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Toxic Metals in the Air and Soil of the Paso del Norte Region

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Abstract

In the first of the individual studies that comprise this chapter, air concentrations are presented for four toxic metals—copper (Cu), lead (Pb), arsenic (As), and chromium (Cr)—based on particulate matter (PM) trapped on filters from eight sampling stations in the Paso del Norte airshed in 1994, 1995, and 1996. One representative low-wind day in each season (spring, summer, fall, and winter) was chosen for analysis by inductively coupled plasma mass spectrometry (ICP-MS). The resultant data set thus can be interrogated to reveal both geographic and seasonal variation trends in airborne toxic metals.

Concentrations of copper, lead, chromium, and arsenic were found to increase during fall and winter, relative to spring and summer. Ground-level atmospheric inversions during the colder seasons in this desert region are believed to trap anthropogenic particulates by preventing vertical mixing. Elevated metal levels characterized

sampling stations in the urban core, with lower values at more distal samplers. This suggests the importance of local sources of the metals.

The chapter also details a study in which levels of lead, copper, and arsenic in PM in the El Paso, Tex.-Ciudad Juárez, Chih., airshed were found to exhibit significant decreases over the past quarter-century. These overall trends are evident even in a limited data set of samples from 1977, 1980, 1987, 1994, and 2001. Decreases in lead are dramatic and a significant contribution to the public health of the El Paso-Ciudad Juárez binational community.

The chapter further details the collection of soil samples from areas surrounding various facilities in El Paso that are potential point sources (historical as well as current) for metals contamination. Areas of interest include the American Smelting and Refining Company (Asarco) smelter on the west side of El Paso, Memorial Park in central El Paso (where the Federal smelter was formerly located), and the Phelps Dodge copper refinery on the east side of El Paso. Soil samples were also collected from outlying areas north and east of El Paso in an effort to observe the effects of distance from urban sources.

The soil samples were prepared and analyzed for arsenic, barium, calcium, cadmium, copper, chromium, lead, nickel, selenium, and zinc. Values for arsenic, lead, copper, and chromium are presented on maps of the El Paso area and correlations between concentrations of the various metals were determined.

Concentrations of arsenic, lead, copper, and chromium were highest in the area around the Asarco smelter. Higher concentrations were observed in the surface (2.5 centimeter [cm]) samples than in the samples taken at greater depths. The Memorial Park area exhibited slightly elevated levels of these metals relative to the El Paso urban background values. The samples from the Phelps Dodge refinery region were generally indistinguishable from the background samples.

Finally, the geographic distribution of lead in El Paso soils is presented in maps based on more than 300 composite soil samples collected in the region. The use of such composites highlights the distribution of lead at the neighborhood level, and de-emphasizes any anomalous elevated level associated with an individual house or

structure.

Lead levels are highest in the downtown commercial district; in the adjacent area to the east, which comprises an old central business, transport, and light industry complex; and to the west in the area of the Asarco smelter. The continuity of this zone and the age of its structures make it difficult to differentiate lead sources. Lead values decrease systematically away from this urban core zone, with the lowest levels generally encountered in the peripheral, lightly populated developments and communities.

This geographic distribution of lead in soil is consistent with lead measurements reported on PM taken from four air monitoring stations during the 1990s. Soil data thus can complement air studies by providing an essentially infinite geographic network of sampling sites that, with varying accuracy, record and integrate air conditions over years and decades.

Metales Tóxicos en el Aire y Suelo de la Región Paso del Norte

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Resumen

En el primero de los estudios individuales que comprende este capítulo, las concentraciones del aire son presentadas para cuatro metales tóxicos—cobre (Cu), plomo (Pb), arsénico (As), y cromo (Cr)—basados en la materia particulada (PM) atrapada en filtros de ocho estaciones de muestreo en la cuenca atmosférica Paso del Norte en 1994, 1995, y 1996. Se eligió un día representativo de bajos vientos en cada estación (primavera, verano, otoño, e invierno) para el análisis por espectrometría de masas (ICP-MS) acoplado con plasma. El conjunto de datos resultante revela ambas tendencias geográficas y estacionales de variación en metales tóxicos aerotransportados.

Se encontró que las concentraciones de cobre, plomo, cromo, y arsénico aumentan durante el otoño e invierno, con relación a la primavera y el verano. Se cree que inversiones atmosféricas en niveles del suelo durante las estaciones más frías en esta región desértica atrapan partículas antropogénicas al prevenir la mezcla vertical. Niveles elevados de metal caracterizaron a las estaciones de prueba en el núcleo urbano, con valores inferiores en muestras distantes. Esto sugiere la importancia de las fuentes locales de los metales.

El capítulo también detalla un estudio en el cual se encontró que los niveles de plomo, cobre, y arsénico en PM en la cuenca atmosférica de El Paso-Ciudad Juárez exhiben disminuciones significativas en el pasado cuarto de siglo. Estas tendencias generales son evi-

dentes aun en un conjunto de datos limitado de pruebas de 1977, 1980, 1987, 1994, y 2001. Las disminuciones de plomo son dramáticas y una contribución significativa para la salud pública de la comunidad binacional El Paso- Ciudad Juárez.

El capítulo detalla sobre la colección de muestras del suelo de áreas que rodean diversas instalaciones en El Paso que son fuentes puntuales potenciales (Históricas y actuales) de contaminación por metales. Las áreas de interés incluyen a la American Smelting and Refining Company (Asarco) en el lado del oeste de El Paso, el Parque Memorial en el centro de El Paso (donde anteriormente estaba ubicada la fundición Federal), y la refinería de cobre Phelps Dodge en el lado Este de El Paso. Muestras de suelo fueron también obtenidas de áreas en las afueras al Norte y Este de El Paso en un esfuerzo por observar los efectos de la distancia con fuentes urbanas.

Las pruebas de suelo fueron preparadas y analizadas para arsénico, bario, calcio, cadmio, cobre, cromo, plomo, níquel, selenio, y zinc. Los valores para el arsénico, plomo, cobre, y cromo son presentados en mapas del área de El Paso y se obtuvieron las correlaciones entre las concentraciones de los diversos metales.

Las concentraciones de arsénico, plomo, cobre, y cromo fueron las más altas en el área alrededor de la fundición Asarco. Concentraciones superiores fueron observadas en las muestras superficiales (2.5 centímetros [cm]) que en las de profundidades mayores. El área del Parque Memorial exhibió niveles ligeramente elevados de estos metales en relación con valores anteriores urbanos de El Paso. Las pruebas de la región de la refinería Phelps Dodge fueron generalmente indistinguibles de los valores anteriores de referencia.

Finalmente, la distribución geográfica de plomo en suelos en El Paso se presenta en mapas basados en más de 300 muestras del suelo obtenidas en la región. El uso de los mapas permite resaltar la distribución de plomo en el nivel vecindad, y resta importancia a cualquier nivel anómalo elevado asociado a una estructura o casa individual.

Los niveles de la plomo son más altos en el distrito comercial del centro de la ciudad; en el área adyacente hacia el Este, que comprende una vieja central de negocios, de transporte, y un complejo de industria ligera; y hacia el oeste en el área de la fundición Asarco. La continuidad de esta zona y la edad de sus estructuras dificultan el

diferenciar fuentes de plomo. Los valores de plomo disminuyen sistemáticamente fuera de esta zona urbana núcleo, con los niveles más bajos generalmente encontrados en las comunidades y desarrollos periféricos poco poblados.

Esta distribución geográfica de plomo en el suelo es consistente con medidas de plomo reportadas en PM tomada de cuatro estaciones de monitoreo de aire durante los 1990s. Los datos del terreno pueden así complementar estudios de aire al proveer una red geográfica esencialmente infinita de sitios de muestreo que, con exactitud variable, registran e integran condiciones del aire a través de años y décadas.

Seasonal and Spatial Variation of Metals in Airborne Particulate Matter in the El Paso-Ciudad Juárez Airshed[1]

Previous Studies

Einfeld and Church (1995) reported on a short-term (December 3–21, 1990) investigation of particulate matter (PM) in the El Paso-Ciudad Juárez airshed. Their study identified the importance of biomass combustion and crustal sources of PM, and the relatively small contribution (< 20%) from vehicles. Levels of PM were higher in Ciudad Juárez than in El Paso, and much of this was found to be aerosol carbon. Winter stagnation events exacerbated the particulate load by preventing dilution. Einfeld and Church (1995) also provided a comprehensive summary (to 1995) of the findings of earlier research on all aspects of air quality in the region.

Dattner (1994) furnished additional details of x-ray fluorescence (XRF) analysis of 72 (22 coarse, 50 fine) 12-hour filters also collected during the December 1990 study. He indicated that elevated metal values were consistent with a smelter source, and that high lead values in Ciudad Juárez were related to leaded gasoline. Note that by the mid-1990s leaded gasoline was severely restricted in Mexico.

Materials and Methods

Meteorology and Sample Selection

Meteorological records were investigated from two sources—a local newspaper, *The El Paso Times,* and the U.S. National Weather Service. The goal was to find one low wind velocity day in each of the four seasons of 1994, 1995, and 1996. Samples taken on days with low wind velocity would emphasize local production of particulates, which might assist in source determination.

Pearson and Fitzgerald (2001) applied the MM5 wind model for the El Paso-Ciudad Juárez airshed; their model was concerned with high ozone concentration days. They found that high ozone episodes occur primarily during periods of low wind speeds for the Paso del Norte region.

Samples for this study were selected to meet three criteria: low wind speed, wind direction consistent with seasonal trend (Chapter I, Figure 2), and lack of such confounding conditions as rain or snow. Among the available filters, the authors were able to select days with average wind speeds between 5.8 kilometers per hour (km/hr) and 14.0 km/hr (3.6 miles per hour [mph] to 8.8 mph) (Table 1).

Filter Samples

Qualifying filters were selected from the archives at the laboratory of the El Paso City-County Health and Environmental District (EPCCHED). A total of 141 PM_{10} (particulate matter with an aerodynamic diameter of 10 micrometers [µm] or less) quartz filters were sub-sampled for analyses by removing 1-inch-by-3-inch strips with a ceramic knife (zirconia) to prevent contamination with metals of interest. These 24-hour samples had been taken from four sites in El Paso and four in Ciudad Juárez. The sampling period was midnight to midnight, scheduled every sixth day. The sampler systems—two-stage Sierra Andersen PM_{10}—were impaction type with size-selective inlet and a design flow rate of 1.13 cubic meters per minute (m^3/min) (EPA 1992).

The four El Paso sites were Tillman, Riverside, Northeast, and Ivanhoe, and the four Ciudad Juárez sites were Pestalozzi, Tecnológico, Advance Transformer, and Zenco. Data from a ninth

Table 1. Weather Data Used for Selection of Appropriate PM_{10} Filters

	Wind Average Speed (mph)	Peak Wind (mph)
1996		
October 30	3.6	10
July 26	4.8	15
April 15	8.2	22
January 10	7.8	24
1995		
October 18	5.3	16
July 8	5.3	16
April 27	7.3	23
January 3	5.4	16
1994		
October 11	4.6	14
July 31	7.2	23
April 20	8.8	22
January 8	4.8	9

Source: Authors

station, Club 20-30 in Ciudad Juárez, are not reported here because of the limited number of samples available. Appendix Figure 1 (page 305) presents these locations and a regional map. Duplicate samplers are sited at Tillman (Tillman A and B) and Tecnológico (Tecnológico 1 and 2); these collocated samplers replicated analytic results. The sites had been selected previously using criteria under the 1987 PM_{10} regulation (EPA 1987).

The four outermost sites (Northeast, Ivanhoe, Zenco, and Tillman) enclose or define a roughly rhomboidal area of approximately 250 km^2. Appendix Figure 1 (page 305) indicates that the two western sides of the rhomboid abut, respectively, the Franklin Mountains in Texas and the Sierra de Juárez in Chihuahua.

Instrumental Analysis Procedures

For microwave extraction, the authors followed the protocols of U.S. Environmental Protection Agency (EPA) Method 3051, *Microwave Assisted Acid Digestion of Sediments, Sludges, Soils and Oils* (EPA 1994). Extractions were performed in a CEM MDS-2000 microwave unit with sealed Teflon reaction vessels. For quality control, in each carousel of 12 reaction vessels the authors included a laboratory-fortified blank and a laboratory-fortified sample (matrix blank) with U.S. National Institute of Standards and Technology (NIST)-traceable spikes.

Inductively coupled plasma-mass spectrometry (ICP-MS) analysis was performed on the filter extracts. The ICP method of analysis offers the advantage of high sensitivity and multi-element (up to 65 cations) quantification; however, it consumes the filter sample. For ICP-MS analyses, a Hewlett Packard HP 4500 instrument was used, following appropriate protocols in two EPA methods: *Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry* and *Determination of Metals in Ambient Particulate Matter Using Inductively Coupled Plasma/Mass Spectrometry (ICP/MS).* The first of these is Method 200.8 and the second is a preliminary draft method, EPA/625/R-96/010a (EPA 1991, 1997). Interferences from polyatomic ions from gas, air, reagents, and sample matrices were corrected using appropriate protocols (EPA 1991, 1997). Samples were analyzed for 65 elements, of which some 30 elements typically were present at quantifiable levels. All results presented herein fell within the relevant EPA guidelines. Additional analytic details are found in Espino (2000).

Results and Discussion

The authors focused their attention on four elements of particular interest in the Paso del Norte airshed: copper, lead, arsenic, and chromium. There are no significant natural sources of these elements beyond the typical crustal (rock) background in the region; thus they represent chiefly anthropogenic input. The selection of four elements from 30 is based on concerns about their toxicity and on simplicity of presentation.

Geographic Patterns

Examination of Tables 2, 3, 4, and 5 indicates that the concentrations of the elements correlate across stations on each sampled day. There are days with high values across the map and other days with low values. This reflects a degree of interconnectedness of the airshed in terms of meteorological conditions and production of pollutants.

Table 2. Seasonal (Spring, Summer, Fall, Winter) Concentrations (in Nanograms per Cubic Meter [ng/m^3]) of Copper for 1994, 1995, and 1996 at Sampling Stations in the El Paso-Ciudad Juárez Area

Copper (ng/m^3)	1994				1995				1996			
	S	S	F	W	S	S	F	W	S	S	F	W
Tillman A	24	30	51	230	28	25	150	62	36	58	420	320
Tillman B	20	38	55	220	28	27	184	64	31	91	460	360
Riverside	12	16	50	199	12	20	46	20	20	42	108	140
Ivanhoe	19	37	29	nd	10	30	85	19	17	31	141	121
Northeast	21	34	71	116	30	44	60	59	31	47	49	114
Tecnológico 1	40	65	99	780	45	31	143	nd	69	nd	125	156
Tecnológico 2	28	103	118	420	120	31	133	47	67	nd	66	180
Pestalozzi	11	84	79	156	39	35	89	35	nd	96	174	163
Zenco	nd	30	nd	nd	nd	13	98	22	65	88	nd	128
Advance Transformer	50	38	89	210	66	29	55	41	41	116	210	96

Note: nd = no data
Source: Authors

Table 3. Seasonal (Spring, Summer, Fall, Winter) Concentrations (ng/m^3) of Lead for 1994, 1995, and 1996 at Sampling Stations in the El Paso-Ciudad Juárez Area

Lead (ng/m^3)	1994				1995				1996			
	S	S	F	W	S	S	F	W	S	S	F	W
Tillman A	8	17	29	85	10	5	50	29	6	6	75	98
Tillman B	12	9	26	78	7	4	47	27	6	6	122	103
Riverside	7	4	32	72	4	2	22	11	7	5	16	38
Ivanhoe	3	4	7	21	4	2	16	7	3	4	5	23
Northeast	4	7	8	28	4	3	13	10	4	3	5	17
Tecnológico 1	4	3	24	76	5	1	65	nd	27	nd	33	59
Tecnológico 2	4	6	26	76	6	1	73	8	23	nd	16	60
Pestalozzi	6	24	34	105	nd	4	71	22	nd	13	90	62
Zenco	nd	7	nd	nd	9	4	56	9	13	30	nd	71
Advance Transformer	26	3	125	185	51	7	115	34	22	7	133	71

Note: nd = no data
Source: Authors

Table 4. Seasonal (Spring, Summer, Fall, Winter) Concentrations (ng/m^3) of Arsenic for 1994, 1995, and 1996 at Sampling Stations in the El Paso-Ciudad Juárez Area

Arsenic (ng/m^3)	1994				1995				1996			
	S	S	F	W	S	S	F	W	S	S	F	W
Tillman A	2	1	2	46	2	1	18	10	2	3	39	66
Tillman B	2	1	1	42	3	1	18	9	1	3	39	69
Riverside	1	0	1	19	2	0	8	2	8	7	6	23
Ivanhoe	0	0	0	10	2	0	4	2	3	7	9	39
Northeast	1	0	1	15	3	0	4	6	2	6	13	20
Tecnológico 1	1	0	1	18	3	0	7	nd	2	nd	7	23
Tecnológico 2	1	1	1	19	2	0	7	2	2	nd	3	21
Pestalozzi	1	4	2	13	nd	0	14	3	nd	7	53	25
Zenco	nd	1	nd	nd	2	0	14	3	4	5	nd	16
Advance Transformer	3	1	3	42	5	0	7	3	4	3	40	11

Note: nd = no data
Source: Authors

Table 5. Seasonal (Spring, Summer, Fall, Winter) Concentrations (ng/m^3) of Chromium for 1994, 1995, and 1996 at Sampling Stations in the El Paso-Ciudad Juárez Area

Chromium (ng/m^3)	1994				1995				1996			
	S	S	F	W	S	S	F	W	S	S	F	W
Tillman A	2	4	6	5	3	3	5	11	4	2	13	11
Tillman B	2	3	3	5	4	4	6	7	3	2	10	13
Riverside	2	4	3	6	3	3	4	6	5	2	6	4
Ivanhoe	3	5	3	0	4	3	3	6	3	1	3	2
Northeast	6	5	2	2	4	3	2	8	4	2	2	2
Tecnológico 1	3	2	11	4	4	1	6	nd	3	nd	5	8
Tecnológico 2	4	2	11	4	5	1	6	11	2	nd	2	5
Pestalozzi	7	4	15	5	nd	1	10	3	nd	4	13	6
Zenco	nd	3	nd	nd	5	1	7	7	3	6	nd	6
Advance Transformer	6	3	19	6	5	1	5	8	5	3	8	6

Note: nd = no data
Source: Authors

Interconnectedness notwithstanding, outlying stations—those most distant from the industrial districts and other known or expected pollutant sources in both El Paso and Ciudad Juárez—consistently show the lowest concentrations. This obviously reflects both the greater production of pollutants in the core urban areas and the limited degree of mixing in the airshed on these generally calm-wind days. For example, the Northeast station in El Paso records higher quality air (for these four elements in PM), resulting from low-density residential land-use, its distance from major pollutant sources, and the open land that surrounds this neighborhood on three sides.

In contrast, the stations in the urban core—Tillman in El Paso and Advanced Transformer, Tecnológico, and Pestalozzi in Ciudad Juárez—typically show the highest values. The northern part of Ciudad Juárez is the site of many maquiladoras and other local

industries. Although environmental regulations are similar, enforcement is often difficult in Mexico when compared to the United States. The large American Smelting and Refining Company (Asarco) copper-ore smelter is located less than five kilometers northwest of the Tillman station in downtown El Paso. This operation apparently was a significant, but not dominant, point source of metal and semi-metal particulates in the past. The Asarco smelter was shut down in February 1999 after more than a century of operation; no plans or date for reopening had been announced as of March 2004.

Seasonal Patterns

Tables 2, 3, 4, and 5 also demonstrate the seasonal variation in particulate pollution. Fall and winter levels of copper, lead, arsenic, and chromium are considerably higher than spring and summer values—often by more than an order of magnitude at individual stations. This effect is seen most dramatically in fall and winter of 1995 and 1996 for all four elements.

With one exception, there is no evidence of significant seasonal changes in pollutant releases in the region. The burning of nonstandard materials in fireplaces and stoves for residential heating does occur in Ciudad Juárez during the colder months of the year. This practice is unusual in El Paso. Burning such materials as tires and trash may release metals to the air and contribute to pollutant levels, mainly in or contiguous to Ciudad Juárez.

Discussion

Retarded vertical circulation in the Paso del Norte airshed is believed to be the major cause of the increased levels of anthropogenic pollutants—i.e., the copper, lead, arsenic, and chromium—in fall and winter. Atmospheric inversions are common at that time of year, with rapid radiative cooling at ground level at night due to elevation and the typical lack of cloud cover. Occasionally these inversions last several days, with consequent trapping of pollutants near ground level and significant deterioration of air quality.

It has long been realized that the Paso del Norte airshed has a high loading of natural mineral material in its ambient PM (Dattner 1994; Einfeld and Church 1995). The extremely dry climate, often

windy weather, sparsity of vegetation, and prevalence of unpaved streets and roads, particularly in Ciudad Juárez, combine to release natural PM into the local atmosphere. These processes are augmented by production and escape of mineral PM from quarry operations within the municipal limits of both cities. These geologic dusts are not significant contributors of the four metals documented herein.

There are no current metal-ore mining operations in the region and no extensive mining spoil piles to act as a source of the copper, lead, arsenic, and chromium observed. The local geologic section consists chiefly of Paleozoic and Mesozoic sediments, many of which are carbonates, and unconsolidated Tertiary and Quaternary sediments (Hawley 1978). The relatively minor exposures of igneous and metamorphic rocks also are not significant sources of those metals.

Obvious industrial sources of metals in the airshed include a copper-ore smelter and light industry in El Paso. Ciudad Juárez hosts a large number (several hundred) of maquiladoras, various industries, and small, essentially unregulated operations such as brick kilns (these often burn tires, pallets, and sawdust as fuel).

Conclusions

Metals concentrations (copper, lead, arsenic, and chromium) are highest in the fall and winter seasons, apparently due to retarded vertical circulation associated with inversions. Fall and winter levels may be an order of magnitude higher than spring and summer levels. Geographically, metal concentrations in the urban core of El Paso-Ciudad Juárez often exceed those recorded at distal stations by an order of magnitude or more. Smelter operations in El Paso appear to have made a significant, but not dominant, contribution to metals in PM in the airshed. Industrialization and population growth combined with poverty are contributing to emissions in Ciudad Juárez. Continuing international cooperation is required to monitor, assess, and regulate anthropogenic sources of metals in the air shared by El Paso and Ciudad Juárez.

Reduction in Levels of Toxic Elements in Particulate Matter in the El Paso-Ciudad Juárez Airshed Over the Past Quarter-Century[2]

Introduction

Archived PM air filters provide contemporary and future researchers an opportunity to document secular changes in air quality throughout the collection period represented in a given filter library. In El Paso, the EPCCHED and its predecessor organizations have maintained an exceptional archive with an extensive collection of filters dating back to the late 1970s. Of particular interest to air quality in this period are the implementation of restrictions on leaded gasoline in both the United States and Mexico, significant alterations at the Asarco plant in El Paso, and a changing regulatory and enforcement climate.

The earliest year for which filters representing broad areal and temporal coverage are available in the EPCCHED collection is 1977. This section presents analyses of filters for selected elements (chromium, copper, arsenic, and lead) for samples from 1977, 1980, 1987, 1994, and 2001. Although the data set is sparse, the overall trend toward cleaner air is unmistakable.

In cooperation with EPCCHED, a group at the University of Texas at El Paso (UTEP) is currently engaged in a large-scale project to document changes in toxic elements in PM at five-year intervals, starting in 1977. That research involves hundreds of samples from multiple stations and sampling periods throughout each year, and should provide a definitive record of change through time.

Materials and Methods

Samples and Analysis

Filters from the EPCCHED archives representing days with low wind velocities were selected for examination. Samples were from different available sites in El Paso and Ciudad Juárez; these had been collected on a single day in each of the summers of 1977, 1980, and

1994, the spring of 1987, and the winter of 1994. The 1994 samples are also reported in the section titled "Seasonal and Spatial Variation of Metals in Airborne Particulate Matter in the El Paso-Ciudad Juárez Airshed."

The 2001 samples were collected by UTEP researchers using dichot samplers at various sites on the UTEP campus. After analysis, the compositions of the separated $PM_{2.5}$ fine and PM_{10} coarse components were totaled. Stations at five sites were operated continuously from February 19, 2001, through March 23, 2001. Sampling times ranged from three days to seven days, yielding six filters at each site. There was no evidence that loading beyond the usual 24 hours adversely affected air flow rates to a degree that compromised the validity of the elemental data for the purposes of this study.

All samples underwent microwave-assisted acid digestion, followed by multi-element analysis by ICP-MS. These procedures are described in the section titled "Seasonal and Spatial Variation of Metals in Airborne Particulate Matter in the El Paso-Ciudad Juárez Airshed."

Results and Discussion

Air Sample Analyses

Concentrations of chromium, copper, arsenic, and lead in air filters from respective years are presented in Table 6. Data for winter 1994 are included for comparison inasmuch as this season typically yields higher values for pollutants (see the section titled "Seasonal and Spatial Variation of Metals in Airborne Particulate Matter in the El Paso-Ciudad Juárez Airshed"). Additional data for 1977 from Herbert, Candelaria, and Applegate are presented to validate the present results with those generated at a time closer to the collection of the samples. The Herbert, Candelaria, and Applegate study was presented at a symposium held in November 1979. These data are based on quarterly averages of typically 15 samples at each site; the three-site quarterly averages were averaged in turn. The UTEP data for 2001 are part of an unpublished study of air quality on campus and are included to represent more recent conditions.

Table 6. Average Particulate Composition in Nanograms per Cubic Meter of Air

Sampling Season	Number of Sites	Location of Sites	Chromium	Cooper	Arsenic	Lead
Summer 1977	5	El Paso, Ciudad Juárez	19	680	15	850
Summer 1977*	3	El Paso	nd	nd	10	500
Winter 1977*	3	El Paso	nd	nd	45	1250
Summer 1980	15	El Paso, Ciudad Juárez	4	170	15	270
Spring 1987	3	El Paso, Ciudad Juárez	16	176	24	211
Summer 1994	9	El Paso, Ciudad Juárez	4	49	1	9
Winter 1994	8	El Paso, Ciudad Juárez	4	300	23	81
Spring 2001	6	UTEP	14	52	5	23

Note: nd = no data
Source: *Data derived from Herbert, Candelaria, and Applegate (No Date); authors

Limitations of the Data

The data in Table 6 are not comprehensive nor definitive conditions during a given season or year in the El Paso-Ciudad Juárez airshed. In some cases, the number of sites averaged is small; in others, data for a single day can have only limited significance. There are also differences in the types of samplers used for collection of the particulates. Nonetheless, the overall large and consistent differences between the 1977 through 1987 data and the 1994 through 2001 results show an unmistakable trend toward better air quality.

Lead Reduction

Table 6 reveals significant changes in the levels of toxic elements in the El Paso-Ciudad Juárez airshed over the last quarter century. The data for lead are the most dramatic, with a decrease between one and

two orders of magnitude. Much of this decrease is likely attributable to two transitions during that period—the phase-out of leaded gasoline and changes at the Asarco smelter.

In 1970, amendments to the 1963 Clean Air Act addressed the issue of leaded gasoline, the gradual phase-out of which was initiated in 1973. Although lead at other-than-trace levels was not eliminated officially in motor-vehicle fuel until the end of 1995, the use of leaded gasoline in the U.S. vehicle fleet was largely over at that time. By 1980, lead used in gasoline had dropped to half the 1976 levels, and in 1982 the U.S. Environmental Protection Agency (EPA) stepped up its campaign to decrease lead in gasoline. The decrease in ambient lead that accompanied this change throughout the United States has been documented in numerous studies (Lin-Fu 1992; Warren 2000). The official end of leaded gasoline in Mexico came in 1998.

During the study period, a number of changes in the Asarco smelting operation occurred. These included installation of an ore unloading and handling facility in 1978, installation of a sinter plant in 1979, shut down of the zinc plant in 1982, suspension of the lead plant operations in 1985, installation of continuous top-feed oxygen process technology in 1993, and placing the plant on care and maintenance status in 1999 (Asarco 2004).

Most of the dramatic decreases in airborne lead during this period undoubtedly can be attributed to these changes in leaded fuel consumption and in the smelter's fugitive dust and stack emissions. Currently, there do not appear to be any data that can apportion the reduction between these two sources. Additional contributing factors in reducing the El Paso-Ciudad Juárez burden of airborne lead may include mandated phase-outs of lead in such products as paint and solder.

Changes in Copper, Arsenic, and Chromium

Among these elements, copper and arsenic decrease, whereas a trend for chromium is unresolved. The drop in copper probably can be attributed to both the changes at Asarco and its closing. The levels of arsenic in the recent spring and summer data are lower than those of the corresponding seasons in the early years in Table 6; the same is true of the more limited winter data. Arsenic is common in sul-

fide ores and its release is often associated with smelting operations of the El Paso Asarco type. Other sources of airborne arsenic include open burning of arsenic-treated lumber, various industrial operations, and, in the past, fugitive dusts laden with arsenic from agricultural chemicals.

The origin and significance of the minor amounts of chromium in local air are uncertain. Although chromium may be present in some of the ores that Asarco processed, high chromium concentrations typically are associated with minerals in unrelated rare ore deposits in ultramafic rocks. Chromium is a common industrial metal and a significant component of stainless steels and certain pigments. Its presence in the air is likely due to a variety of urban and industrial sources. The values encountered in the UTEP study may reflect the location of the campus, which is bordered by an interstate highway (I-10) and an active railroad line to the west, and a busy commercial state highway to the east (Mesa Street). UTEP also hosts thousands of vehicles on its parking lots daily. Thus, the values for chromium listed in 1994, which are based on a broad areal network of sampling stations, may better summarize current levels of chromium in the El Paso-Ciudad Juárez airshed.

Significance

An overall decrease in the concentrations of three (lead, arsenic, and copper) of four toxic elements in the air is indicated by this limited historical study. The data suggest that none of the current levels in the airshed represents a regulatory violation or a significant known threat to public health. Such was not the case a quarter-century ago.

Toxic Metals in El Paso Soils: Introduction[3]

The two following sections on concentrations of toxic metals and semi-metals in El Paso soils are included because of the often close association between the elemental contaminants encountered in soil and air particulates. Airborne deposition links soil composition to that of the PM; soil entrainment by wind drives the reverse transfer. Such exchanges may comprise natural and/or anthropogenic particles, and these in turn may be innocuous or toxic. Soil data can

complement air studies by serving as a proxy network of sampling sites that record and integrate, albeit imperfectly, air conditions over years and decades.

In the El Paso region, strong winds, a desert climate, and sparse vegetative cover ensure the presence of a significant geologic component in the local air particulates (as discussed in Chapter I and Chapter III). Likewise, dusts and particles produced by local commerce and industry may be subject to cycles of injection or entrainment, deposition, and re-entrainment because of the Chihuahuan desert climate.

Significant local anthropogenic sources, discussed in Chapter I, include ore smelters, brick kilns, open burning, unpaved streets, and unwatered quarry and earth-moving operations. Smelter emissions have received particular attention because of the known toxicity of such elements as arsenic, lead, and cadmium and their compounds. These can be released as stack emissions or as dusts and particulates in ground operations involving crushing, processing, transport, and loading of raw ore and smelter byproducts.

The section titled "Levels of Toxic Metals in El Paso Soils Proximal to Three Potential Industrial Point Sources," presents the results of a study completed in 1993 that was designed to document levels of toxic metals in soil proximal to then-current or former smelting and refining operations. As such, the sampling strategy was non-random geographically, emphasizing areas adjacent to those industrial sites. This section also provides a concise history of smelting and refining in El Paso.

The section titled "Lead in El Paso Soil," presents a uniquely detailed map of lead in El Paso soil. This contemporary study employed a randomized sampling strategy, based on population density, to choose 500 city blocks for soil testing. The research team is producing a similar map for Ciudad Juárez.

Recently, El Paso soils have been in the news because of an ongoing EPA investigation of arsenic and lead levels in soils proximal to the Asarco smelter. Topsoil removal from selected residential yards in nearby neighborhoods was underway in 2003 and 2004.

Levels of Toxic Metals in El Paso Soils Proximal to Three Potential Industrial Point Sources[4]

Introduction

At least three metal smelters and one metal refinery have been located within what is now the City of El Paso. All three smelters were established and operating around the start of the 20th century, long before any environmental controls on atmospheric emissions were implemented or even considered necessary. The purpose of this study was to collect and analyze soil samples from areas near these sites to quantify levels of metals contamination. Sites of special interest in this study are the Asarco smelter, the Memorial Park area where the Federal smelter was located, and the Phelps Dodge refinery area.

The El Paso Smelter, owned by Asarco, was constructed at its current location in 1887. Lead, copper, and zinc were extracted from ores at the smelter (Lee 1950). Two additional smelters were located in El Paso in the past. The International smelter was located at the present site of Guillen School (formerly Bowie High School) at Sixth Street and Cotton Avenue in central El Paso (Lee 1950) and was operated sporadically from 1888 until 1894. It was not a part of this study. The Federal smelter was located off Gold Street near what is now Memorial Park. The Federal smelter began smelting copper in 1901 and after four years of financial difficulties was closed due to bankruptcy in 1904. The property changed hands several times, but the smelter was never re-opened and was dismantled in 1907 (Rand 1977). The City of El Paso acquired the property and in 1921 planted several thousand trees and shrubs on what was to become Memorial Park (Stockwell 1926). The Nichols Copper Company constructed and began operating its El Paso Refinery in the late 1920s (Corwin and Harloff 1930). The refinery, currently owned by the Phelps Dodge Corporation, receives anodes of copper and electrolytically removes the impurities; the refined metals are then cast into bars (Bailey 1983).

Previous Studies

Studies of the effects of industrial pollution on the El Paso area have been performed since the early 1950s (Schatzman 1977). The studies have included air monitoring by local, state, and federal air pollution control agencies, blood lead level testing of residents, and soil and dust testing for metals concentrations.

The El Paso City County Health Unit performed a comprehensive study in the early 1970s that included sampling of ambient air, soil, household dust, food and water, pottery, and human blood (Rosenblum, Shoults, and Candelaria 1975). In conjunction with that study, the Centers for Disease Control collected paint samples for lead analysis (Landrigan, et al. 1975). Abnormally high lead levels were found in the blood of children 1 to 19 years of age who lived within one mile (1.6 km) of the Asarco smelter. The geographic distribution of high blood lead levels was similar to the ambient lead levels found in household dust. Although lead levels in soils near the smelter were found to be high (ranging from 1,000 parts per million [ppm] to 3,600 ppm), it was determined that lead in the soils contributed to adverse health effects to a lesser extent than lead in household dust. The study concluded that neither paint ingestion, the culinary use of glazed pottery with high lead content, nor vehicular lead could adequately account for the high blood lead levels encountered.

At this time, the Secretaría de Salud (Secretariat of Health) in Mexico performed a similar study in Ciudad Juárez in 1974 (Ordonez No date). Blood samples and glazed pottery were analyzed for lead while soils from gardens and courtyards and household dust were analyzed for lead, copper, zinc, and cadmium. Concentrations of these metals in dust and soils were found to be higher near the Asarco smelter and decreased with distance from the smelter. A positive correlation was found between blood lead levels and lead concentrations of soils and dust.

New Mexico followed suit with an investigation of lead in soils of various communities in southern New Mexico (Summers 1972). Soil samples collected from Anthony, Anapra, and Meadow Vista exhibited lead concentrations from below instrument detection limits to 220 ppm (or milligrams per kilogram [mg/kg]).

Miller (1972) documented lead levels of soils of the Rio Grande Flood Plain in the "Upper Valley" and "Lower Valley" of El Paso. The study found lead contents of the soils ranging from 0.4 ppm to 35.0 ppm. No correlation was found between lead content and either vehicular traffic or soil type. Relationships were noted between lead content and distances from five potential point sources of lead contamination, which included Smeltertown, the junction of Alameda Avenue and Paisano Drive (Highways 20-85 and 180-62), the Standard Oil and Texaco refineries, Fort Bliss, and the El Paso International Airport.

Schatzman (1977) detailed stationary air pollution in El Paso from 1951 to 1975 and observed that political decisions made about air pollution in El Paso appeared more often to favor economics than potential impacts on human health and the environment.

In 1989, the Texas Air Control Board performed a heavy metals analysis of soils from various sites in Texas. Concentrations ranging from below instrument detection limits to 1,100 ppm were found in soil samples from El Paso. The concentrations were highest near the Asarco smelter and declined rapidly away from the smelter. The levels encountered were judged to pose no threat to human health because the areas with highest concentrations were not considered to be places "frequented by the general public" (Dydek 1990).

EPA in 2001 initiated an investigation of arsenic and lead levels in soils proximal to the Asarco smelter. The project is still underway and topsoil is being removed from selected residential yards in nearby neighborhoods. Although EPA has released copies of several reports from their subcontractors, a full report authored by EPA is not yet available.

Materials and Methods

Field Sampling Procedures

Sample collection locations include the area around the Asarco smelter on the west side of El Paso, Memorial Park in central El Paso (where the Federal smelter was located), and the Phelps Dodge Copper Refinery on the east side of El Paso. Additional sample col-

lection points were located in outlying areas north, northeast, and east of El Paso. Full descriptions of the sampling locations and procedures are available in Barnes (1993).

Soil samples were collected from apparently undisturbed locations, where possible, using protocols established by EPA. Samples from the surface (0.0 centimeters [cm] to 2.5 cm) and from various depths ranging from 10 cm to 60 cm below the surface were collected from selected sample locations in an effort to document downward migration of metals.

After collection, the samples were refrigerated for approximately three weeks until they were carried through the sample preparation processes, in accordance with EPA protocols (EPA 1986).

Sample Preparation

EPA Method 3050, *Acid Digestion of Sediments, Sludges and Soils,* was followed for the initial digestion of the soil samples (EPA 1986). A set of selected soil samples that exhibited high total metals concentrations was prepared for analysis using the Toxicity Characteristic Leaching Procedure (TCLP) (Code of Federal Regulations 1991). At the time of this study, the TCLP procedure was used to determine whether a substance could be classified as a "hazardous waste." EPA considers the total metals analysis a preliminary test. If a sample exhibits high total metals concentrations, EPA then requires TCLP for determination of the leachability of a contaminant. TCLP was designed by EPA to approximate the rainfall conditions to which a substance would be exposed in the natural environment. Details of the total digestion and TCLP procedures are provided in Barnes (1993).

Instrumental Analysis

A Beckman SpectraSpan VI Direct Current Plasma (DCP) Atomic Emission Spectrometer was used for analysis of the digestates prepared from the samples, following EPA Method 6010, *Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP).* Method 6010 was chosen because EPA has not provided a method specifically for use with DCP, but the two spectroscopic instruments (DCP and ICP) are equivalent, except for the source of the plasma. Metals examined were arsenic, barium, cadmium, calcium, chromium, cop-

per, lead, nickel, selenium, and zinc. Wavelengths and instrument detection limits for each of the elements studied are provided in Table 7. The analytical and quality assurance/quality control (QA/QC) procedures followed in the study are presented in full in Barnes (1993).

Results and Discussion

Soil Sample Analyses

Concentrations of lead, copper, arsenic, and cadmium in surface samples from the Asarco area are presented in Figure 1. Table 8 and Figure 2 give the ranges of each metal in nine geographic subdivisions of El Paso. Additional maps and complete data sets (for Memorial Park and Phelps Dodge area maps, subsurface samples, and TCLP values) are found in Barnes (1993).

General Findings

The highest levels of lead, copper, arsenic, and cadmium are centered in the downtown region and on the west side of the Franklin Mountains (Figure 1, Table 8, and Figure 2). The north-south trending Franklin Mountains bisect the city and the commercial downtown district is at the southern tip of the Franklins, where the U.S.-Mexican border bulges southward. Low concentrations characterize the less-populated peripheral regions to the north, east, and southeast of the central business district.

The map of the contiguous portions of the west side and downtown areas, Figure 1, reveals the highest metals concentrations encountered in this study. These elevated values appear to be associated with the location of the Asarco smelter.

Some elevated metals values are encountered at Memorial Park, the site of the Federal smelter a century ago. Memorial Park lies along the railroad tracks between downtown and Fort Bliss. Note that the upper metal levels here are approximately one-tenth of those encountered near the Asarco smelter (Table 8).

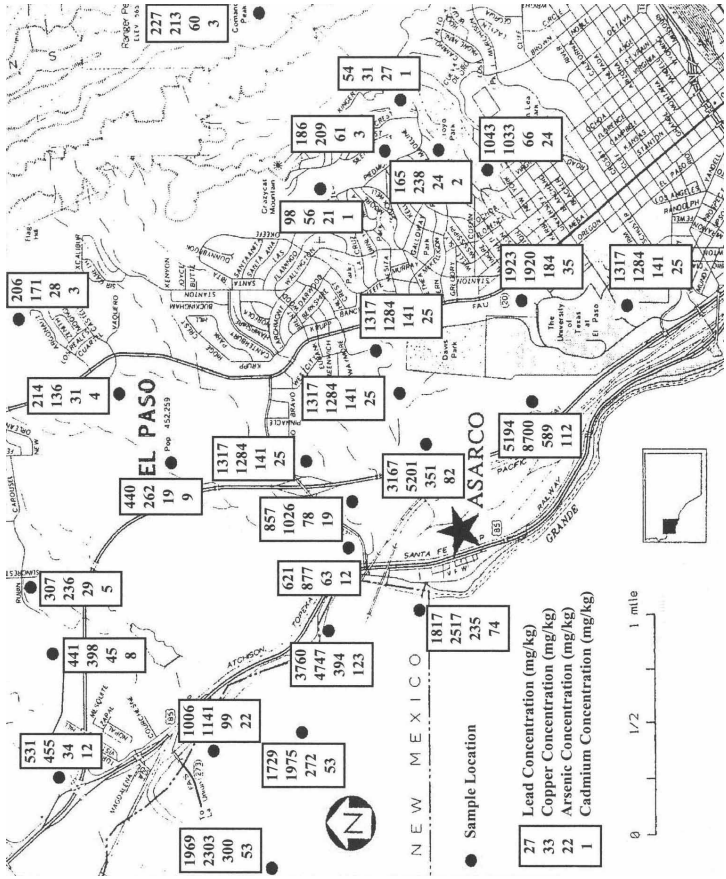
Low metal values characterize samples taken near the Phelps Dodge refinery (Table 8). These metal concentrations correspond to those encountered in the peripheral areas of El Paso.

Table 7. Wavelengths and Instrument Detection Limits (IDL) for Each Metal Quantified

Metal	Wavelength (nm)	EPA-Suggested Wavelength	Linear Range (ppm)	Total Metals IDL (mg/L)	Total Metals IDL (mg/kg)	TCLP Metals IDL (mg/L)	TCLP Metals IDL (mg/kg)
Arsenic	193.696	yes	0.8–100	0.3	20	0.2	4
Barium	455.403	yes	0.2–1,000	0.06	4	0.06	1.2
Cadmium	288.802	no	0.05–10	0.02	1.3	0.06	1.2
Calcium	318.128	no	100–5,000	22	1500	NA	NA
Chromium	267.716	yes	0.1–1,000	0.1	7	0.03	0.6
Copper	213.598	no	0.3–1,000	0.2	13	NA	NA
Lead	220.353	yes	2–1,000	0.8	50	0.9	18
Nickel	243.789	no	0.9–1,000	1.3	90	NA	NA
Selenium	196.026	yes	1–1,000	0.4	27	0.2	4
Zinc	202.548	no	0.06–600	0.003	0.2	NA	NA

Note: NA = Not analyzed
Source:

Figure 1. Sample Concentrations—Asarco Area



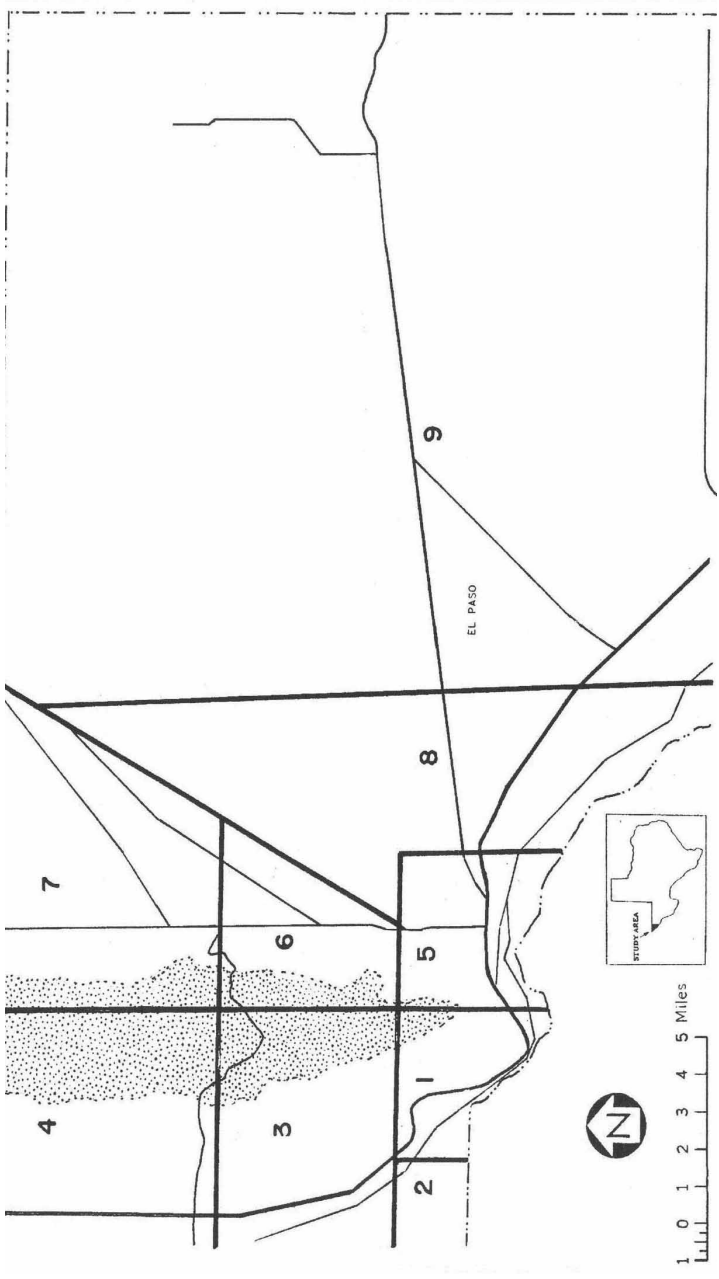
Source: Authors

Table 8. Ranges of Total Metal Concentrations in Surface Samples

Area of El Paso	# of Samples	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Nickel	Selenium	Zinc
Asarco Area (1)	32	<IDL – 589	34 – 319	<IDL – 123	<IDL – 22	30 – 8,700	50 – 5,190	<IDL – 140	<IDL – 58	46 – 3,398
Far West (2)	5	<IDL – 23	<IDL – 187	<IDL – 14	<IDL – 15	<IDL – 100	<IDL – 110	ALL <IDL	<IDL – 34	38 – 87
West Side (3)	11	<IDL – 43	<IDL – 278	<IDL – 19	<IDL – 18	<IDL – 180	60 – 290	<IDL – 130	<IDL – 41	44 – 169
Far Northwest (4)	10	<IDL – 48	<IDL – 127	<IDL – 2.9	<IDL – 18	<IDL – 90	<IDL – 270	<IDL – 110	<IDL – 36	30 – 154
Memorial Park (5)	11	<IDL – 40	<IDL – 281	<IDL – 16	<IDL – 12	30 – 340	<IDL – 390	<IDL – 120	<IDL – 39	39 – 210
Northeast (6)	3	26 – 35	106 – 151	<IDL – 1.3	11 – 18	30 – 50	<IDL – 100	<IDL – 100	<IDL – 16	49 – 77
Far Northeast (7)	10	<IDL – 40	<IDL – 81	<IDL – 5.8	<IDL – 16	<IDL – 50	<IDL – 90	<IDL – 120	<IDL – 34	21 – 115
Phelps Dodge (8)	2	ALL <IDL	ALL <IDL	ALL <IDL	ALL <IDL	20 – 100	<IDL – 80	ALL <IDL	ALL <IDL	20 – 153
East Side (9)	10	<IDL – 66	<IDL – 23	<IDL – 9	ALL <IDL	<IDL – 120	<IDL – 70	<IDL – 110	<IDL – 36	13 – 53

Notes: All values in mg metal/kg soil; numbers in parentheses correspond to the areas on Figure 2; <IDL = less than Instrument Detection Limit.
Source: Authors

Figure 2. Geographic Areas Used in Statistical Analysis



Source: Authors

Overall, the ranges observed for specific metals are similar to those documented in previous studies of the area using comparable sample preparation and analytical techniques (Dydek 1990; Ordonez No date; Shoults 1972; Summers 1972).

Significance

Concentrations of the metals associated with the smelting process—arsenic, cadmium, copper, lead, and zinc (not shown)—were highest in the area surrounding the Asarco smelter and generally decreased with distance from it (Figure 1). Concentrations of arsenic, lead, and copper were higher, typically by several fold, in the surface samples than in the subsurface samples (Barnes 1993). This suggests an above-ground source rather than derivation from the underlying bedrock. The levels of toxic metals and their geographic distribution suggest origination in smelter operations.

The lower levels, by a factor of 10, of these same metals in Memorial Park are consistent with the short-term operation of the Federal smelter on that site a century ago. The low levels of metals proximal to the Phelps Dodge refinery presumably reflect the very different nature of this operation, relative to ore smelting.

Using all of the total metals data, statistically significant (99% confidence level) inter-element correlations were found between arsenic, cadmium, copper, lead, and zinc (Barnes 1993). Generally, correlation coefficients between the metals increased when the data from the sub-surface samples were removed from the analysis, and when the data were limited to the West Side (areas 1, 2, and 3 on Figure 2) or the Asarco area (area 1). These correlations among metals commonly associated with lead and copper smelting operations again underscore the probable source of these metals in the areas proximal to Asarco.

Lead in El Paso Soil[5]

Introduction

In 2001, the National Institute of Environmental Health Sciences funded a five-year study by researchers at the University of Texas at El Paso and the Texas Tech University Health Sciences Center of

lead exposure risks in El Paso, Ciudad Juárez, and the surrounding communities. As part of this project, the researchers are conducting a comprehensive survey of lead levels in soil throughout this area. The aim is to produce a uniquely detailed map of lead for the region.

Scope and Strategy of the Research Project

A total of 1,000 municipal blocks, apportioned equally to both sides of the border, are being studied. Superficial soil in the public area in front of each house or structure around the circumference of the block is being sampled. This typically involves collecting 10 samples per block. Many structures did not have soil present, but instead were surrounded by desert landscaping (crushed rock) or concrete. To ease the burden of analyzing the resultant thousands of samples for lead, two samples are taken from each site. The first is archived and the second is combined with a sample of identical volume from every other parcel on the block. The second procedure produces a composite sample, the analysis of which represents the overall or average conditions of the entire block. In this approach, analysis of the 1,000 composite samples provides a map of lead values that can be considered "smoothed" at the block level. Construction of a map with values for thousands of individual houses would pose graphical challenges, and, in fact, would be too detailed for meaningful regional analysis. The maps of lead in soil in the El Paso area presented herein comprise the data from the 339 blocks that have been sampled and analyzed to date.

The archived samples are being used for both quality control and investigational purposes. For every 50th block, the individual samples are analyzed, their values averaged, and this average then compared to the value obtained from the composite sample. The expectation, of course, is that these values should be similar, and this has been the case thus far. In addition, for selected blocks with high levels of lead, the individual samples are being analyzed. This will suggest whether the elevated levels represent a regional trend or whether the high composite value results from a single anomalous sample, such as one house with peeling lead-based paint.

For an examination of lead in El Paso soil focused on airborne contamination from three potential point sources, see the section "Levels of Toxic Metals in El Paso Soils Proximal to Three Potential Industrial Point Sources."

Materials and Methods

Sampling

El Paso County, excluding Fort Bliss, was divided into 50 area strata by combining adjacent census tracts (from the 126 tracts in the 2000 U.S. Census) such that each stratum contained 13,000 +/- 2,000 residents. Ten blocks, each with at least six households, were then selected at random from each stratum for sampling. This sampling strategy was designed to ensure that the distribution of sampled blocks was random with respect to population, rather than random with respect to geography, such as land area. As a result, the sampled blocks are often smaller and situated closer together in the more densely settled parts of the region. A geographic information system containing geographic, infrastructure, and census data was used to develop the sampling plan and, subsequently, to display the results of the lead analyses.

Field Sampling Procedures

One 50-milliliter (ml) plastic centrifuge tube was used as a scoop to remove loose soil, and then was capped. A second sample was taken with a 10-ml cup that was then emptied into a sealable plastic bag for the composite sample. Before the start of sampling, all containers, samplers, and other materials that could come in contact with the soil samples were analyzed for lead with an XRF instrument, and none contained more than nominal levels. Field assistants used a new pair of laboratory gloves for taking each sample to prevent cross-contamination.

Sample Preparation and Instrumental Analysis

The general procedures of EPA Method 6200 (EPA 1998) for field-portable XRF were followed for preparation of the samples for XRF analysis. These included homogenization of the sample, grinding, sieving, and sealing in a standard XRF sample holder.

Soil samples were analyzed with a Spectrace 9000 field-portable XRF unit equipped with three isotope excitation sources (55Fe, 109Cd, and 241Am), operated in the laboratory. Lead L-series XRF was excited with the 109Cd source. Analysis and quality assurance/quality control were performed in general accordance with the procedures of EPA Method 6200 (EPA 1998) for field-portable XRF. The typical detection limit for lead in a typical soil matrix with the instrument is 20 ppm. NIST Standard Reference Materials 2586 and 2587, Trace Elements in Soil Containing Lead from Paint, nominally 500 mg/kg and 3,000 mg/kg lead respectively, and an analytical-grade Teflon disc (nominally lead-free) were used as primary instrument calibration standards.

Because most soil analyses fell below 500 ppm, the researchers created three additional standards by gravimetric dilution of NIST 2586 (actual NIST certification of 432 ppm lead) with silica sand to 216 ppm, 108 ppm, and 54 ppm. The mean and reproducibility (one relative standard deviation) of 10 repeated measurements were 50 ppm (+/- 30%), 107 ppm (+/- 10%), 233 ppm (+/- 7%), and 414 ppm (+/- 5%) for the 54 ppm, 108 ppm, 216 ppm, and 432 ppm lead standards, respectively.

Results and Discussion

Soil Lead Concentrations

The location, shape, and dimensions (at scale) of the blocks sampled in El Paso are presented in Appendix Figure 3 (page 307). Concentrations of lead in the composite samples from these blocks are color-coded into four categories: blocks with less than 50 ppm lead are green, those with 50 ppm to 99 ppm lead are gray, those with 100 ppm to 150 ppm lead are orange, and blocks in excess of 150 ppm lead are red. The highest composite value encountered was 421 ppm, for a block near western downtown.

Findings and Interpretation

The lowest values of lead are encountered in the peripheral areas away from the urban core (Appendix Figure 3 [page 307], green blocks). Thus, the northeast, far east, southeast, and west (with a single anomalous block) sections of the city and surrounding areas

have low soil lead levels, despite nearly explosive growth and development over the past two decades. In the newer neighborhoods, any soil brought in to replace the humus-poor desert soil has not been exposed to local conditions for very long. Low lead levels would be expected, assuming the imported soil itself was produced in a low-lead, rural environment. Nonetheless, some very old neighborhoods and blocks were sampled in these peripheral areas, and these also were below 50 ppm lead.

The observed low values of lead—less than 50 ppm—are consistent with the generally low population and commercial density of the neighborhoods in Appendix Figure 3 (page 307). These include rural and agricultural settings (parts of the so-called upper and lower valley of the Rio Grande), subdivisions (west and east sides), and separate communities (Horizon City) not contiguous with urban El Paso. For comparison, the average abundance of lead in the earth's crust is estimated to be approximately 15 ppm (Adriano 1986; Li 2000), and 10 ppm to 50 ppm lead is typical of soils in so-called "uncontaminated" settings (Davidson and Rabinowitz 1992).

Blocks with 50 ppm to 99 ppm lead, seen in gray in Appendix Figure 3 (page 307), plot in a general zone strikingly more proximal to the downtown and core central area of the city than the blocks with less than 50 ppm lead. Only a few blocks in that central area are represented on the 50 ppm to 99 ppm map.

Analytical confidence in samples in the 50 ppm range is limited because these are close to the instrumental detection limit (20 ppm lead) and relative standard deviations are high. Nonetheless, the geographic distribution of samples in Appendix Figure 3 (page 307) and its consistency with population density indicates that instrumental precision was sufficient to provide valid discrimination of sample groups even at levels below 100 ppm.

Elevated levels (100 ppm to 150 ppm, seen in orange in Appendix Figure 3 [page 307]) of lead concentrate in a broad swath from the west side of the Franklin Mountains (leftmost part of map), through the downtown business district, and eastward through central El Paso. The highest values, those in excess of 150 ppm and depicted in red, are concentrated in the downtown and central core district, with a noticeable outlier (apparently related to an automobile radiator repair shop) in the far northwest of the city.

The geographic pattern of elevated lead values obviously is not random. The elevated values in the area near the Asarco smelter have been attributed to operations at the plant for more than a century (see, for example, Landrigan, et al. 1975; Barnes 1993; current EPA press releases; García, et al. 2004). The high values in the downtown business and commercial district are consistent with general urban congestion; concentrated vehicular traffic, including Interstate Highway 10, during the leaded-gasoline era; traverse by a major railway system; and vintage construction, with the associated lead hazards, including paint. Elevated values headed east of downtown may reflect the confluence of the interstate, Montana Avenue (a state highway and major commercial district and conduit), extensive railroad yards, a concentration of marginal light industries and shops (such as auto repair), and older residences.

The proximity of the downtown and central districts to Asarco, and their downwind lie, confound the ability to distinguish the relative contributions of lead from the smelter point source and from the local areal sources. The present data do not resolve this issue.

Significance

The geographic distribution of lead in this extensive set of soil analysis is similar to the pattern of lead in PM in air filters from around the city collected in the mid-1990s (see the first two sections of this chapter). In the first section, the Tillman (downtown) station (see Appendix Figure 1 [page 305] for locations) was consistently the highest for lead, sometimes by an order of magnitude. The Northeast and Ivanhoe stations yielded the lowest values. The Riverside station (southeast), closer to downtown, showed values between those of downtown and northeast and east.

The similar spatial variation in lead levels in soil and air samples reflects the inevitable interplay between air deposition, local sources, and re-entrainment. Levels of metals in soil represent an important record of air quality, which complements that obtained from conventional air samplers. Soil analysis provides a proxy signal that integrates exposure at street level over years or decades. The method requires no deployment of filter collectors and can provide spatial resolution down to the level of the individual home.

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Endnotes

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[5] This section authored by N. E. Pingitore Jr., J. W. Clague, M. A. Amaya, M. Delgado, J. L. Gardea-Torresdey, P. Juárez, J. Bader, J. C. Zevallos, and I. Herrera.

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