Contract Report 525

Airborne Fine Particulate Matter (PM_{10}) in Southeast Chicago

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Atmospheric Sciences Division
Champaign, Illinois

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AIRBORNE FINE PARTICULATE MATTER (PM_{10}) IN SOUTHEAST CHICAGO

FINAL REPORT

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ABSTRACT

The airborne concentrations and sources of PM_{10} mass and 26 elements were evaluated in southeast (S.E.) Chicago for the period from 1985 to 1988. X-ray fluorescence and neutron activation analysis were used for elemental determinations, and a weight-of-evidence receptor modeling approach —wind trajectory analysis, enrichment factors, factor analysis and chemical mass balance — was used to provide source identification. Particle concentrations remained in compliance of the PM_{10} National Ambient Air Quality Standard (NAAQS) throughout the study period. Receptor modeling analysis identified steel and steel-related industries as a substantial source of airborne PM_{10}, however, the impact of stack emissions is minor in relation to industrial surface dust emissions. The control of industrial surface dust emissions ofy iuTw-0.3572.451 Tc(dus) Tj23.619 Chicadr t,

ACKNOWLEDGMENTS

Support for this work has been provided by the

INTRODUCTION

A new PM_{10} National Ambient Air Quality Standard (NAAQS) has replaced total suspended particulates (TSP) as the federal ambient standard for particulates. PM_{10} represents the inhalable fraction of TSP, particles ≤10 micrometers (μm); of which particles > 5 μm are generally deposited in the nose and throat and particles < 5 μm reach further into the respiratory tract to the lungs.

Southeast Chicago has some of the worst known air quality in Illinois in terms of criteria pollutants. Several Illinois Environmental Protection Agency (IEPA) monitoring sites in S.E. Chicago have regularly recorded TSP excursions above the old TSP NAAQS. Based on earlier work by Kolaz et al. (1986) showing PM_{10} particles to constitute 60 percent of TSP in urban areas in Illinois, sites in S.E. Chicago are anticipated to exceed the PM_{10} NAAQS. Southeast Chicago has been designated as a Group 1 area, having a greater than 95 percent probability of exceeding the standard (IEPA, 1988).

In addition to criteria pollutants such as TSP and PM_{10}, airborne concentrations of individual elements (e.g.,Cr, Cd, Mn, and Pb) may be high enough to pose a health hazard (Thomson et al., 1985). At present, ambient air quality standards exist only for lead (IEPA, 1988).

The overall objective of the project was to identify important sources of inhalable PM^{10} particles (PM_{10}) in S.E. Chicago. A receptor modeling approach was used, which provides an in-depth chemical and physical characterization of individual elements and their sources. Preliminary results were discussed in four interim reports (Vermette et al.,1988;Vermette and Williams, 1989a; Vermette and Williams, 1989b; and Vermette et al., 1990). This final report contains project findings, conclusions and recommendations on airborne fine particulate matter (PM_{10}) in S.E. Chicago.

SAMPLING LOCATIONS ANDfffl SAMP.590 o Tji-0.294V40 Tc(be

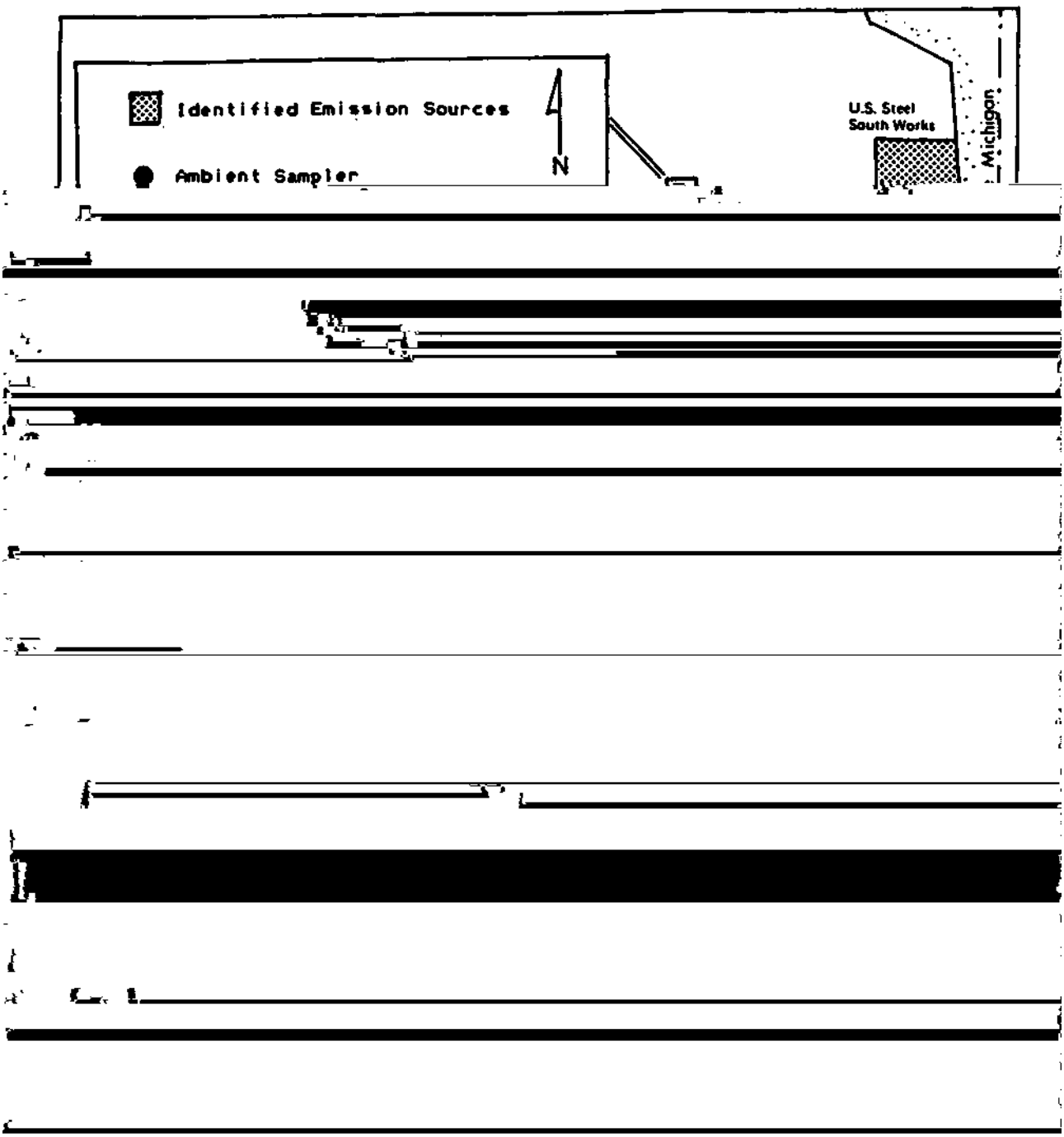


Figure 1. Southeast Chicago study area: major industries and PM_{10} ambient air sampling sites.

Air quality was measured at two sites in the study area: Bright Elementary School at 10740 S.Calhoun, from October 1985 to August 1987, and Washington Elementary School at 3611 E. 114 Street, from December 1987 to June 1988. The locations of these sites and major industries are shown (Figure 1). A recent dispersion model study (Crowder et al., 1989) recommends both sites as suitable to monitor local (within the study area) sources of air pollution.

The third site is in a rural area near Champaign, EL, 8 km south of Bondville, EL. This site, chosen to be representative of regional air quality, is also used in several national air and precipitation monitoring programs. There are no point sources within 10 km, and the site is at least 50 km downwind of urban areas during times of prevailing northwest and southwest winds. In this location, concentrations of airborne toxic air pollutants should be representative of conditions in most of rural Illinois and provide an estimate of the contribution of regional background to urban pollution. Samples were collected between September 1985 and September 1987.

METHODS

Fe, Ni, Cu, Zn, Mo anode, Mo filter, SO KeV, 200 M amps
Ga, As, Se, Br,
Rb, Sr, Ba, La,
Hg. Pb

Filter blanks were analyzed and an average blank spectrum was used as a background subtraction for each sampled filter. The raw analytical data were reviewed by a laboratory supervisor at the contract laboratory before processing was completed. Sample data were then corrected for spectral interferences, particle size, and deposit absorption effects.

NAA Methods

Elemental concentrations for the air filters were determined using the following NAA procedures. The support ring around the filter was removed before analysis. Earlier work by Sweet and Gatz (1988) showed the Teflon^{R} filter support ring to be contaminated with Cr, Mn, and Sb. Removal of the ring was not necessary with XRF, because only the center portion of the filter (1 square centimeter (cm^2)) is analyzed. For the short-lived radioisotopes (Al, Ba, Ca, Cu, In, Sr, Mn, V, Ti, Cl, and Na), filters were inserted in an acid-washed 7 cubic centimeter (cc) polyethylene vial placed in rabbit carriers, and irradiated for a period of five minutes at a flux of 1.5 * 10^{12} neutrons per square-centimeter per second ($n/cm^2/s$). After the return of the carrier, the filter was removed from the vial and carefully placed in an inert acid-washed 7 cc polyethylene vial and presented for counting in front of a hyper-pure germanium counter. Typical delay times were of the order of 4 to 5 minutes. Samples were counted for 10 minutes. Deadtime corrections were evaluated by using a 60 hertz (Hz) pulser. Variations in neutron flux were monitored using sulfur standards every few hours throughout the day. Flux variations (1 percent or less) were constant during the day, but varied up to 5 percentr

Receptor Modeling Methods

Receptor modeling is an approach by which sources contributing to air quality are identified from the perspective of the receptor, in this project, filters from the dichotomous sampler. Source identification, using a receptor modeling approach, is possible, assuming that a measured element is linearly additive and follows the principle of conservation of mass, such that the concentration per unit volume of air at the receptor site is set equal to the sum of the contribution of various sources. Using Fe as an example, these assumptions may be expressed, relative to the receptor, as:

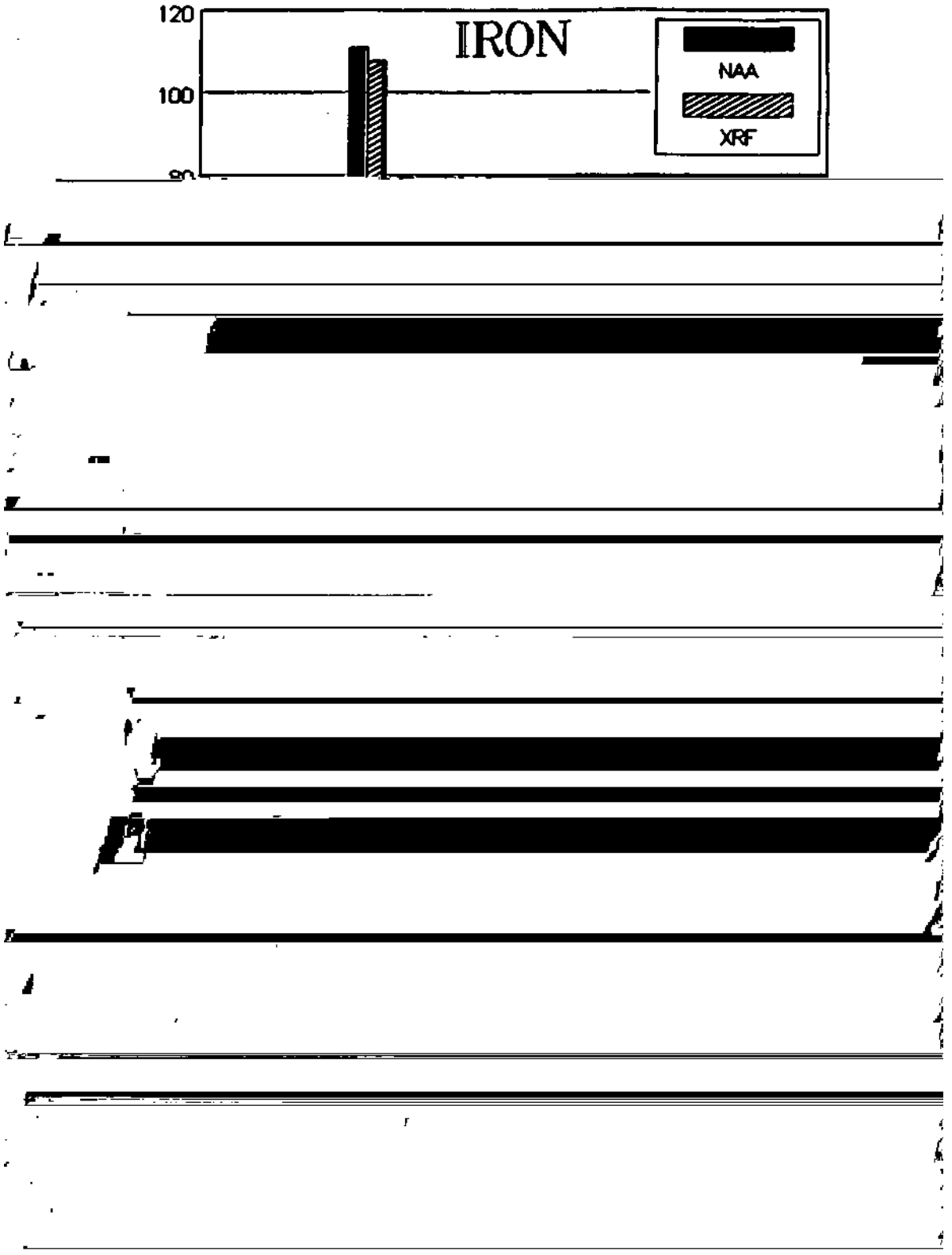
$$Fe_{receptor\ filter} = Fe_{soil} + Fe_{steel} + Fe_{road\ dust} \qquad (1)$$

A number of specific calculations and models exist within the broader receptor modeling approach (e.g.,wind trajectory analysis, enrichment factors, and chemical mass balance), and each may rightfully be described as a receptor model. The approach used in this study is described as "stepwise" or "weight-of-evidence" where a series of models are followed, designed with a degree of redundancy, such that source identification is supported by a number of observations, model outputs, or both.

Quality Assurance

For XRF, the laboratory's approach is based on a well-established, validated standard operating procedure (SOP), an x-ray analysis QA plan, and validated standards. The SOP has been validated through numerous numero0.256 Tc 104l25pTc (s)Tj-0.4 th numr8rn in-0

Table 1. Filter Blanks



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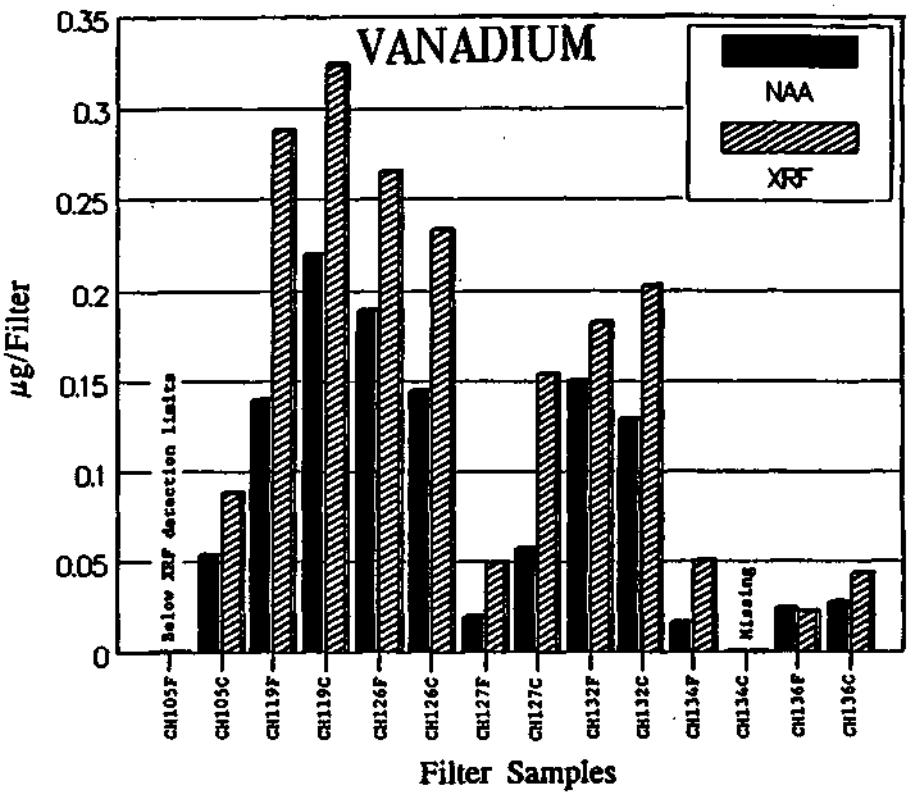


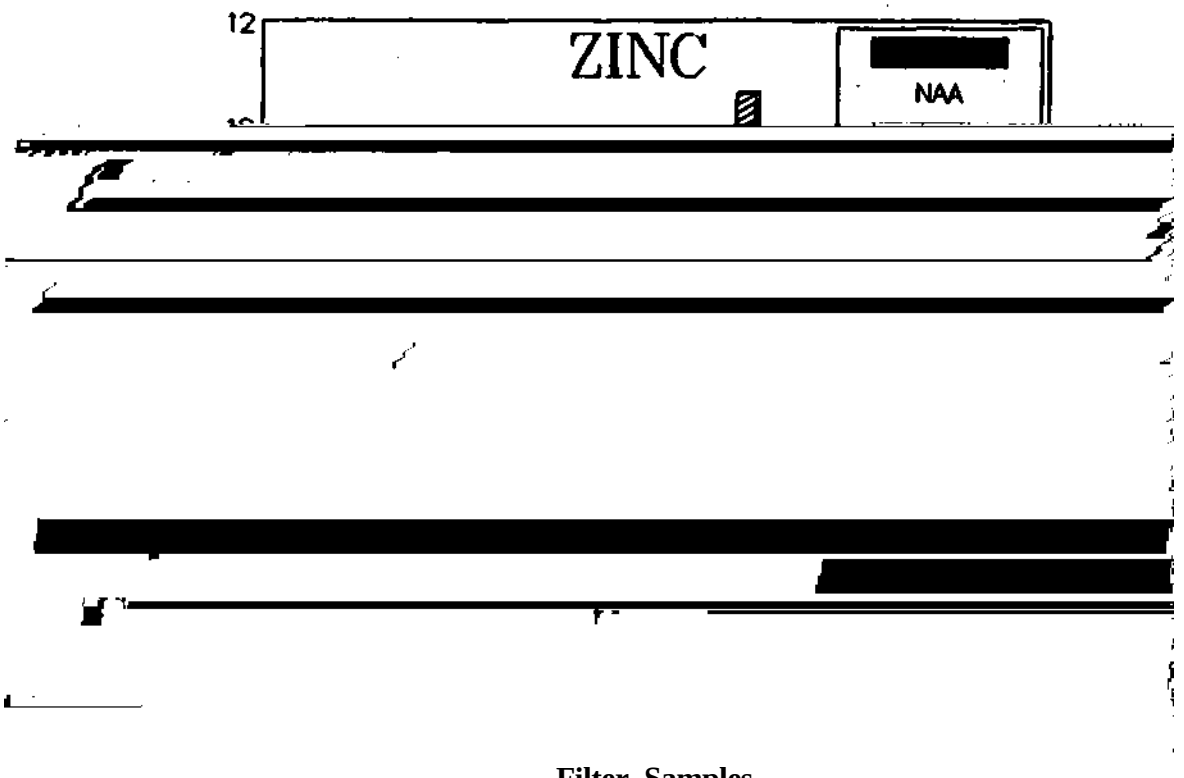
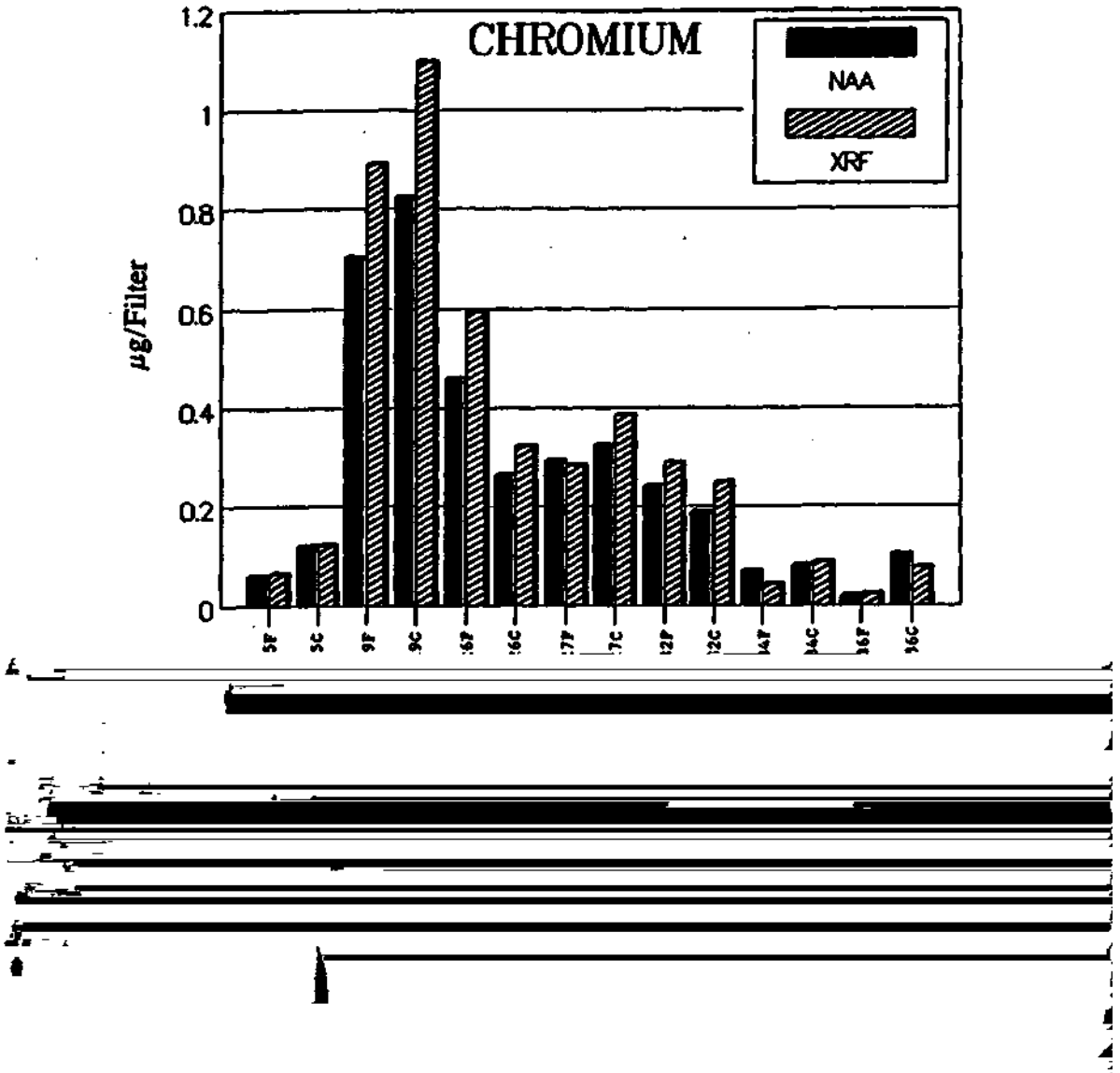


Figure 2. Continued.



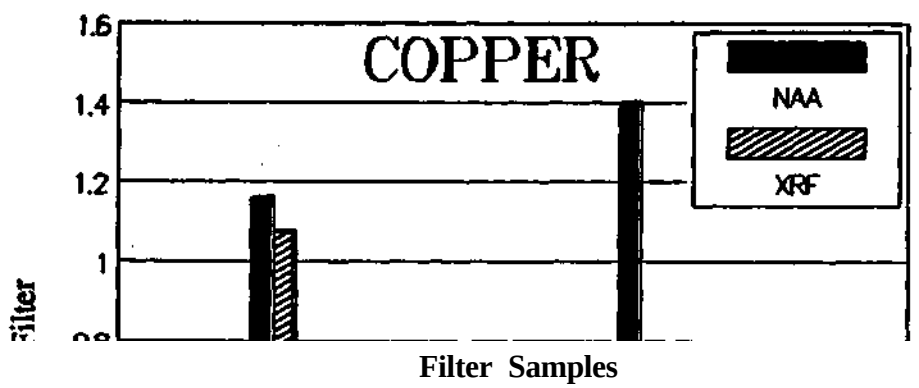


Figure 2. Concluded.

SOURCE IDENTIFICATION

Site Reconnaissance and Emission Inventories

As a first step in identifying PM_{10} sources, industrial facilities and emission inventories were examined for S.E. Chicago. This included a site reconnaissance (see Figure 1), a review of a recent dispersion model (Crowder et al., 1989), and a review of inventoried emissions (IEPA, 1987; Kong et al., 1990). Based on these reviews, local iron and steel and related industries were identified as major sources of airborne particulate matter, and based on dispersion model outputs, show localized impacts. A number of the mills and related industries were closed or at reduced operatingd an

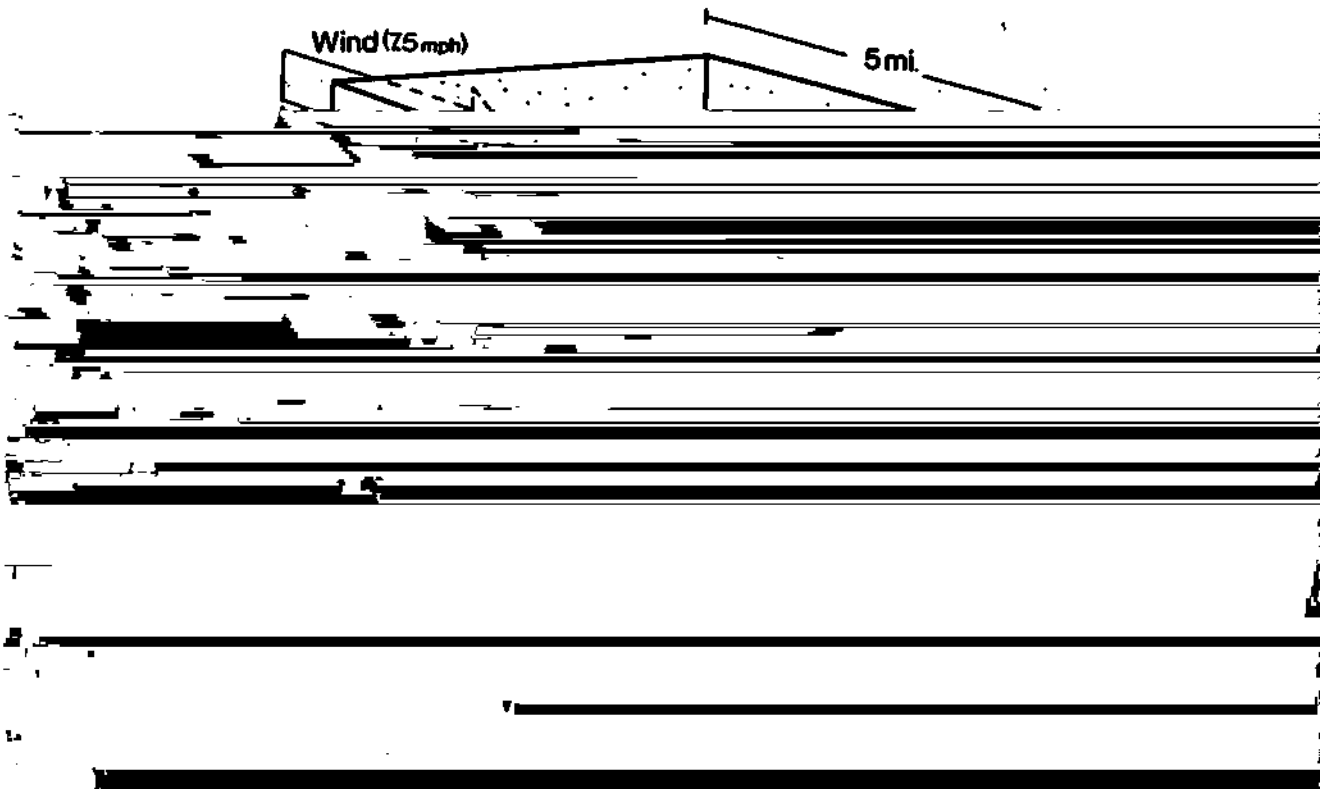


Figure 3. Southeast Chicago airshed box model.

Table 2. Receptor Modeling Estimates of Industrial Primary Emissions

Industry	City	Contribution	Authors
Industrial	Philadelphia[a]	<5% of PM_{10}	Dzubay et al. (1988)
Industrial	Newark	7% of PM_{15}	Morandi et al. (1987)
Industrial	Portland	*5%* of TSP	Cooper and Watson (1979)
Steel	Detroit	12% of CPM[b]	Wolff and Korsog (1985)
Steel	Chicago[c]	4% of TSP	Gatz (1975)
Steel	N/A	3% to 18% of TSP	Lucas and Casuccio (1987)

[a]Primary emissions from five major stationary sources.
[b]CPM = particles ranging in size from 2.5 *µm* to 10 µm.
[c]Sampling sites were located upwind (prevailing direction) from steel mill sources.

inventory for toxic air pollutants

Table 3. Contribution of Inventoried Sources to S.E. Chicago Average Ambient Trace Element Concentrations

Element	PM_{10} Inventoried Emissions* (tons/yr)	Modeled Concentrations[b] (ng/m^3)	Ambient Concentrations (ng/m^3)	Percent[c]
Al	257-429	329-548	496	66-110
Si	n.a.	n.a.	n.a.	n.a.
P	38-63	58-96	100	58-96
S	563-939	719-1199	2273	32-53
CI	255-425	326-543	582	56-93
K	n.a	n.a.	232	n.a.
Ca	n.a.	n.a.	1097	n.a.
Ti	15-25	19-32	38	50-84
V	12-20	16-26	7	229-371
Cr	55-92	71-118	11	645-1073
Mn	49-82	62 - 104	86	72 - 121
Fe	485 - 809	632 - 1053	1233	51-85
Ni	22-36	28-46	5	560-920
Cu	320-533	409-681	15	2727-4540
As	201-335	257-428	3	8567-14267
Zn	206 - 343	263 - 438	166	158 - 264
Se	5-9	7-12	3	233-400
Cd	60-100	77-128	6	1283-2133
Sn	14-24	19-31	11	173-282
Sb	55-92	71-118	11	645-1073
Ba	10-16	13 - 21	10	130 - 210
Br	8-14	11-18	11	100-164
Rb	n.a.	n.a.	n.a.	n.a.
Sr	2-4	3-5	5	60-100
Pb	349-581	445-742	127	350-584

Notes: [a] Calculated PM_{10} inventory ranges from 60-100 percent TSP inventoried emissions, as reported by Kong et al. (1990).
[b] Modeled PM_{10} concentrations calculated from the PM_{10} inventory range.
[c] Percent of average ambient concentration explained by inventoried emissions.
n.a. not available

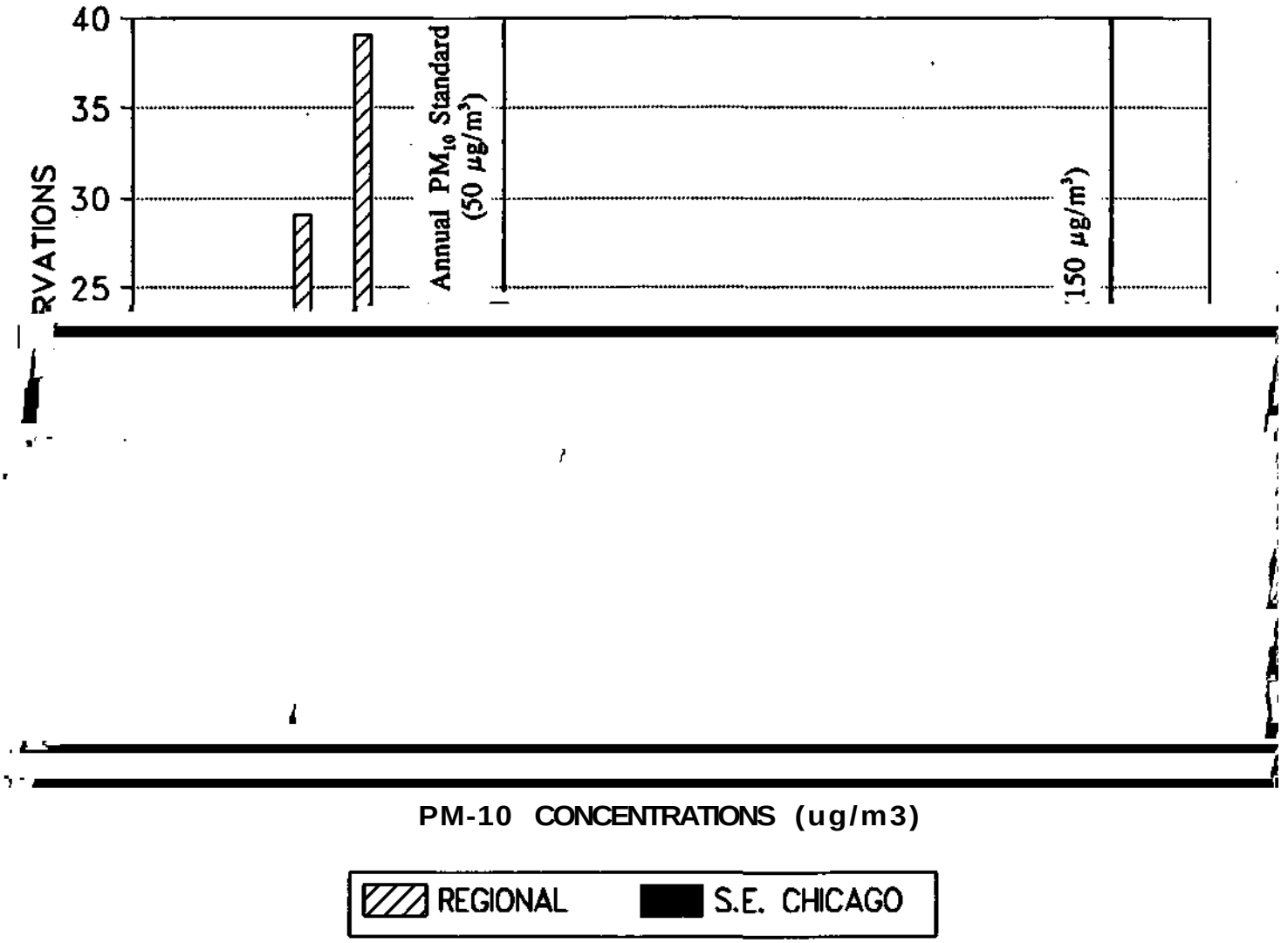


Figure 4. Range of PM_{10} mass concentrations: comparison of a regional site with S.E. Chicago.

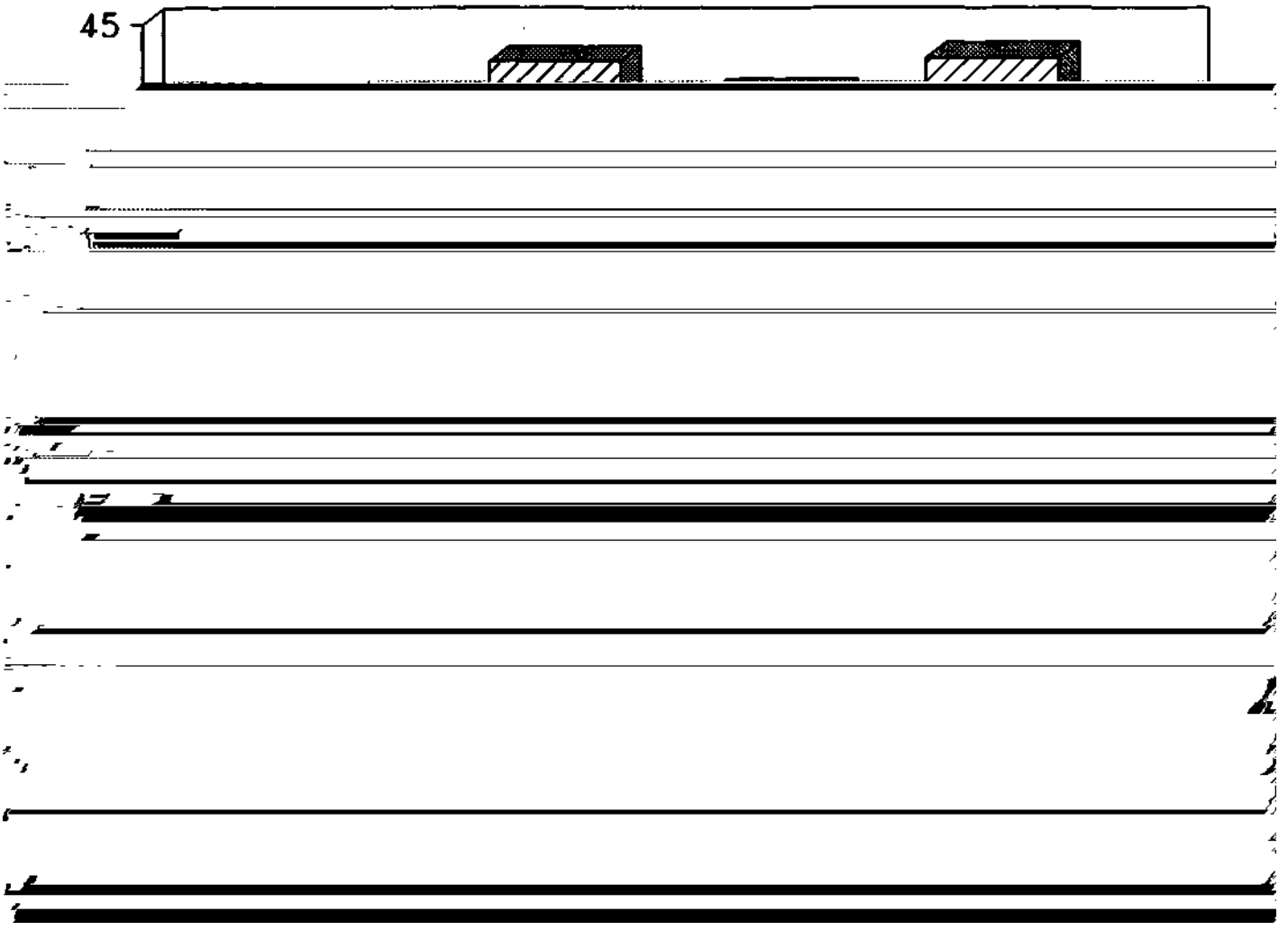


Figure 6. Variability of fine and coarse PM_{10} mass concentrations by season.

Average Trace Element Concentrations

The trace element database used in this work consists of weather data and analytical results from 104 pairs of fine and coarse dichotomous filters. Filter samples were collected between September 1985 and June 1988. Those selected for analysis generally coincided with steady wind direction (standard deviation $\leq 20^{o}$). However, it was attempted to include a representative sample of all wind directions and meteorological conditions in the database. Figures 7 and 8 break down the analyzed filter samples by wind direction and season. The distribution of the analyzed filters closely reflects average wind directions for S.E. Chicago.

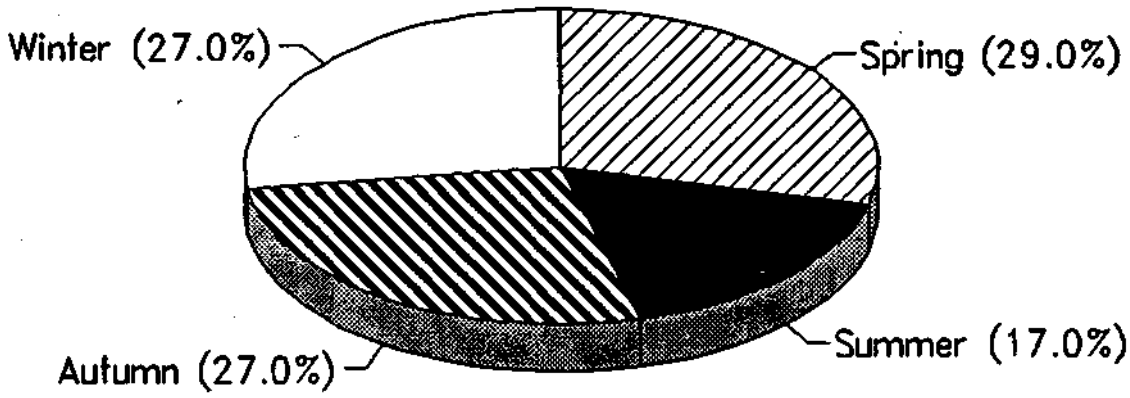


Figure 7. Southeast Chicago Alter samples by season

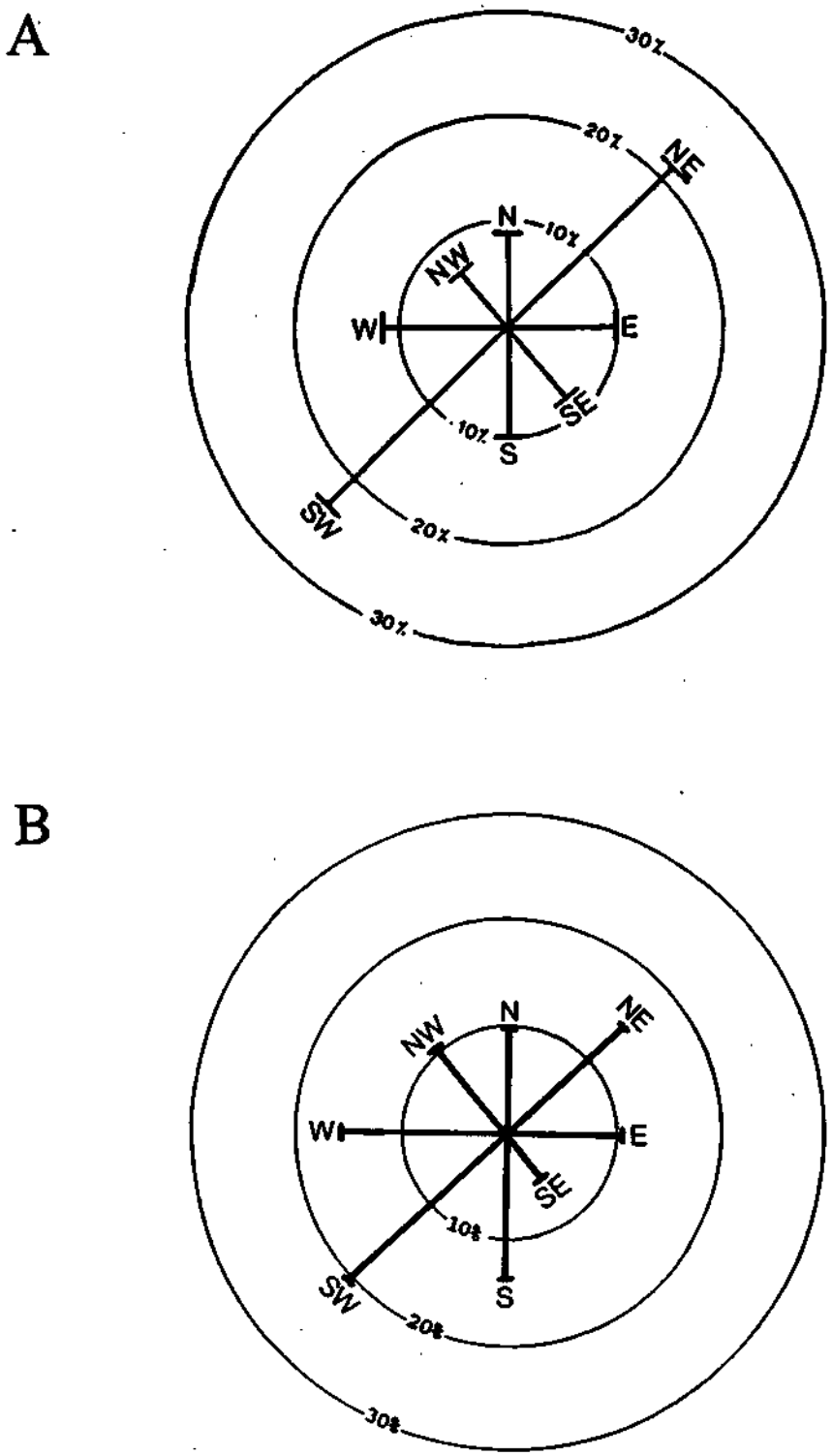


Figure 8. Southeast Chicago filter samples by wind direction (A) and compared with an annual wind rose (B).

Table 4. Average Concentrations of PM_{10} Mass and Trace Elements[1]

Element	Regional[2]		S.E. Chicago	
	Fine	Coarse	Fine	Coarse
Mass	16 ± 6^a	11 ± 10^b	23 ± 11^c	18 ± 11^d
Al	96 ± 57^a	338 ± 527^b	126 ± 97^c	370 ± 349^b
Si	178 ± 156^a	1325 ± 2392^b	235 ± 220^c	1190 ± 1323^b
P	42 ± 18^a	27 ± 22^b	69 ± 44^c	31 ± 23^b
S	1791 ± 845^a	219 ± 254^b	1975 ± 1103^c	298 ± 236^d
Cl	20 ± 41^a	44 ± 73^b	380 ± 616^c	202 ± 224^d
[illegible]				
[illegible]				
[illegible]				
[illegible]				
Ca	52 ± 62^a	390 ± 347^b	103 ± 85^c	994 ± 843^d
Ti	4.3 ± 3.5^a	20 ± 29^b	8.0 ± 6.0^c	30 ± 24^d
V	0.8 ± 0.4^a	1.2 ± 1.4^b	3.0 ± 2.7^c	3.7 ± 2.7^d
Cr	0.7 ± 0.4^a	1.2 ± 1.2^b	4.4 ± 4.8^c	6.8 ± 6.2^d
Mn	3.5 ± 1.8^a	6.4 ± 5.2^b	38 ± 57^c	48 ± 70^d
Fe	53 ± 31^a	180 ± 189^b	393 ± 423^c	840 ± 734^d
[illegible]				

Notes: For each row, values with different superscripts are statistically different from each other at the 90 percent confidence level using a one-tailed T-test.
n.d. not determined.
[1] PM_{10} in $\mu g/m^3$, elements in nanograms per cubic meter (ng/m^3).
[2] Filters collected at a rural sel a

Carbon Determinations

No carbon determinations were made for filters collected at the Bright School site, but sampling at the Washington School site included airborne carbon measurements. The glass fiber filters were collected in sequence with the Teflon^{R} filters. As a percentage of aerosol mass, total carbon varied from 14.5 to 53.0percent, averaging 25.2percent (Figure 9). There appears to be no significant difference between fine and coarse filters, averaging 24.0 and 26.5 percent, respectively. Within S.E. Chicago, two major sources of carbon are diesel exhaust and coal.

Seasonal Trends

The elemental data were examined for seasonal, weekly, and diurnal trends. No clear trends could be found with the exception of a few elements. This is consistent with the fact that urban sources of airborne particles such as industrial stack emissions and vehicular traffic are fairly constant. An interesting pattern was notable for two elements. The seasonal variation of fine chloride (Cl) shows high levels coinciding almost exactly with the snow season and road salt application (Figure 10). Road dust samples from Buffalo, NY, show a similar seasonal pattern for Cl (Vermette et al., 1991). This illustrates the potential for resuspension of fine particles by vehicular traffic. A second pattern was observed for airborne Si and Ti, with higher concentrations present during the spring (Figure 11). These particles presumably come from uncontaminated wind-blown dust from the surrounding region.

Wind Trajectory Analysis

Analysis of the data, based on wind direction, yields information on the sources and the types of emissions. Several steel mills are near the Bright weekly nea

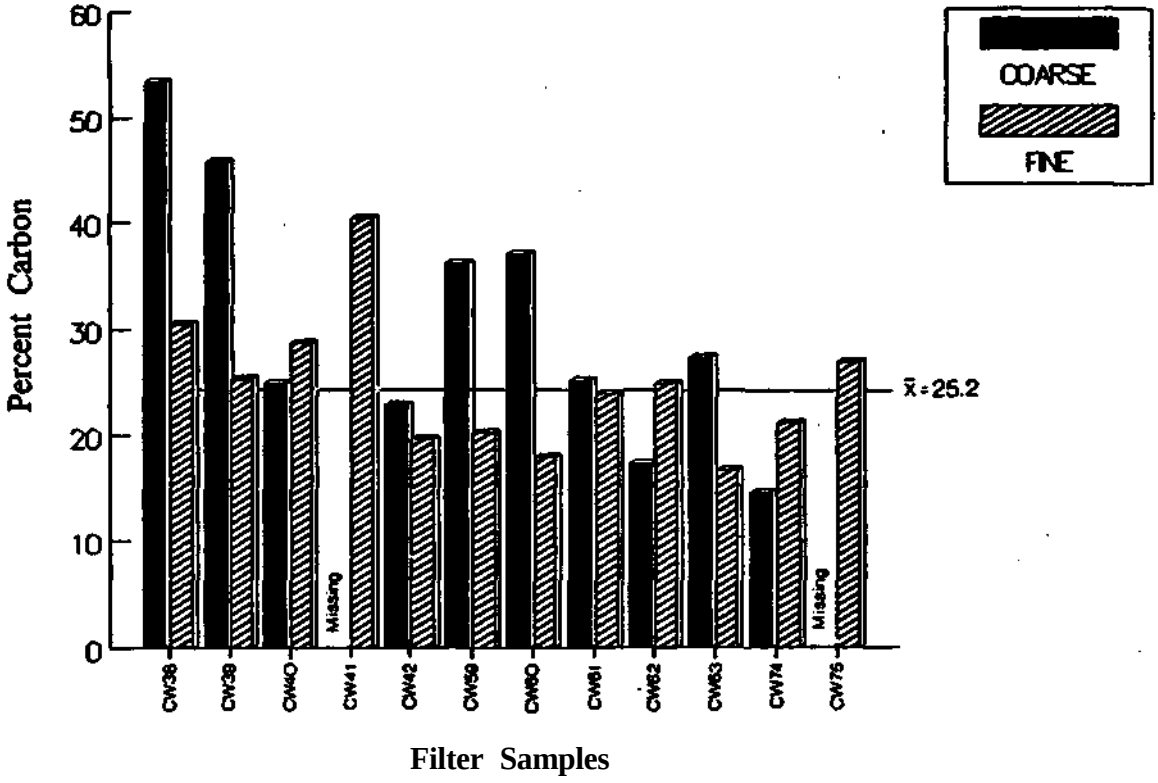


Figure 9. Carbon mass expressed as a

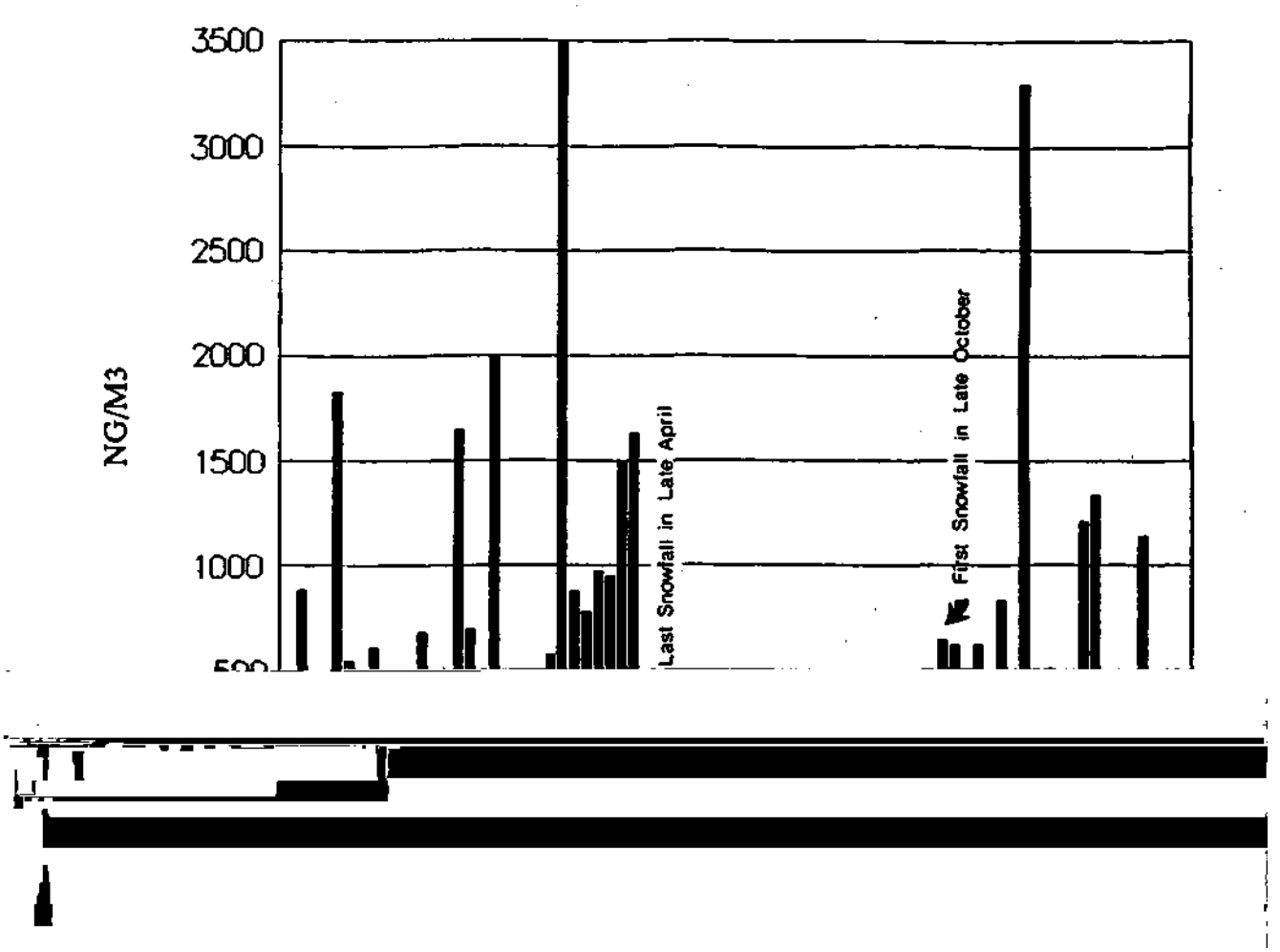


Figure 10. Seasonal variability of fine airborne chloride (Cl) concentrations.

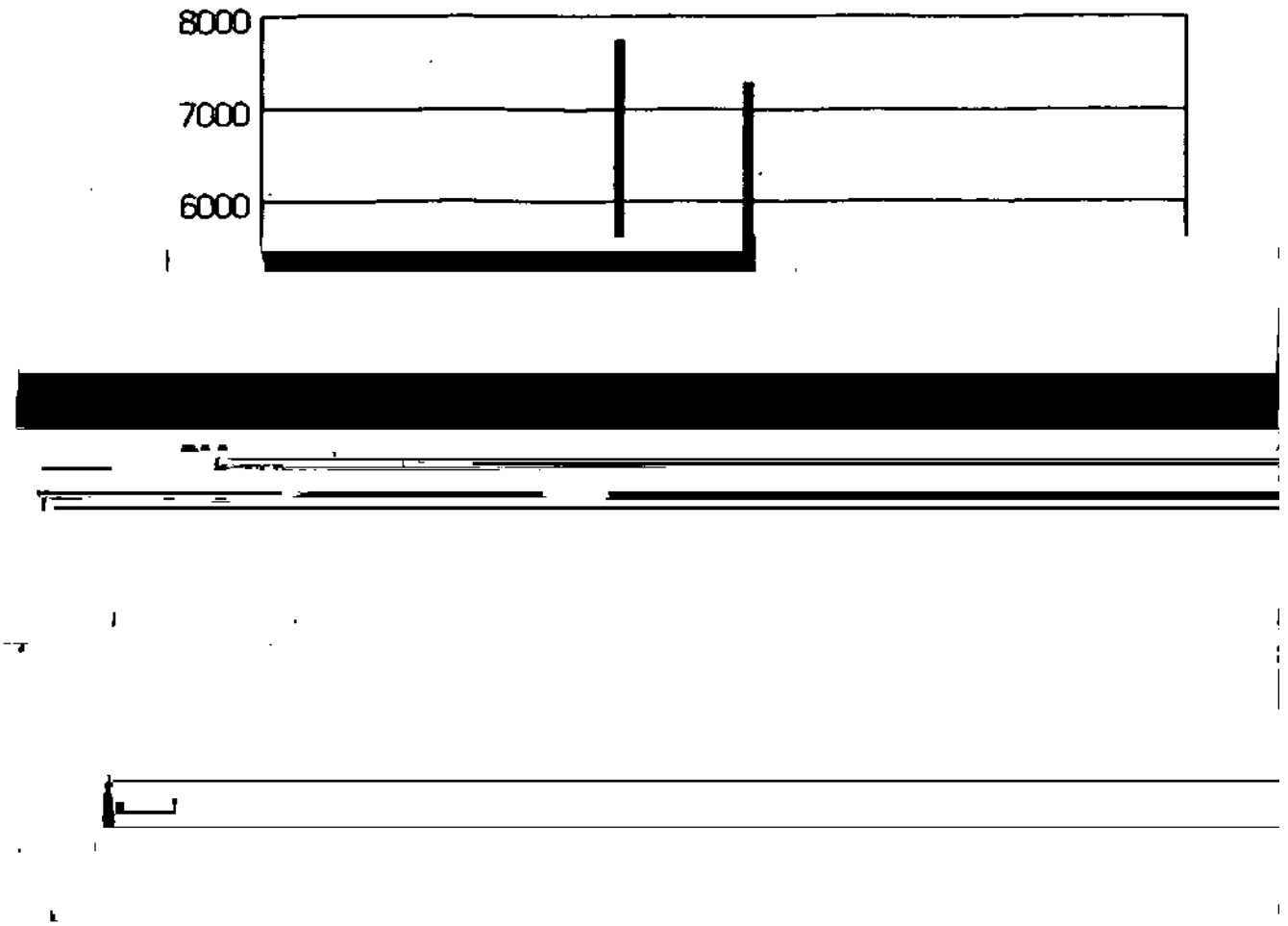


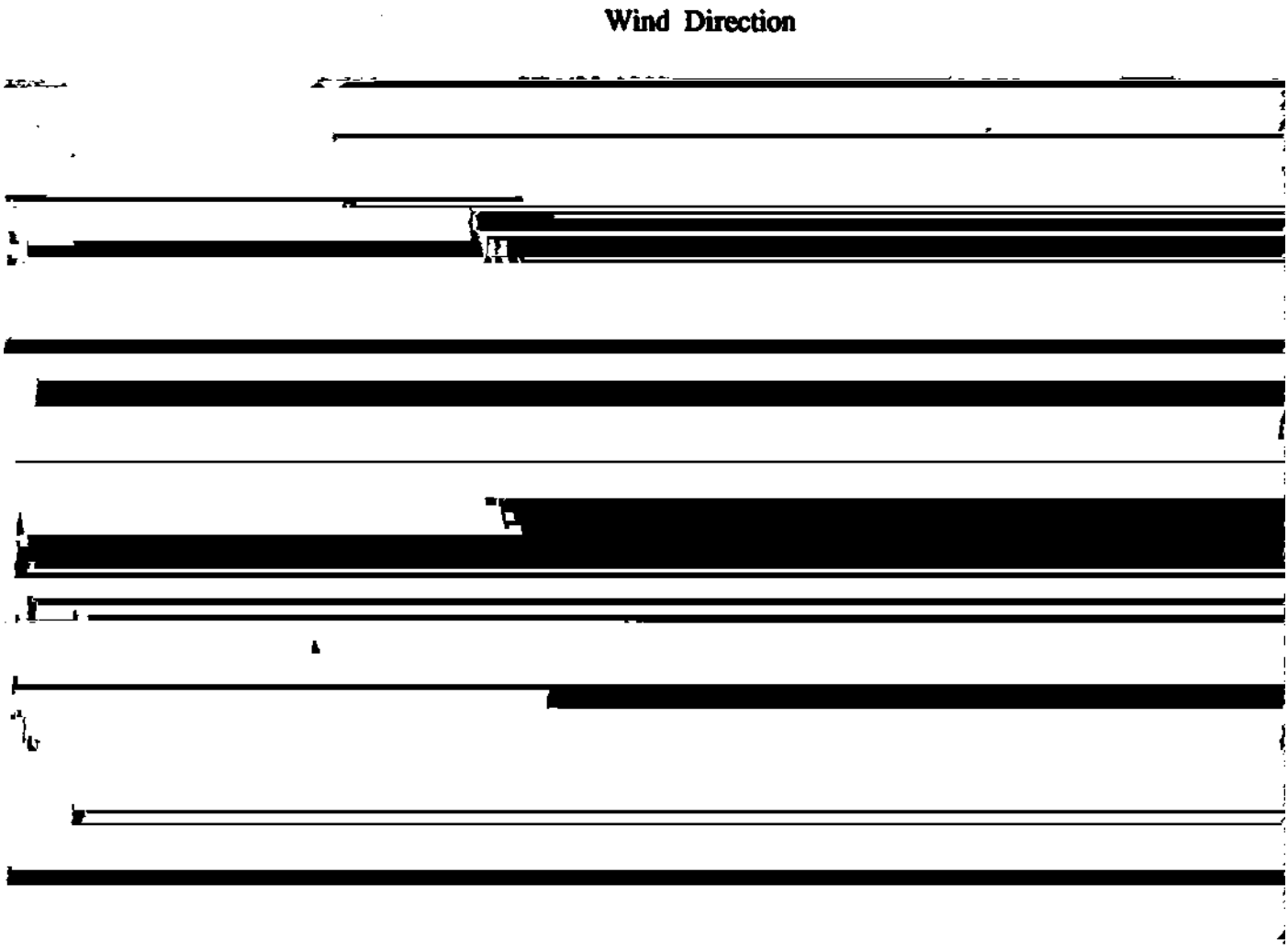
Figure 11. Seasonal variability

Table 5. Airborne Fine Particle Concentrations Sorted by Wind Sectors for the Bright School Site

	Wind Direction			
Element	NE (0-90°)	SE (90-180°)	SW (180-270°)	NW (270-360°)
Mass	22±11	26±10	20±9	17±9
Si	219±209	298± 181	394±286	106±87
P	55±33	78±19	99±59	43±31
S	1943±1219	2666±800	2371±920	1264±887
Cl	601±1035	235±133	431±423	153±201

Note: PM_{10} in $\mu g/m^3$,

Table 6. Airborne Coarse Particle Concentrations Sorted by Wind Sectors for the Bright School Site



Note: PM_{10} in µg/m^3, elements in ng/m^3.

Fe, and Mn) are significantly higher in the fine fraction only when the wind is from the southeast, the direction of active blast furnace operations. In contrast, the concentrations of these elements in the coarse fraction are similar when the wind is blowing from either active or inoperative steel mills. Presumably Cr and Mn from slag piles, contaminated soils, and urban dust are resuspended and contribute to the airborne concentrations of Cr and Mn. When the wind is from the southwest or northwest, the concentrations are lower because steel-related industries are much farther away or absent and thus exert much less or no influence on air quality. Other elements (e.g.,Zn and Pb) are also elevated when the wind is from the industrial southeast sector. Both of these elements are normally associated with the fine fraction indicating high temperature sources. However, the presence of elevated

lle0lated - concentrations of these elements in the airborne d (t c T

Table 7. Airborne Fine Particle Concentrations Sorted by Wind Sectors for the Washington School Site

Element	Wind Direction NE (0-90°)	SE (90-180°)	SW (180-270°)	NW (270-360°)
Mass	16±8	17±3	17±7	21±7
Al	106±36	107±49	54±11	87±20
[illegible]				
P	64±33	51±15	64±14	58±22
S	1890±640	1849±752	1140±404	1589±414
Cl	269±362	24±23	56±91	404±287
[illegible]				
Ca	124±134	99±57	37±16	96±83
Ti	9±6	6±3	4±1	2±1
V	3±2	1±0.3	1±0.4	2±1
Cr	5±6	3±1	2±1	3±2
[illegible]				

Note: PM_{10} in $\mu g/m^3$, elements in ng/m^3.

Table 8. Airborne Coarse Particle Concentrations Sorted by Wind Sectors for the Washington School Site

	Wind Direction			
Element	NE (0-90°)	SE (90-180°)	SW (180-270°)	NW (270-360°)
Mass	17±10	17±11	11±4	14±5
Al	340±197	485±386	154±109	241±133
Si	1058±670	1752±1617	515±444	781±481
P	30±13	28±16	17±5	23±9
S	274±144	137±34	120±38	147±59
Cl	165±128	111±22	107±69	514±315
K	115±64	166±142	54±41	81±44
Ca	1310±963	1282±827	366±213	743±751
Ti	37±22	45±38	14±9	25±14
V	6±3	3±2	2±0.6	3±2
Cr	9±7	10±6	2±2	5±3
Mn	84±83	28±20	15±14	34±34
Fe	1391±943	540±369	302±170	916±558
Ni	3±2	1±0.6	1±0.4	2±2
Cu	5±4	4±2	2±0.5	3±2
Zn	60±60	12±5	12±8	32±30
Se	0.5±0.2	0.3±0.2	0.2±0.1	0.3±0.1
Br	2±1	13±8	0.5±0.3	1±0.8
Rb	1±0.9	2±1	0.4±0.2	1±1
Sr	4±3	4±2	1±0.6	3±2
Pb	11±8	18±9	5±1	8±6

Note: PM_{10} in $\mu g/m^3$, elements in ng/m^3.

$$EF = \frac{(X/C)_{urban\ air}}{(X/C)_{reference\ material}} \qquad (2)$$

where X is the concentration of the element of interest, and C is the concentration of the reference element. The usefulness of EF calculations is based on the assumption that similar elemental ratios (ratio = 1) found

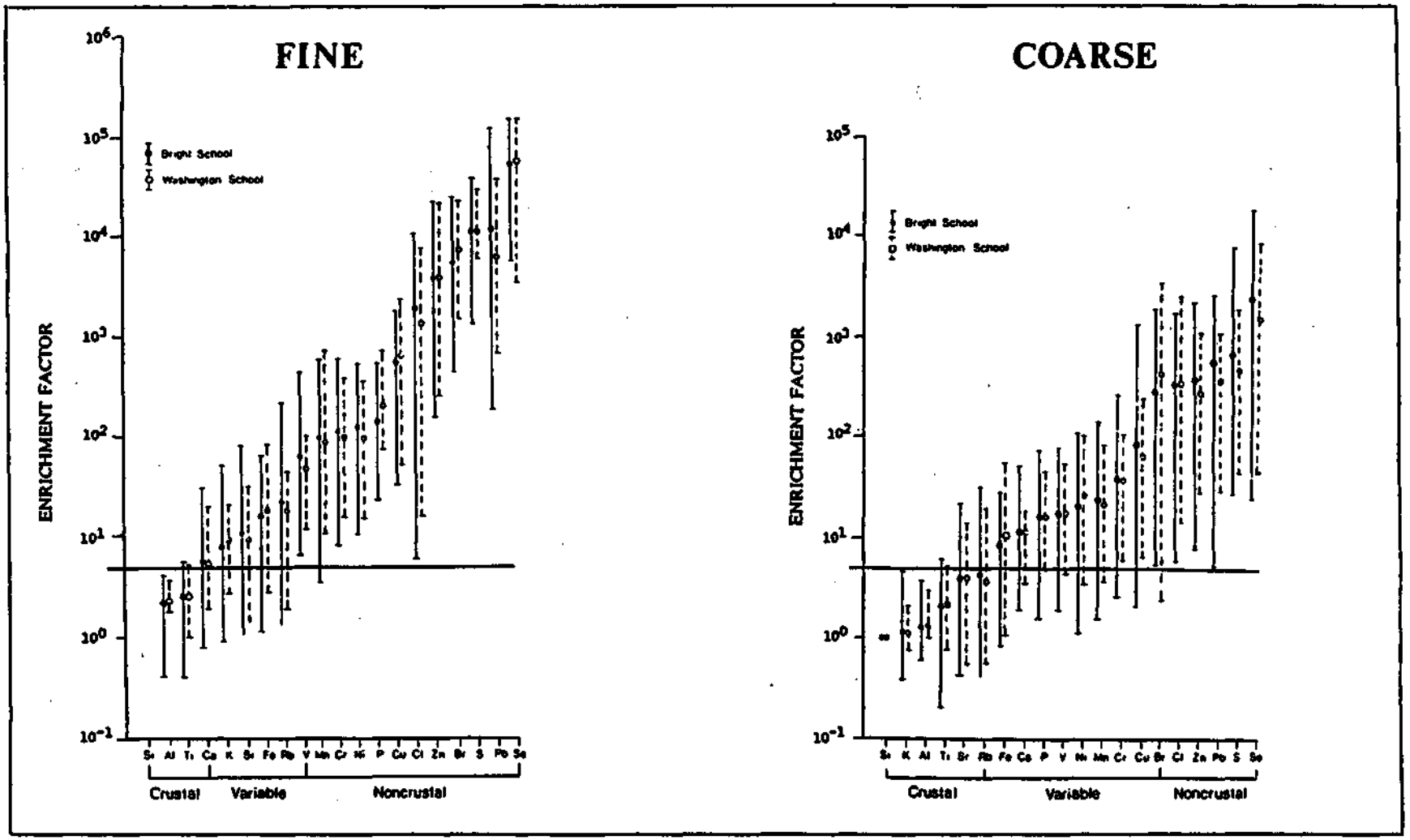


Figure 12. Average enrichment factors for S.E. Chicago using a crustal reference material.

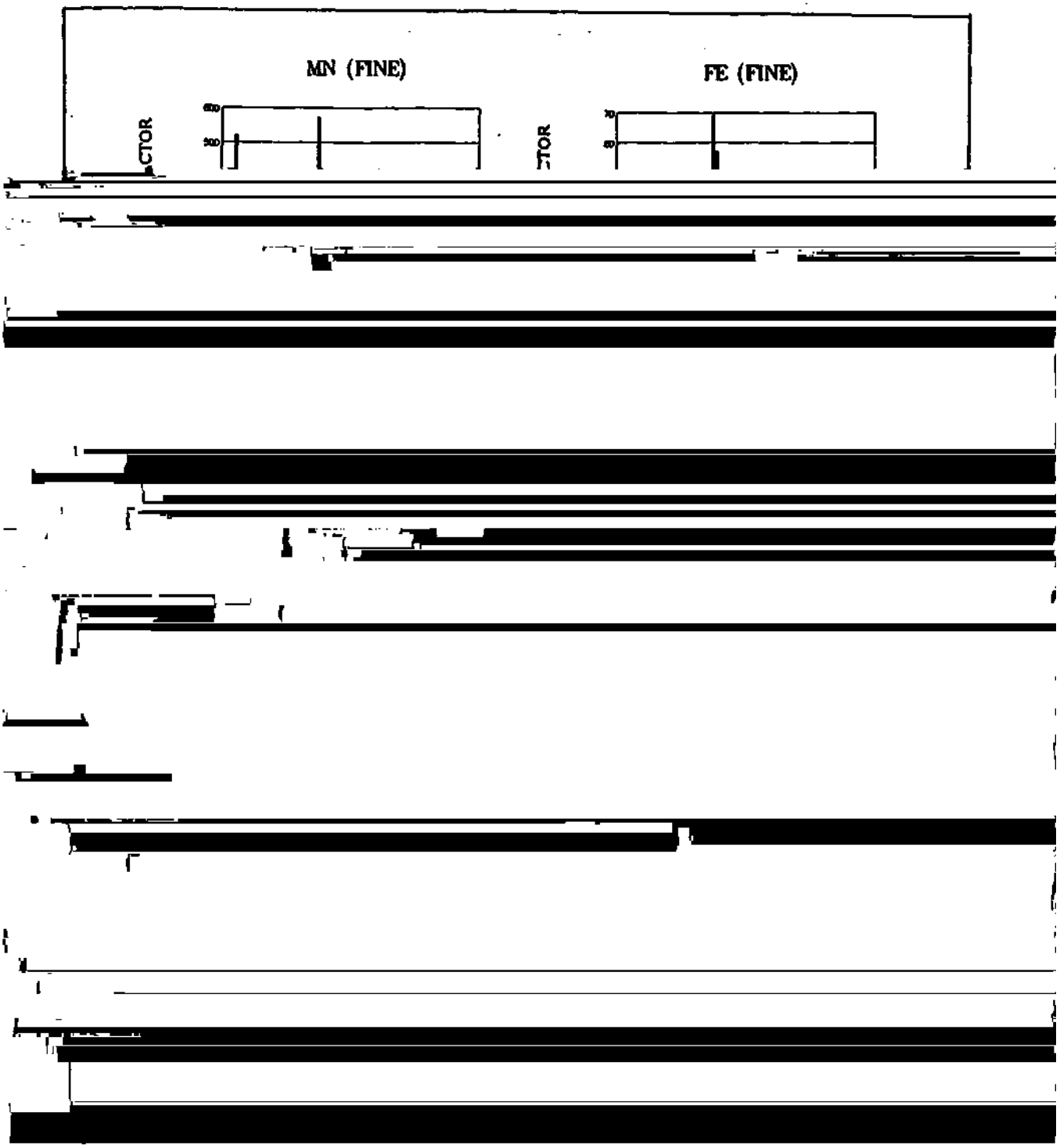


Figure 13. Enrichment factors for S.E. Chicago plotted by wind direction using a crustal reference material.

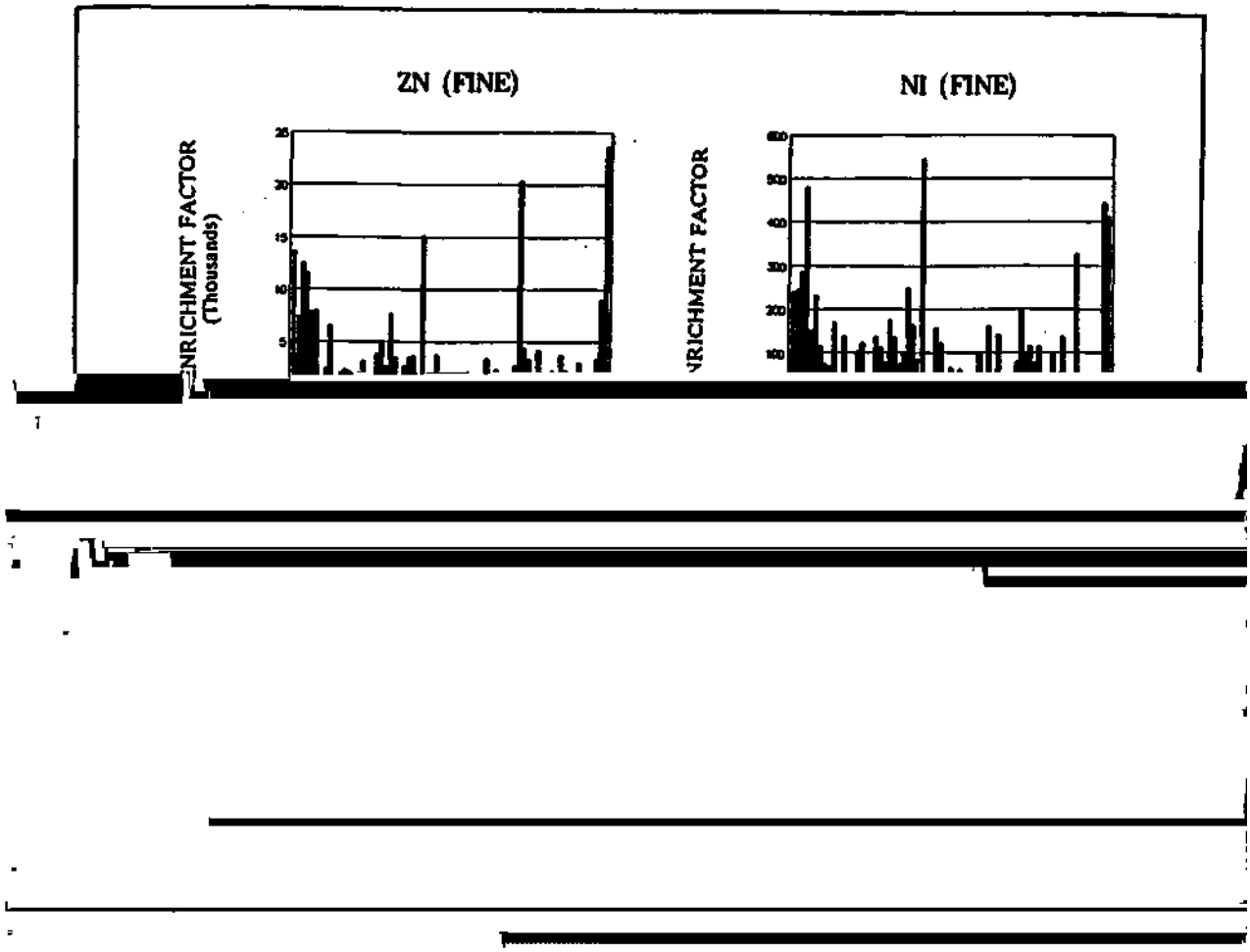


Figure 13. Concluded.

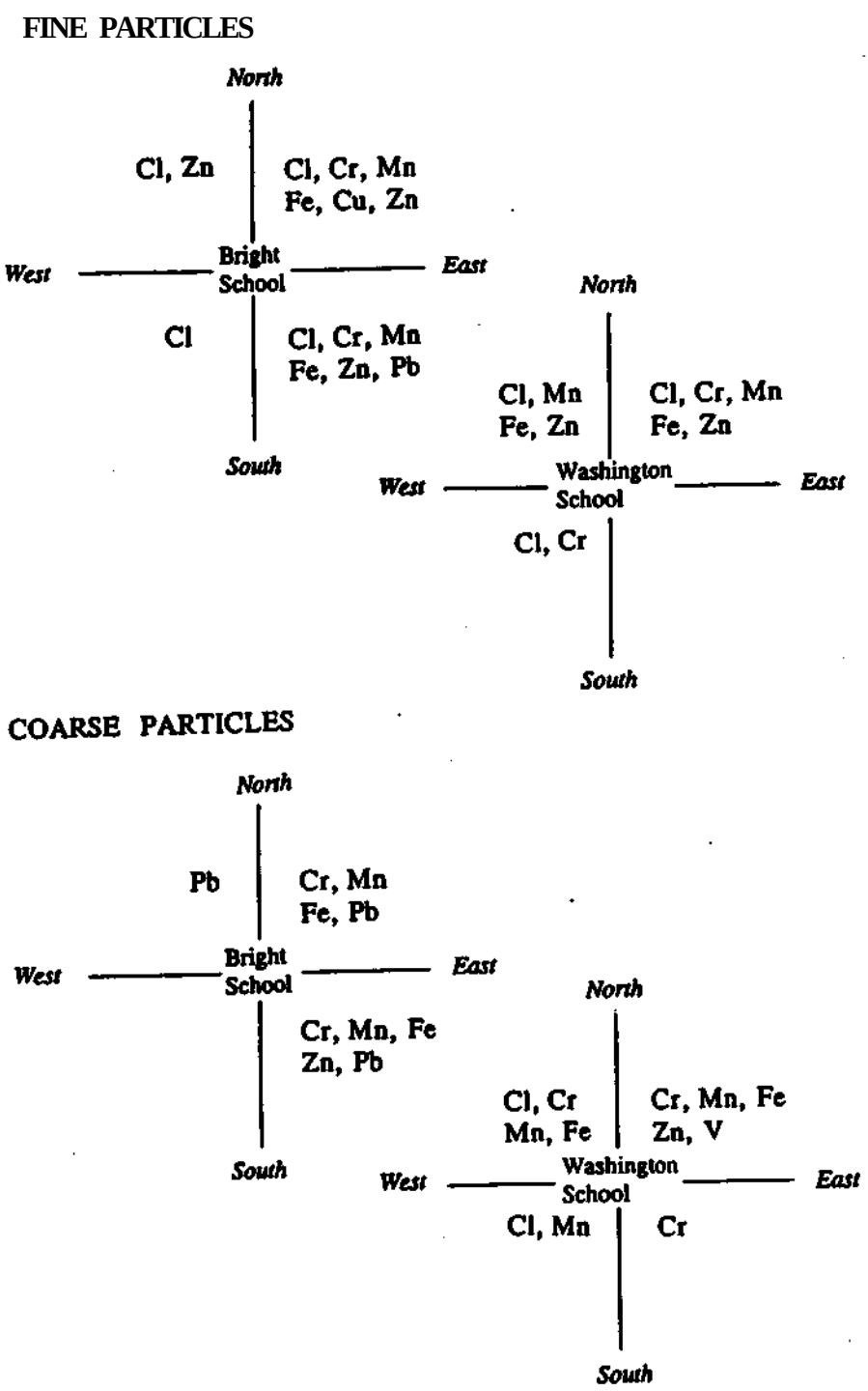


Figure 14. Enriched (EF>5) elements plotted by wind sector using regional air concentrations as a reference material.

but also to other steel industry sources

Table 9 . Fine Particle Factor Loadings for S.E. Chicago[a]

Elements	Identified Sources	Factor Loadings[b]	Percent Variance[c]
FACTOR 1	Steel industry stack		39.2
Ni		0.90	
Zn		0.85	
V		0.80	
Mn		0.78	
Cr		0.75	
Fe		0.68	
Pb		0.61	
Ca		0.40	
Wind direction		-0.40	
FACTOR 2	Regional sulfate and coal		13.4
Mass		0.90	
Br		0.70	
Se		0.69	
P		0.65	
S		0.62	
Cl		0.50	
K		0.40	
FACTOR 3	Unknown		8.9
Fe		0.40	
Br		0.56	
Cl		0.68	
Rb		0.75	
K		0.72	
Cu		0.40	
Wind direction		-0.60	
FACTOR 4	Soil		7.7
Si		0.82	
Al		0.81	
Ti		0.72	
Cu		0.52	
Ca		0.40	
Wind speed		0.50	
FACTOR 5	Steel industry dust		5.0
Mn		0.58	
Cr		0.55	
Fe		0.40	
Rb		0.41	
Sr		0.79	
Ca		0.50	

Note: [a] Varimax rotation (percent of variance explained by factor analysis) = 74.2%.
[b] Only factor loadings ≥ 0.4 are included.
[c] Percent of the variance explained by the factor.

Coarse

Table 10. Coarse Particle Factor Loadings for S.E. Chicago[a]

Elements	Identified Sources	Factor Loadings[b]	Percent Variance[c]
FACTOR 1	Soil		46.5
K		0.92	
Si		0.91	
Al		0.91	
Ti		0.80	
Ca		0.68	
Sr		0.67	
Mass		0.61	
P		0.61	
V		0.50	
Fe		0.50	
Rb		0.49	
FACTOR 2	Road dust		11.9
Mass		0.42	
Zn		0.80	
Ni		0.80	
Pb		0.65	
Cu		0.64	
V		0.60	
Br		0.52	
Cr		0.50	
Fe		0.50	
S		0.40	
FACTOR 3	Industrial yards		6.7
Ca		0.55	
Sr		0.45	
Mass		0.44	
Ni		0.44	
Cu		0.44	
V		0.50	
Br		0.44	
Mn		0.65	
Cr		0.55	
Fe		0.55	
Se		0.45	
Rb		0.45	
S		0.50	
Wind direction		-0.80	
FACTOR 4	Coal dust		6.0
Se		0.70	
Wind speed		0.60	
Rb		0.58	

errors in a few individual filters will not be as significant when averaged into a large database. Although all sources with an impact

AVERAGE CONDITIONS

Coarse Particles

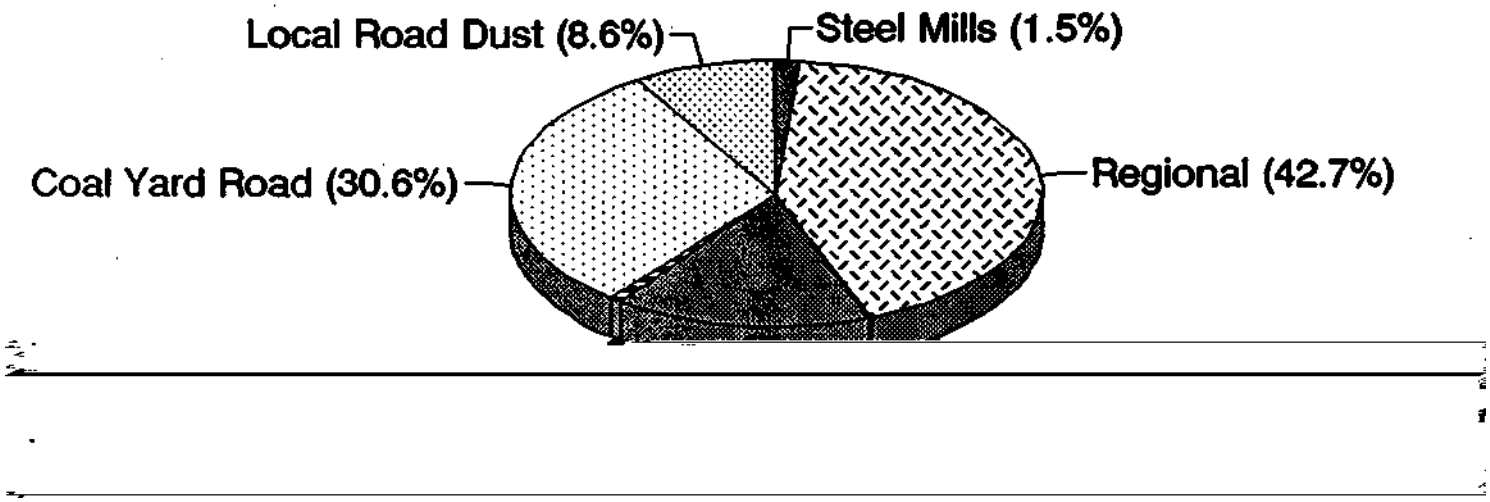


Figure 15. Southeast Chicago source contribution estimates: coarse particle average conditions.

STEEL MILL FETCH

Coarse Particles

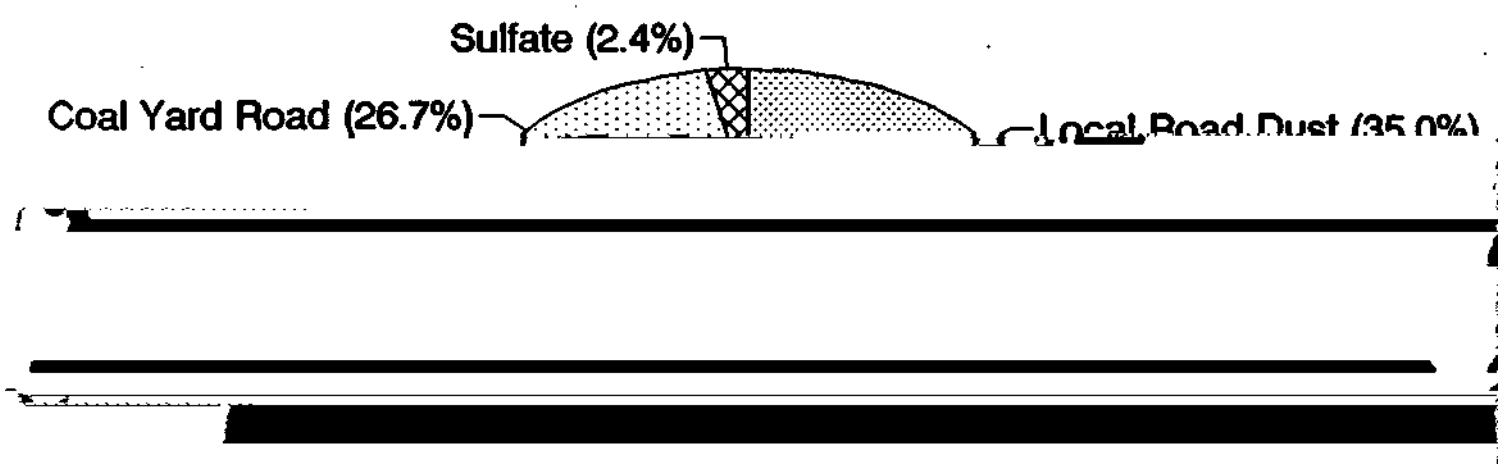


Figure 16. Southeast Chicago source contribution estimates: coarse particle steel fetch.

Table 13. Southeast Chicag

URBAN FETCH
Coarse Particles

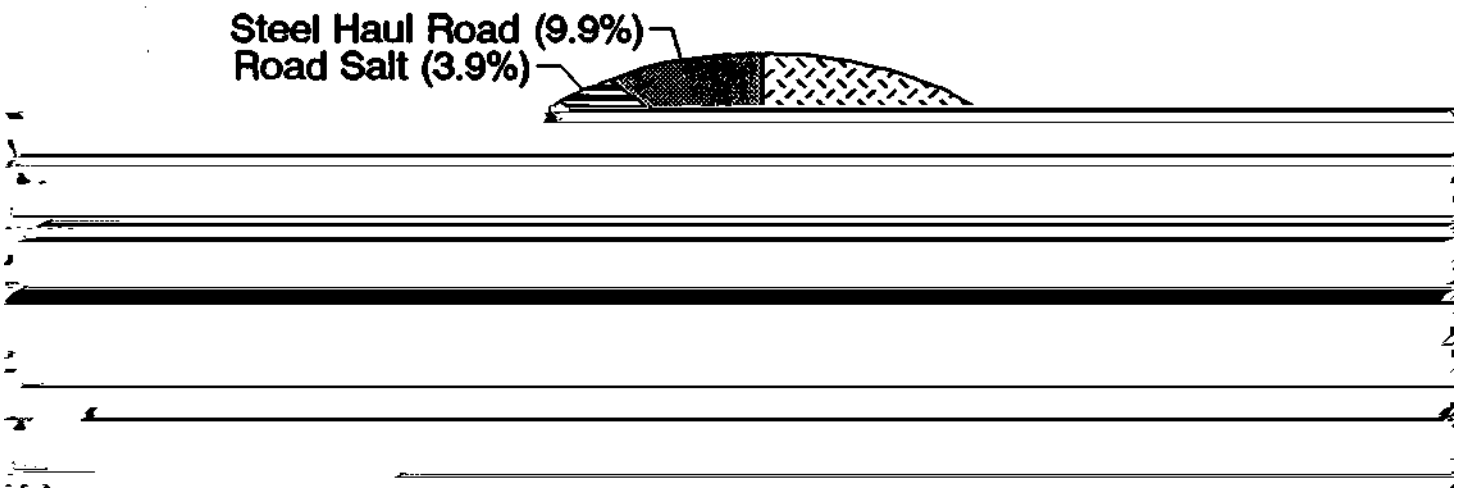


Figure 17. Southeast Chicago source contribution estimates: coarse particle urban fetch.

Table 14. Southeast Chicago Elemental Source Contributions —Coarse Particle Urban Fetch

		Percent					
Element	C* M	Regional	Coal Yard	Steel Yard	Road Dust	Road Salt	Vehicle Exhaust
Al	1.31	71	18	9	2	0	0
Si	1.25	81	11	6	2	0	0
S	1.15	84	12	1	3	0	0
Cl	1.00	5	0	0	1	93	1
K	1.02	86	8	6	1	0	0
Ca	0.99	51	3	37	8	0	0
Ti	0.72	71	21	4	3	0	0
V	0.58	69	19	7	5	0	0
Cr	0.48	50	14	16	21	0	0
Mn	1.05	25	7	43	25	0	0
Fe	0.99	27	14	53	4	0	1
Ni	1.16	60	12	19	4	0	4
Cu	2.14	63	28	1	2	0	5
Zn	0.97	49	0	41	4	0	5
Se	0.33	91	0	0	9	0	0
Br	3.21	11	0	1	0	0	88
Pb	0.83	14	0	17	13	0	55
C	1.01	0	91	4	3	0	0

Notes: * Calculated/measured
R-square = 0.97
Chi-square = 3.52
Percent mass = 108.0

A sensitivity test was conducted, removing carbon from both the coal yard and diesel sources, and only the coal yard source was accepted by CMB. The identification of a vehicle exhaust source in only the urban fetch may be attributed to controls on leaded fuels and the relative increased influence of other Pb sources (e.g., steel industry). Table 14 presents a breakdown by element for the urban fetch.

Fine Particle CMB

Modeled results are presented as source contribution estimates (Figures 18-20) and as elemental contribution estimates (Tables 15-17). Both source and elemental contribution estimates are reported as a percent of calculated mass. Model statistics show a poorer agreement between measured and calculated coarse PM_{10}, underpredicting mass by 30 percent. This may be attributed to the absence of important modeled elements/compounds (e.g., $N0_3$) and the lackk

AVERAGE CONDITIONS
Fine Particles

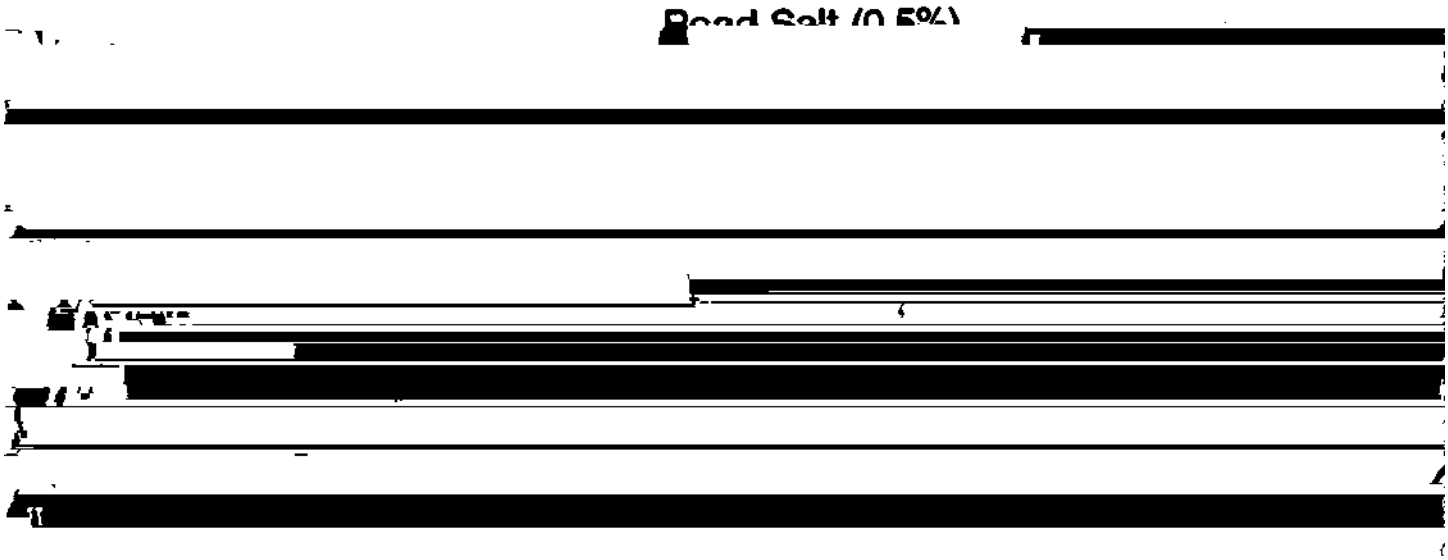


Figure 18. Southeast Chicago source contribution estimates: fine particle average conditions.

Table 15. Southeast Chicago Elemental Source Contributions — Fine Particle Mean Conditions

Element	C* M	Percent Sulfate	Coal Yard	Incin-erator	Diesel	Steel Mills	Steel Yard	Se	Road Salt	Oil Burning
Al	0.91	0	74	8	3	3	12	0	0	0
Si	1.01	0	74	7	1	5	14	0	0	0
S	1.00	95	2	1	1	1	0	0	0	0
Cl	1.00	0	0	64	4	0	0	0	32	0
K	0.76	0	11	75	0	6	4	0	0	0
Ca	1.14	0	24	2	6	20	46	0	0	0
Ti	1.29	0	73	1	9	11	5	0	0	0
V	0.80	0	17	0	0	14	2	0	0	68
Cr	0.93	0	17	4	3	70	4	0	0	1
Mn	0.74	0	14	1	0	72	13	0	0	0
Fe	0.74	0	48	1	4	21	26	0	0	1
Ni	1.36	0	10	10	3	8	1	0	0	69
Cu	0.95	0	16	16	63	3	1	0	0	0
Zn	1.07	0	0	93	1	2	1	0	0	0
Se	1.00	0	0	1	0	0	1	99	0	0
Br	1.30	0	0	58	3	40	1	0	0	0
Pb	0.93	0	0	93	1	4	2	0	0	0
C	0.99	0	77	1	16	4	2	0	0	0

Notes: * Calculated/measured
R-square = 0.97
Chi-square 0Tz-0.346 Tc(Pe 0 Trj0 Tc(e) 0037 Tc(Diese) Tj0 Tce 0 Tr3-0.00 Tc(:) Tj—0:) 12.666 Twee0ihCalcu Tweeo

STEEL MILL FETCH

Fine Particles

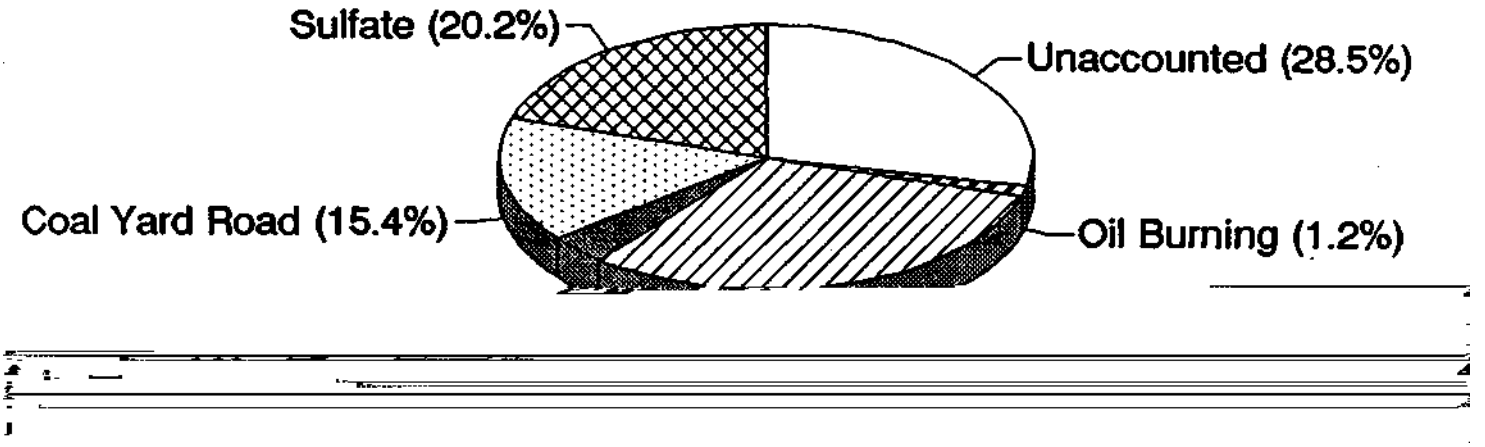


Figure 19. Southeast Chicago source contribution estimates: fine particle steel fetch.

Table 16. Southeast Chicago Elemental Source Contributions — Fine Particle Steel Fetch

Element	C* M	Sulfate	Coal Yard	Steel Mills	Steel Yard	Oil Burning
			Percent			
Al	1.00	0	43	39	17	1
Si	1.13	0	35	48	16	1
S	1.00	88	2	8	0	2
Cl	1.23	0	0	100	0	0
Ca	1.24	0	4	74	20	1
Ti	0.87	0	23	72	4	1
V	0.86	0	2	31	1	67
Cr	1.01	0	1	99	0	0
Mn	0.79	0	1	97	2	0
Fe	0.47	0	9	80	12	1
Ni	1.95	0	1	19	0	79
Cu	0.37	0	21	72	4	4
C	1.01	0	48	51	3	0

Notes: * Calculated/measured
R-square = 0.98
Chi-square = 4.40
Percent mass = 71.5

K, Zn, Se, Br and Pb were omitted as fitting species because they provided a poor fit. Given the dominance of the steel mill stack emissions, the omitted species are likely incorrectly defined in that profile.

URBAN FETCH
Fine Particles

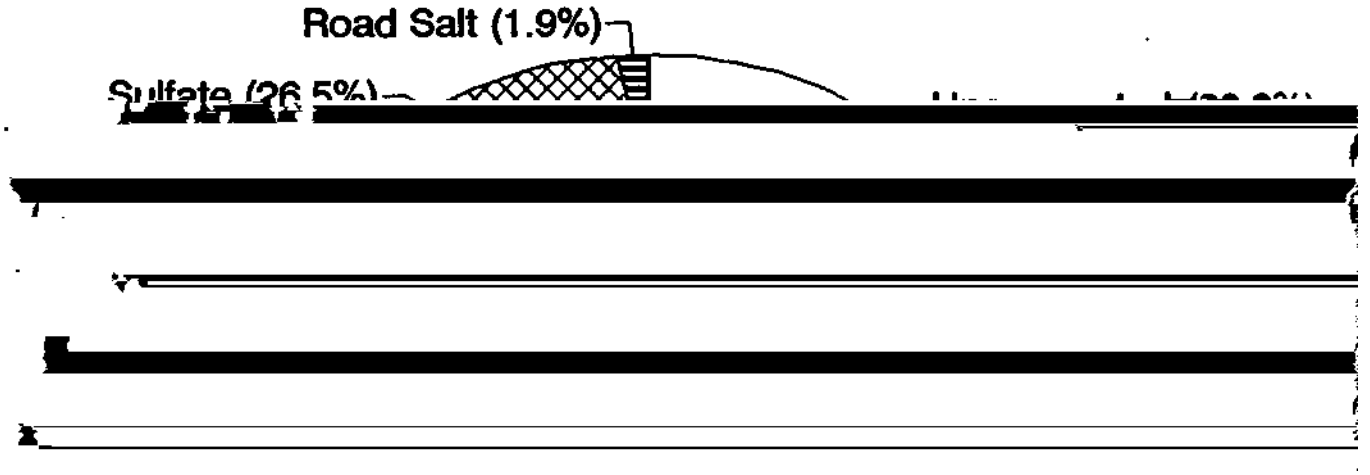


Figure 20. Southeast Chicago source contribution estimates: fine particle urban fetch.

Table 17. Southeast Chicago Elemental Source Contributions — Fine Particle Urban Fetch

Element	C* M	Sulfate	Coke Dust	Steel Mill	Incinerator	Diesel	Road Salt
			Percent				
Al	1.05	0	96	0	3	1	0
Si	0.95	0	96	1	3	0	0
S	1.00	96	3	0	1	0	0
Cl	1.00	0	1	0	19	**1**	79
K	0.4S	0	**43**	2	56	0	**0**
Ca	1.07	0	92	**4**	**1**	3	0
Ti	1.59	0	93	2	**1**	**4**	**0**
V	0.32	**0**	90	9	0	0	0
Cr	0.65	**0**	50	**41**	5	5	0
Mn	**0.94**	**0**	**49**	50	1	0	**0**

CONCLUSION AND RECOMMENDATIONS

Source identification of PM_{10} in a complex urban airshed requires

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APPENDIX A
SURFACE DUST PROFILE: METHODOLOGIES

Table 1A. MRI Dust Samples Selected for Suspension

Facility	Sample Code*	Description
Calumet Industrial Disposal	01U010	Unpaved Haul Road
	01U004 & 01U013	Unpaved Haul Road
Paxton II Landfill	02U001#	Unpaved Haul Road
	02U002	Unpaved Haul Road
Land & Lakes No. 3 Landfill	03U004	Unpaved Haul Road
	03S010	Clay Stockpile
	03S011#	Landfill Sample
Land & Lakes No. 1,2, &	04U007	Unpaved Haul Road
Dolton Landfill	04S004	Flyash
	04P184	Paved Haul Road
Acme Steel Furnace Plant	0SU014	Unpaved Haul Road
	05P014	Paved Haul Road
	05S002	Tilden Pellets
	OSSOOS	Wabash Pellets
	0SS101	Flue Dust
Acme Steel Coke Plant	06U004#	Coal Yard Road
	06S003	Coal
	06P001	Paved Haul Road
Acme Steel Riverdale Plant	07P008	Paved Haul Road
	07S301	Limedust
	07S302#	BOF Dust
Hechett Riverdale Plant	08U003	

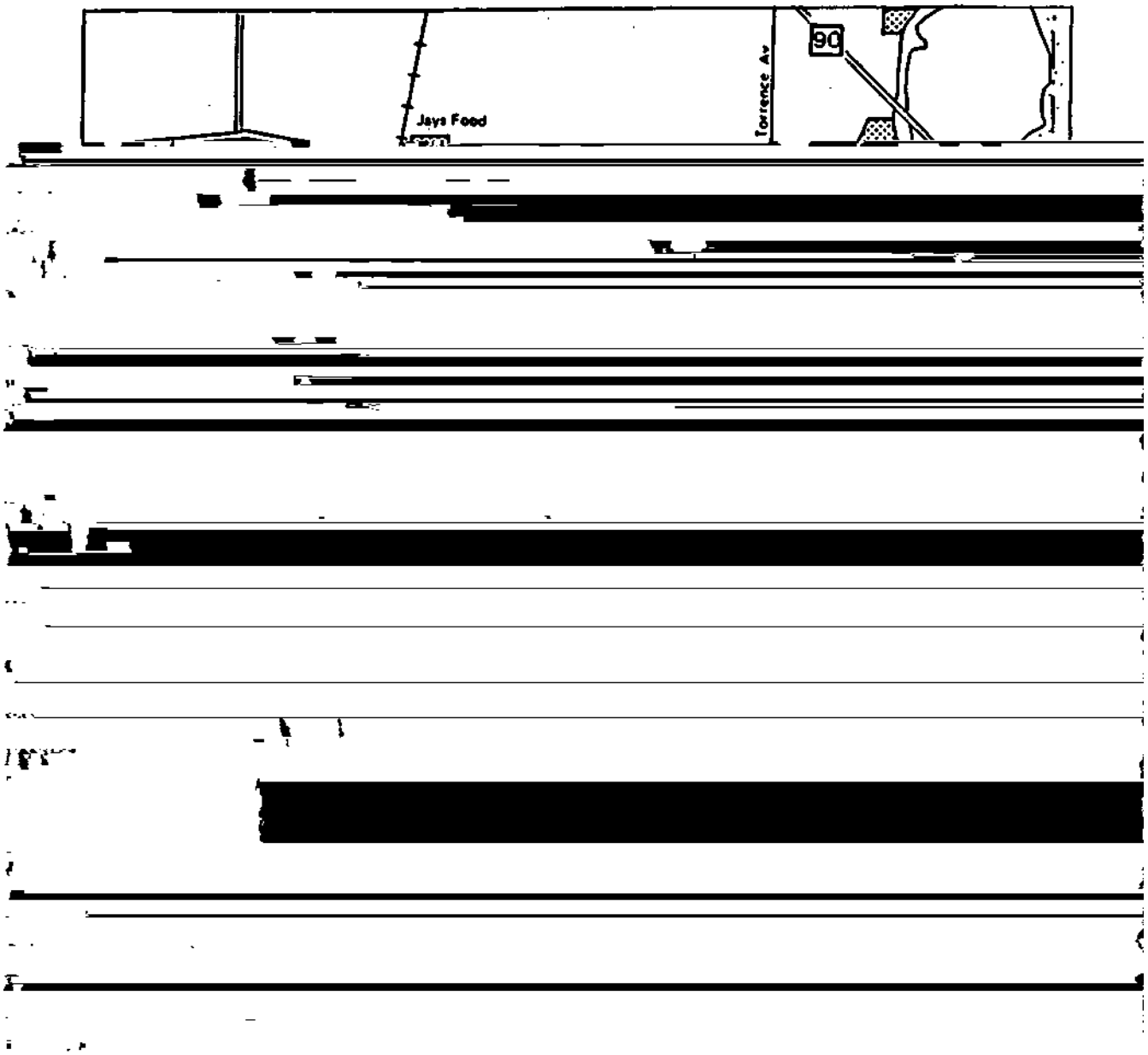

Figure 1A. Lake Calumet study area showing locations of sampled facilities and other industries.

were sampled along a transverse strip with a Hoover Model S vacuum fitted with a tare-weighed vacuum bag. Storage piles were sampled with a pointed shovel to a nominal depth of 15 cm.

The 29 profiles represent suspected sources of fugitive dust in the Lake Calumet and McCook areas. However, the analyzed samples represent only 13 percent of the collected samples, and thus an important dust source may have inadvertently been omitted. It should also be noted that the elemental profiles reported from this project represent concentrations at the time of collection and that many industrial facilities use chemical dust suppressants (especially in the dust control season March-October), which may or may not be reflected in the elemental profiles.

Suspension

The surface dust samples were sieved to < S3 µm to be used as the bulk material for suspension and deposit onto filters. The suspension chamber consists of a

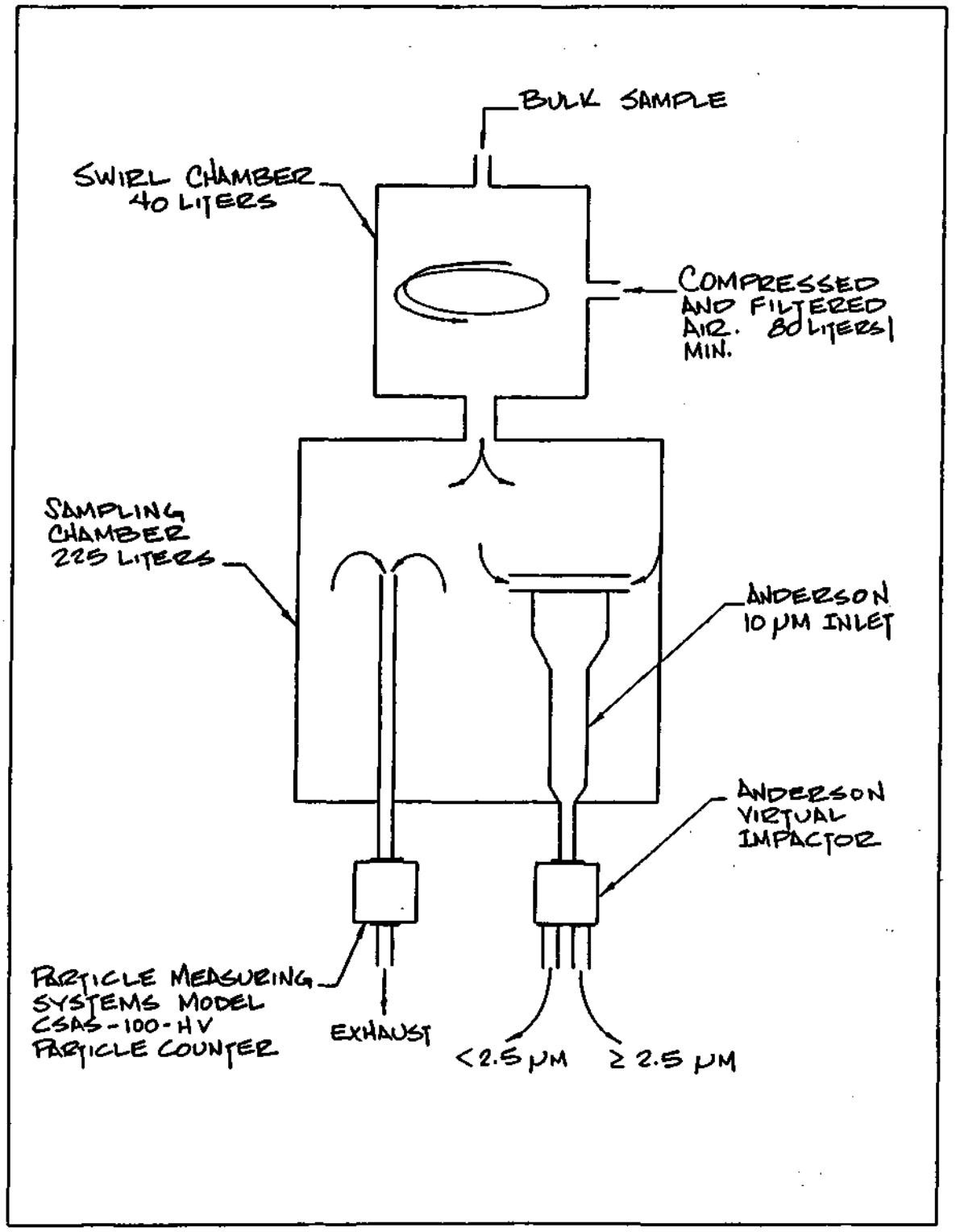

Figure 2A. Schematic of the dust suspension apparatus.

is based on the atomic excitation of electrons with the subsequent emissions of characteristic x-rays when electrons from higher levels fill the void spaces. The method of NAA is based on the measurement of induced radioactivity where the radioactive decay measuremen

The dust profiles presented in this report are predominantly from XRF determinations. Important inputs were made by NAA for element

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