of mothers employed in a battery factory in Raleigh; blood lead levels in the mothers and their children were also measured. Carpet dust was found to contain 1701 to 47,534 ppm lead in six homes where the children had elevated blood lead levels (>40 µg/dl). The authors concluded that lead carried home on the mothers' clothing resulted in increased exposure to their children (Dolcourt et al., 1978). In this particular plant, no uniforms or garment covers were provided by the factory; work clothing was worn home.

In a second case, discarded automobile battery casings from a small-scale lead recovery operation in rural North Carolina were brought home by a worker and used in the family's wood-burning stove (Dolcourt et al., 1981). Two samples of indoor dust yielded 13,283 and 41,283 ppm lead. A three-year-old girl living in the house developed encephalopathy resulting in permanent brain damage.

In a third case, also in rural North Carolina, a worker employed in an automobile battery reclamation plant was found to be operating an illicit battery recycling operation in his home. Reclaimed lead was melted on the kitchen stove. Soil samples obtained near the house measured as high as 49.2 percent lead by weight; the driveway was covered with fragments of battery

casings. Although no family member had evidence of lead poisoning, there were unexplained deaths among chickens who fed where the lead waste products were discarded (Dolcourt et al., 1981).

7.A.2.9 Oklahoma

Morton et al. (1982) studied lead exposure in children of employees at a battery manufacturing plant in Oklahoma. A total of 34 lead-exposed children and 34 control children were examined; 18 children in the lead-exposed group had elevated blood lead levels (>30 µg/dl), while none of the controls were in this category.

It was found that many of the battery factory employees also used lead at home, such as casting lead into fishing sinkers and using leaded ammunition. A significant difference in blood lead levels between the two groups of children was found even when families using lead at home were deleted from the data set. Using the results of personal interviews with the homemaker in each household, the authors concluded that dust carried home by the employees resulted in increased exposure of their children. Merely changing clothes at the plant was deemed insufficient to avoid transporting appreciable amounts of lead home: showering and shampooing, in addition to changing clothes, was necessary.

7.A.2.10 Oakland, California

Environmental lead contamination at the former site of wet-cell battery manufacturing plant in Oakland, California was reported by Wesolowski et al. (1979). The plant was operational from 1924 to 1974, and was demolished in 1976. Soil lead levels at the site measured shortly after demolition are shown in Table C-11. The increase in median concentrations with depth suggested that the battery plant, rather than emissions from automobiles, were responsible for the elevated soil lead levels. The levels decreased rapidly below 30 cm depth. The contaminated soil was removed to a sanitary landfill and replaced with clean soil; a park has subsequently been constructed at the site.

7.A.2.11 Ontario, Canada

Studies of lead concentrations in soils, vegetation, and the ambient air were conducted in the vicinity of a secondary smelter and a battery manufacturing plant in a large urban area in southern Ontario. For comparative purposes, data were also collected in a similar control neighborhood that had

no such industrial sources. Emissions of lead from the smelter were estimated to be 17 tons per year; from the battery plant, 6 tons per year. Averages and ranges of lead concentration in Table C-11. Both soil and foliage samples showed definite trends toward reduced concentrations with increasing distance from the industrial sources.

TABLE C-11. LEAD CONCENTRATIONS IN SOIL AT THE FORMER SITE OF A WET-CELL BATTERY MANUFACTURING PLANT IN OAKLAND, CALIFORNIA (ppm)

Depth	N	Range	Mean	Median
Surface	24	57-95,588	4270	198
15 cm	23	13-4234	374	203
30 cm	24	13-4546	1119	358

Source: Wesolowski et al. (1979)

7.A.2.12 British Columbia, Canada

Neri et al. (1978) and Schmitt et al. (1979) examined environmental lead levels in the vicinity of a lead-zinc smelter at Trail, British Columbia. Total emissions from the smelter averaged about 135 kg lead/day. Measurements were conducted in Trail (population 12,000), in Nelson, a control city 41 kilometers north of Trail (population 10,000), and in Vancouver. The annual mean airborne lead concentrations in Trail and in Nelson were 2.0 and 0.5 $\mu g/m^3$, respectively. Mean lead levels in surface soil were 1320 ppm in Trail (153 samples), 192 ppm in Nelson (55 samples), and 1545 ppm in Vancouver (37 samples). Figure C-7 shows the locations of elevated soil lead concentrations in Trail.

Blood lead measurements shows a positive correlation with soil lead levels for children aged 1-3 years and for first graders, but no significant correlation for ninth graders. The authors concluded that small children are most likely to ingest soil dust, and hence deposited smelter-emitted lead may pose a potential hazard for the youngest age group.

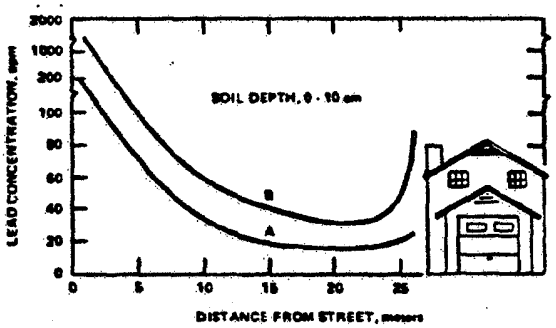

Figure C-7. Soil transects by two streets: Curve A = low-traffic-volume (400 veh/day); Curve B = high-traffic-volume (14,000 veh/day).[20]

Figure C-7. Soil transacts by two streets: Curve A = low-traffic-volume (400 veh/day); Curve B = high-traffic-volume (14,000 veh/day). (Rolfe, G. L. and Haney, A., 1975).

7.A.2.13 Manchester, England

Elwood et al. (1977) measured lead concentrations in air, dust, soil, vegetation, and tap water, as well as in the blood of children and adults, in the vicinity of a large battery factory near Manchester. It was found that lead levels in dust, soil, and vegetation decreased with increasing distance from the factor; Figure C-8 shows this trend for dust collected from the curbs and gutters of roads in the area. Airborne lead concentrations did not show a consistent effect with downwind distance, although higher concentrations were found downwind compared with upwind of the factor. Blood lead levels were greatest in the households of battery factor employees: other factors such as distance from the factory, car ownership, age of house, and presence of lead water pipes were outweighed by the presence of a leadworker in the household. These results strongly suggest that lead dust carried home by the factor employees is a dominant exposure pathway for their families. The authors also discussed the work of Burrows (1976), who demonstrated experimentally that the most important means of lead transport from the factory into the home is via the workers' shoes.

7.A.2.14 Netherlands

Environmental lead concentrations were measured near a secondary lead smelter in Arnhem, Netherlands (Diemel et al., 1981). Air and dust were sampled in over 100 houses at distances of 450 to 1000 meters from the smelter, with outdoor samples of air, dust, and soil collected for comparison. Results are presented in Table C-13. Note that the mean indoor concentration of total suspended particulates (TSP) is greater than the mean outdoor concentration, yet the mean indoor lead level is smaller than the corresponding outdoor level. The authors reasoned that indoor sources such as tobacco smoke, consumer products, and decay of furnishings are likely to be important in affecting indoor TSP; however, much of the indoor lead was probably carried in from the outside by the occupants, e.g., as dust adhering to shoes. The importance of resuspension of indoor particles by activity around the house was also discussed.

7.A.2.15 Belgium

Roels et al. (1978; 1980) measured lead levels in the air, in dust, and on childrens' hands at varying distances from a lead smelter in Belgium (annual production 100,000 metric tons). Blood data from children living near the

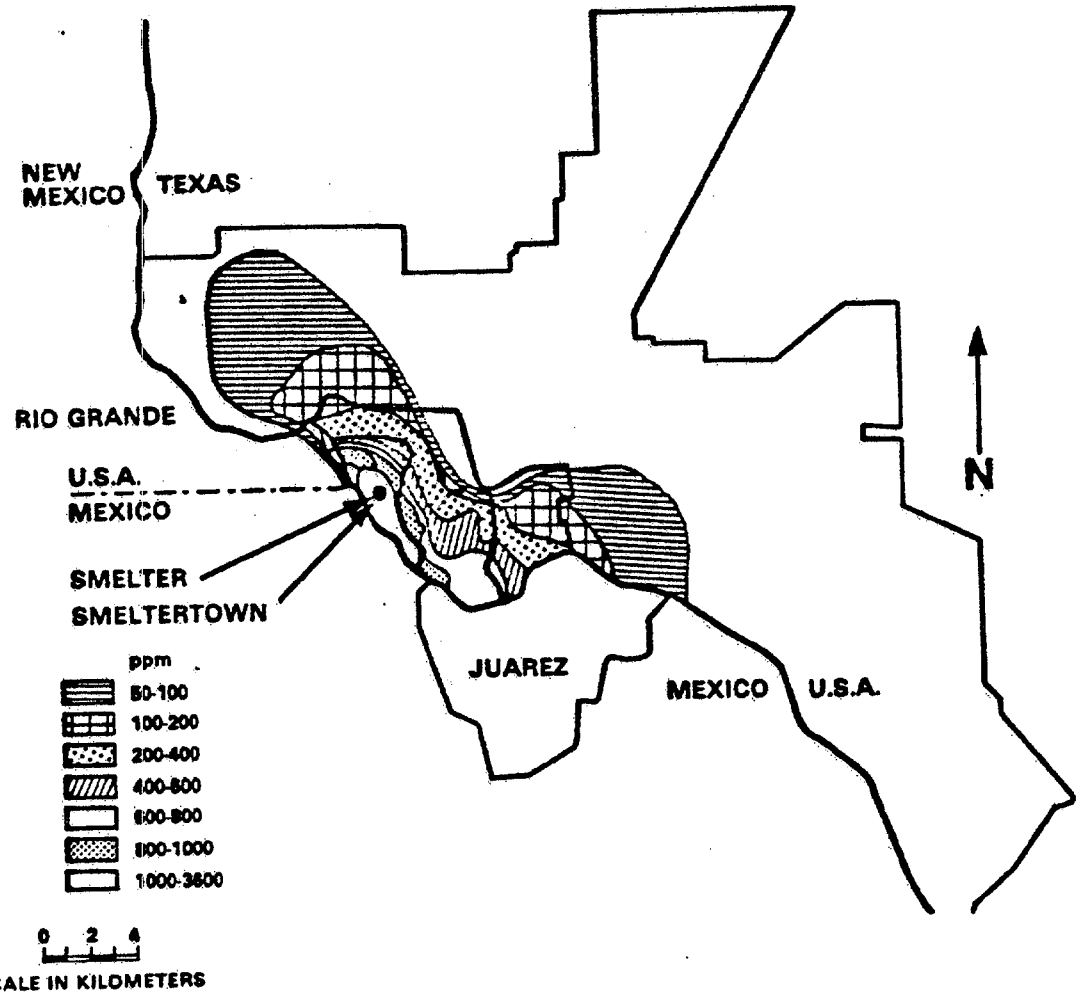

Figure 8. Survey areas and surface soil lead concentrations, El Paso, Texas, 1972.

C-4

C-8 replaced by C-4

Figure C-8. Survey areas and surface soil lead concentrations, El Paso, Texas, 1972. (U.S. Department of Health, Education, and Welfare, 1973)

TABLE C-13. LEAD CONCENTRATIONS IN INDOOR AND OUTDOOR AIR, INDOOR AND OUTDOOR DUST, AND OUTDOOR SOIL NEAR THE ARNHEM, NETHERLANDS SECONDARY LEAD SMELTER
(INDOOR CONCENTRATIONS)

Parameter	Arithmetic mean	Range	n*
Suspended particulate matter			
dust concentration (μg/m³)	140	20-570	101
lead concentration (μg/m³)	0.27	0.13-0.74	101
dust lead content (mg/kg)	2670	400-8200	106
Dustfall			
dust deposition (mg/m³/day)	15.0	1.4-63.9	105
lead depositon (μg/m³/day)	9.30	1.36-42.35	105
dust lead content (mg/kg)	1144	457-8097	105
Floor dust			
amount of dust (mg/m³)	356	41-2320	107
amount of lead (μg/m³)	166	18-886	101
Dust lead content (mg/kg)			
in "fine" floor dust	1054	463-4741	107
in "coarse" floor dust	370	117-5250	101

*N number of houses.

(OUTDOOR CONCENTRATIONS)

Parameter	Arithmetic mean	Range
Suspended particles		
dust concentration (μg/m³)	64.5	53.7-73.3
lead concentraton (μg/m³) (high-volume samplers, 24-hr samples, 2 months' average)	0.42	0.28-0.52
Lead in dustfall (μg/m³/day) (deposit gauges, weekly samples, 2 months' average)	508	208-2210
Lead in soil (mg/kg 0-5 cm)	322	21-1126
Lead in streetdust (mg/kg <0.3 mm)	859	77-2667

Source: Diemel et al (1981).

smelter were also obtained. Air samples were collected nearly continuously beginning in September 1973. Table C-14 lists the airborne concentrations recorded during five distinct population surveys between 1974 and 1978, while Figure C-9 presents air, dust, and hand data for Survey #3 in 1976. Statistical tests showed that blood lead levels were better correlated with lead on childrens' hands than with air lead. The authors suggested that ingestion of contaminated dust by hand-to-mouth activities such as nail-biting and thumb-sucking, as well as eating with the hands, may be an important exposure pathway. It was concluded that intake from contaminated hands contributes at least two to four times as much lead as inhalation of airborne material.

7.A.2.16 Helsinki, Finland

Investigators for the Agricultural Research Center in Tikkurila, Finland, an industrial and residential area near Helsinki, found high lead levels in soil. To clarify the origin of this excess lead, the Institute of Occupational Health conducted a dustfall lead survey in the area. Eighty collectors were located over a 40-km^2 area for a period of 1 month, October 6 to November 7, 1970. Individual ashed samples were analyzed by emission spectrography and the water-soluble fractions were analyzed by atomic absorption spectroscopy.

The highest lead deposition values in Helsinki were observed in areas with heavy traffic and ranged from 10 to 20 $mg/m^2/mo$ as compared to 0 to 4 $mg/m^2/mo$ in predominantly housing and residential areas.

In the Tikkurila area, industrial contributions increased deposited lead values fortyfold in some areas. The deposited lead values ranged from background in outlying areas to as high as 200 $mg/m^2/mo$ near a lead smelter, with most of the values below 100 $mg/m^2/mo$.

7.A.2.17 Meza River Valley, Yugoslavia

In 1967, work was initiated in the community of Zerjav, situated in the Slovenian Alps on the Meza River, to investigate contamination by lead of the air, water, snow, soil, vegetation, and animal life, as well as the human population. The smelter in this community produces about 19,954 MT of lead annually; until 1969 the stack emitted lead oxides without control by filters or other devices. Five sampling sites with high-volume samplers operating on a 24-hr basis were established in the four principal settlements within the Meza River Valley (Figure C-6): (1) Zerjav, in the center, the site of the smelter, housing 1503 inhabitants, (2) Rudarjevo, about 2 km to the south of

TABLE C-14. AIRBORNE CONCENTRATIONS OF LEAD DURING FIVE POPULATION SURVEYS NEAR A LEAD SMELTER IN BELGIUM*

Study populations		Pb-Air ($\mu g/m^3$)
1 Survey (1974)	<1 km	4.06
	2.5 km	1.00
	Rural	0.29
2 Survey (1975)	<1 km	2.94
	2.5 km	0.74
	Rural	0.31
3 Survey (1976)	<1 km	3.67
	2.5 km	0.80
	Urban	0.45
	Rural	0.30
4 Survey (1977)	<1 km	3.42
	2.5 km	0.49
5 Survey (1978)	<1 km	2.68
	2.5 km	0.54
	Urban	0.56
	Rural	0.37

*Additional airborne data in rural and urban areas obtained as controls are also shown.

Source: Roels et al. (1980).

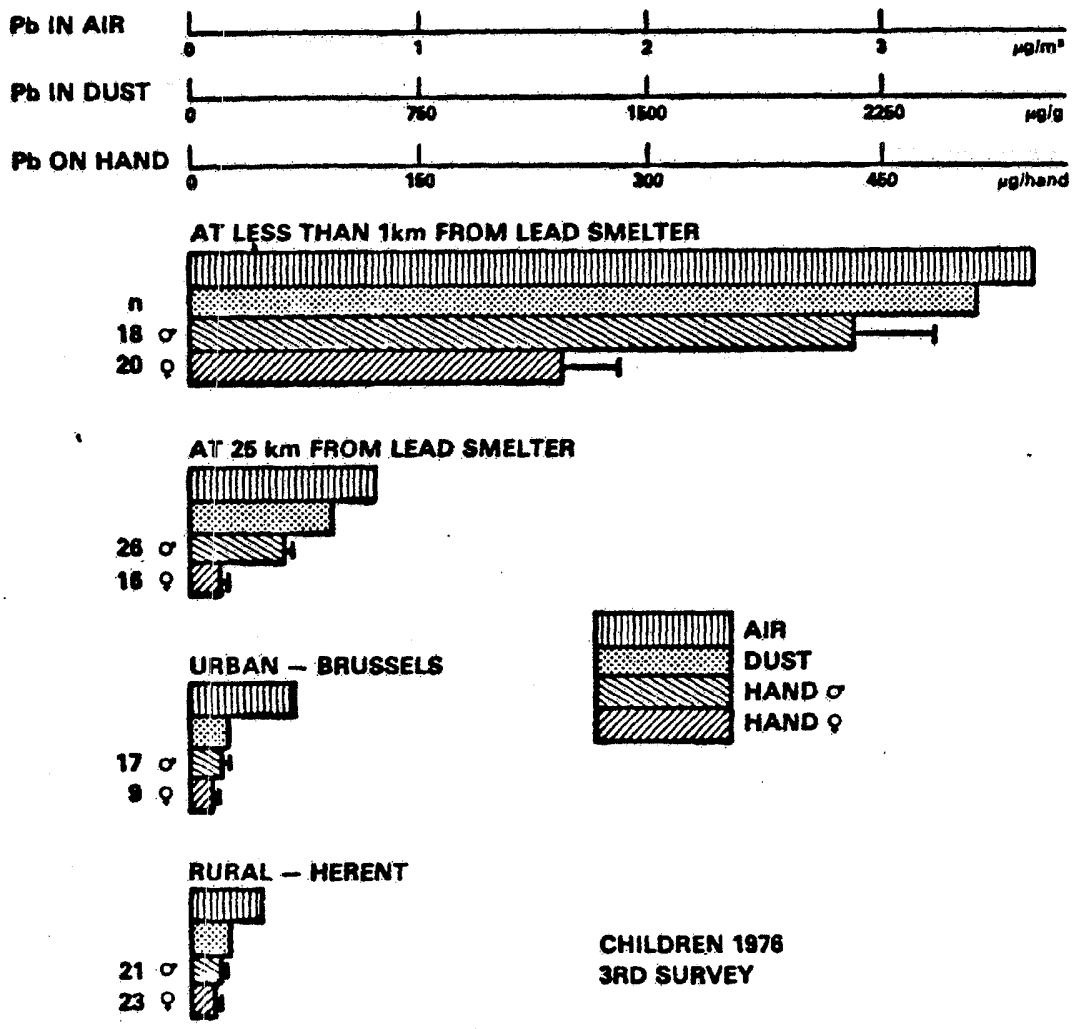

Figure 7C-9. Concentrations of lead in air, in dust, and on children's hands, measured during the third population survey of Table E. Values obtained less than 1 km from the smelter, at 2.5 km from the smelter, and in two control areas are shown.
Source: Roels et al. (1980).

Figure C-9. Concentrations of lead in air, in dust, and on children's hands, measured during the third population survey of Table E. (Roels et al., 1980).

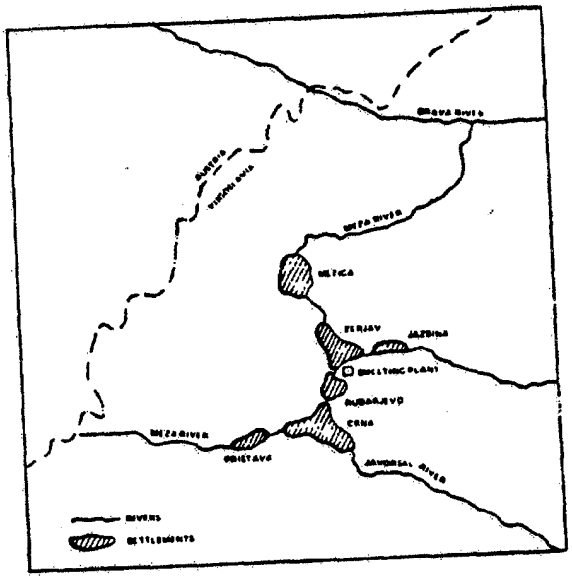

Figure C-6. Schematic plan of lead mine and smelter from Meza Valley, Yugoslavia, study.[12]

Figure C-6. Schematic plan of lead mine and smelter from Meza Valley, Yugoslavia, study. (Fugas, M. D. et al., 1974).

Zerjav with a population of 100; (3) Crna, some 5 km to the southwest, population 2198, where there are two sites (Crna-SE and Crna-W); and (4) Mezica, a village about 10 km to the northwest of the smelter with 2515 inhabitants. The data in Table C-10 are sufficient to depict general environmental contamination of striking proportions.

7.A.2.18 Kosova Province, Yugoslavia

Popovac et al. (1982) discuss lead exposure in an industrialized region near the town of Kosova Mitrovica, Yugoslavia, containing a lead smelter and refinery, and a battery factor. In 1979, 5756 kg of lead were emitted daily from the lead smelter alone. Ambient air concentrations in the town were in the range 21.2 to 29.2 $\mu g/m^3$ in 1980, with levels occasionally reaching 70 $\mu g/m^3$. The authors report elevated blood lead levels in most of the children tested; some extremely high values were found, suggesting the presence of congenital lead poisoning.

7.A.2.19 Czechoslovakia

Wagner et al. (1981) measured total suspended particulate and airborne lead concentrations in the vicinity of a waste lead processing plant in Czechoslovakia. Data are shown in Table C-16. Blood lead levels in 90 children living near the plant were significantly greater than in 61 control children.

TABLE C-16. CONCENTRATIONS OF TOTAL AIRBORNE DUST AND OF AIRBORNE LEAD IN THE VICINITY OF A WASTE LEAD PROCESSING PLANT IN CZECHOSLOVAKIA, AND IN A CONTROL AREA INFLUENCED PREDOMINANTLY BY AUTOMOBILE EMISSIONS (Wagner et al., 1981)

Exposed	n	300	303
	$\bar{x}$	113.6	1.33
	a	83.99	1.9
	min. -	19.7-	0.12-
	max.	553.4	10.9
	95% c.i.	123.1-104.1	1.54-1.11
Control	n	56.0	87
	$\bar{x}$	92.0	0.16
	a	40.5	0.07
	min. -	10-	0.03-
	max.	210	0.36
	95% c.i.	102.7-81.3	0.17-0.14

n = number of samples; $\bar{x}$ = mean of 24-hour samples;
s = standard deviation; 95% confidence interval.

7.A.2.20 Australia

Heyworth et al. (1981) examined child response to lead in the vicinity of a lead sulfide mine in Northhamptom Western Australia. Two samples of mine tailings measured in 1969 contained 1.2 percent and 2.8 percent lead; several additional samples analyzed in 1978 contained 2.2 to 15.7 percent lead. Surface soil from the town boundry contained 0.03 percent, while a playground and a recreational area had soil containing 1.1 percent and 1.2 percent lead respectfully.

Blood lead levels measured in Northhamptom children, near the mine, were slightly greater than levels measured in children living a short distance away. The Northhampton blood lead levels were also slightly greater than those reported for children in Victoria, Australia (De Silva and Donnan, 1980). Heyworth et al. concluded that the mine tailings could have increased the lead exposure of children living in the area.

7.A.3 CONCENTRATION OF LEAD IN SOILS AND URBAN DUSTS

As mentioned in Chapter 5, surficial materials in the continental United States contain an average of about 15 ppm of lead; 94 percent of the measurements showed 30 ppm or less. Higher concentrations are encountered in the vicinity of lead ore deposits and, of course, in the proximity of human activities involving lead. Soils apparently receive lead in the amounts of about 1 $\mu g/cm^2/yr$ from precipitation and 0.2 $\mu g/cm^2/yr$ from dustfall (Lombardo, 1973) in areas remote from intensive human activity. These small additions to the lead content of the soil are not detectable by ordinary means because they add only about 0.2 percent to the total lead in the top 6 inches of the soil. Lead levels are higher in surface soils than in deeper layers. Swain and Mitchell (Pinkerton et al., 1973) studied lead profiles in 8 soil types in Scotland and showed that the lead content at 115 cm (45 in) averaged one-half that at the surface. The reduction of concentration with depth is also substantiated by the findings of others. Goldschmidt (Ter Haar and Aronow, 1974) proposed the theory that lead is concentrated in the humus or organic fraction of soils in forests because it is taken up slowly be tree roots and transported to the leaves, which fall and decay. Tyler (Shapiro et al., 1973) points out that a passive ion exchange favors an accumulation of lead and other heavy metals in dead organic matter, litter, and humus. He also states that most

plant material subjected to decomposition usually shows an increase in the concentration of lead, cadmium, nickel, iron, copper, etc., calculated on dry weight.

The use of leaded gasolines has produced elevated soil lead levels adjacent to most streets and roadways. This phenomenon was first observed as early as 1933 in England, (U.S. Environmental Protection Agency, 1973) and has been intensively studied in recent years. (Rameau, 1973) An example of this phenomenon is taken from a study of the Saline Branch watershed, which includes Champaign, Illionis. One facet of this comprehensive study (National Academy of Sciences, 1972) consisted of analyses for lead in soil at increasing distances from a low-traffic-volume street (400 vehicles/day) and a high-traffic-volume street (14,000 vehicles/day). As shown on curve A in Figure C-7, lead concentrations stabilized at about 20 ppm beyond 15 meters from the low-volume street and rose slightly near the house. Unfortunately, the exterior construction of the house is not described. As curve B in Figure C-7 shows, lead concentrations of about 1800 ppm in the soil adjacent to the high-volume street are 9 times higher than in soil adjacent to the low-volume street; the concentration drops rapidly to a minimum of 30 ppm a little more than 20 m from the street and then rises again abruptly near the house to 90 ppm. This house is described as brick and unguttered. Although some leaching of lead from painted trim may be involved, the increase near the house is believed attributable chiefly to lead particles in traffic dust washed from the unguttered roof by rain and deposited in the soil next to the house.

Soil lead levels in the vicinity of stationary sources of lead emissions are often very high, and, unlike the rapid drop-off near highways, very extensive. This is particularly true for old installations. Figure C-8 shows levels recently found near an old smelter in El Paso, Texas. (Needleman and Scanion, 1973) Similar data, compiled from a 3-year-old Russian lead smelter, (Landrigan et al., 1975) are shown in Table C-12. The concentraton decrease with both depth and distance is also apparent here. Information on soluble lead levels in soil near a similar complex in Great Britian is presented in a report by Little and Martin. (Needleman et al., 1974) Baltrop reported values up to 30,000 µg/g in villages in the eastern half of Derbyshire County, England. (Yankel et al., 1977) In this instance, the soil included lead contamination from old mine tailings and possible natural mineralization, i.e., the concentrations were not exclusively atmospheric in origin.

Table C-13, derived from studies done in 1959 and 1960, (Landrigan et al., 1976) gives lead levels of soil adjacent to another Russian lead smelter. The plant is located in a valley surrounded by mountains that hinder natural ventilation, In addition, plant emissions are inadequately contorlled. Methods of sample preparation and analysis of the soil samples are not given, however; nor is it stated whether the solid weights used were for dried or undried material.

Paluch and Karweta (1968) reported observations on soil lead near a new lead-zinc primary smelter in Poland. Soil analyses were made in several areas prior to operation of the factory and after 1 year of operation. Samples were extracted with hot concentrated hydrochloric acid and analyzed for lead content by the dithizone method. Levels found are given in milligrams of lead per kilogram of dried soil. Values given are the average of three samples. Two sites are of particular interest, a woods of young pines 2 km from the smelter and a tree nursery at 3 km. Before and after lead levels in the top 5 cm of soil at these locations were 39 and 89 mg/kg for the former, and 54 and 81 mg/kg for the latter. At other sampling sites the data were quite variable, but these were agricultural lands subject to cultivation, to fertilization, or to both. The wooded sites were not disturbed in this manner.

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