

To the Graduate Council:

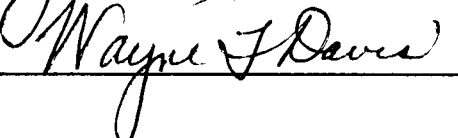
I am submitting herewith a thesis written by Robert Jan Benjamin entitled "Source Contribution Modeling Of Probable Source-types' Emissions Of Particulate Toxic Trace Elements Near Knoxville, Tennessee - A Screening Method." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.



Dr. Terry L. Miller, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:



Associate Vice Chancellor
and Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of the source is made.

Request for permission for extensive quotation from or reproduction of thesis in whole or in parts may be granted by the copyright holder.

Signature

Robert Jan Benjamin

Date

12/3/93

SOURCE CONTRIBUTION MODELING
OF PROBABLE SOURCE-TYPES' EMISSIONS
OF PARTICULATE TOXIC TRACE ELEMENTS
NEAR KNOXVILLE, TENNESSEE -
A SCREENING METHOD

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Robert Jan Benjamin

December, 1993

Copyright 1993 by Robert Jan Benjamin

All rights reserved

DEDICATION

Without family and beginning a second career, this thesis
is dedicated to my Strength and ever present
Help, my Savior, the Lord Jesus Christ.

ACKNOWLEDGEMENTS

I give my sincere thanks to Dr. Terry L. Miller for his academic guidance, work relationship, and friendship. I thank the Environmental Engineering Program of the Department of Civil Engineering and Environmental Engineering for being scholarly and professional examples for me. I especially thank Drs. Wayne T. Davis, Terry L. Miller, and James L. Smoot, my thesis committee, for their zeal and commitment to our engineering profession.

ABSTRACT

Ambient atmospheric sampling is necessary to assess the level of pollution contributed by anthropogenic and natural sources. Emission source-types were determined from particulate matter ≤ 10 microns sample data collected in Knoxville, Tennessee for one year beginning in September, 1990.

After surveying the sampled area for probable sources, emission source elemental composition profiles from an EPA emission source data base were selected for comparison with the elemental composition profiles from the particulate matter ≤ 10 micron samples data base. Source contribution modeling, a type of receptor modeling, was developed to screen emission sources where a weighting technique is applied to the emission sources and the resulting emission sources elemental composition composite profile is evaluated by normal distribution difference analysis.

The annual average sample's range of maximum percent contribution from sources was 0.289 to 34.592 percent of the particulate matter ≤ 10 microns. This sample had four major contributors which were sulfate from sulfur dioxide emissions, wood burning sources, diesel fuel burning sources and soil particulate. Their annual maximum percent contributions were 37.191, 34.592, 22.753, and 8.118, respectively. The source-type with the highest maximum percent contribution for a single day was sulfate from sulfur dioxide emissions with 81.288 percent.

TABLE OF CONTENTS

CHAPTERS	PAGES
I. INTRODUCTION	1
II. LITERATURE REVIEW	4
Source and Receptor Models	4
Modeling Objective	4
Models Comparison	5
Receptor Modeling	6
Particle Size Differentiation	6
Chemical Methods	7
Fundamental Modeling Equations	8
Equation Assumptions	9
Source or Receptor Location	9
Source Contribution Modeling Limitation	10
III. SAMPLE COLLECTION	11
Equipment	11
Monitored Area	11
Gravimetric and Flow Quality Assurance	13
Dichotomous Sampler	13
Electronic Balance	13
Filter Blanks	13
Elemental Analysis	13
IV. SAMPLING RESULTS	15
Fort Loudon Lake Atmospheric Deposition Study	15
Ambient Atmospheric Monitoring Technical Paper	15
Results	16
Conclusion	23
V. CONSTRUCTING THE DATA BASE	25
Element Selection	25
Sample Selection	26
Source-type Selection	27
Data Base Size	29
VI. SOURCE CONTRIBUTION MODELING	30
Method	30
Source of Parameters	30
Estimating the Relative Contribution of Selected Source-types to the Elemental Composition of the Sample	31
Definition	31
Illustration	32
Assumptions	33
Models' Differences	34
Models' Results Table	35
General	35
Description and Calculations	36

<i>Model's Abbreviated Data Sheets</i>	38
Element Percent Weights	38
Source Contribution Variations	39
VII. RESULTS	41
Selected Sources and Samples	41
Model's Normal Distribution Difference	42
Limiting Element Model Results	43
<i>Interpretation of Samples</i>	43
<i>Interpretation of Source-types</i>	46
VIII. CONCLUSION	54
IX. RECOMMENDED FUTURE RESEARCH DIRECTIONS	57
LIST OF REFERENCES	59
APPENDIXES	61
APPENDIX A. Figures	62
APPENDIX B. Tables	76
VITA	93

LIST OF TABLES

TITLE	PAGE
Table 1. Monitoring statistics	77
Table 2. Monthly ff and concentrations	77
Table 3. Annual concentration and ff by ranked order .	78
Table 4. IP analyte and its compound identification .	79
Table 5. Unit cancer risk	79
Table 6. Annual Average sample	80
Table 7. Annual Average sample model results	83
Table 8. High Coarse Fraction sample model results . .	84
Table 9. High Fine Fraction sample model results . . .	85
Table 10. High PM10 sample model results	86
Table 11. High Sulfur sample model results	87
Table 12. High Arsenic sample model results	88
Table 13. High Nickel Coarse sample model results . .	89
Table 14. High Lead Fine sample model results	90
Table 15. Models' results	91

LIST OF FIGURES

TITLE	PAGE
Figure 1. Receptor model types	63
Figure 2. Anderson sampler aerosol inlet	64
Figure 3. Anderson sampler aerosol virtual impactor .	65
Figure 4. Monitoring site map	66
Figure 5. Laboratory coarse results sheet	67
Figure 6. Laboratory fine results sheet	68
Figure 7. Meteorological components	69
Figure 8. Particulate matter monthly trends	69
Figure 9. Iron & manganese monthly trends	70
Figure 10. Selected elements' monthly trends	70
Figure 11. Sulfur's monthly trends	71
Figure 12. Particulate matter speciation report . . .	72
Figure 13. Source A profile	73
Figure 14. Sample B profile	73
Figure 15. Annual Average sample model - group 1 . . .	74
Figure 16. Annual Average Sample Model - group 2 . . .	74
Figure 17. Annual Average sample model - group 3 . . .	75

LIST OF ABBREVIATIONS

Annual.....	Ann1
Coarse.....	Crs
Coarse Particulate.....	CP
Concentration	$\mu\text{g}/\text{m}^3$
Fine.....	Fin
Fine Fraction.....	FF
Fine Particulate.....	FP
Inhalable Particulate - PM10.....	IP
Inductively Coupled Plasma Spectrometry.....	ICP
Ion Chromatography.....	IC
Model.....	Mod
Sample.....	Smp
Source.....	Src
Source Contribution Modeling.....	SCM
Total Inhalable Particulate.....	PM10

Units:

Kilometer.....	km
Meter.....	m
Liters per minute.....	lpm
Milligram.....	mg
Microgram.....	μg
Micrograms per cubicmeter	$\mu\text{g}/\text{m}^3$
Micrometer.....	μm
X-Ray Fluorescence Spectrometry.....	XRF

I. INTRODUCTION

A year-long monitoring program of dichotomous sampling for toxic trace pollutants was conducted by the University of Tennessee and sponsored by the Tennessee Valley Authority. The program results characterize a semi-rural area, less than 27 km from an Environmental Protection Agency (EPA) Prevention of Significant Deterioration Class I region, the Great Smoky Mountains National Park in East Tennessee. The monitoring site was 8.8 km southwest of Knoxville, Tennessee. Sampling began in September, 1990 and continued for one year. A 24-hour duration, 3-day cycle schedule was followed. Concentrations for 36 elements and two compounds were determined. Sulfur, silicon, calcium, nitrates, and iron were the principal analytes. Concentrations for five carcinogenic elements--chromium, nickel, arsenic, cadmium, and beryllium--were also determined.

This thesis presents an evaluation of air monitoring data collected during this one-year period. Eighteen elements were determined to be related in the atmospheric activity for the year of sampling. Eight principle samples were selected because they represented the highest concentration for the year of study for that element or particulate matter ≤ 10 microns (PM₁₀). They were: a high coarse particulate fraction (High CF), a high fine particulate fraction (High FF), the highest particulate matter ≤ 10 microns (High PM₁₀),

the highest sulfur (High "S"), the highest arsenic (High "As"), the highest nickel coarse fraction (Hi-Ni-Crs), the highest lead fine fraction (Hi-Pb-Fin), and the annual average (Ann1-Avg) for the year of sampling. Thirteen natural and anthropogenic sources were selected from an EPA emission source elemental composition profile data base that were similar to sources surveyed in the monitored area. This study shows that the four selected major contributors to the annual average sample were wood burning, sulfate (from sulfur dioxide emissions), diesel fuel burning, and soil source-types.

The monthly concentration averages of PM10, sulfur, iron, manganese, aluminum, silicon, calcium, strontium, and titanium showed similar annual patterns to some others in this list. These variation patterns were observed when the normalized concentrations for each constituent were graphed for the months of sampling.

An aggregate cancer risk for the monitored area was determined from the carcinogenic elements' concentrations, i.e., As, Cd, Cr, and Ni. The risk level determined was larger than expected for this semi-rural area.

An unsuccessful attempt was made using "pollution roses" from the meteorological data and the samples' elemental concentrations to determine the directions to the sources. The inconsistency of the 24-hour sample collection and the one-hour meteorological data gave indistinguishable results.

A source contribution modeling technique was developed

and used to prioritize the 13 probable source contributors to the eight ambient samples. This technique used particle size, elemental composition and the maximum contribution percent from probable source-types to weight them for ranking from the largest probable contributor to the smallest. The objective of this thesis is to illustrate the use of this technique on particulate matter samples collected near Knoxville, Tennessee; to determine emission source composites' profiles from EPA emission source data base which are comparable to receptor samples' profiles from the analyzed samples' results; and to comment on the sample-source relationships found.

II. LITERATURE REVIEW

Source and Receptor Models

Modeling Objective

The objective of source, receptor, and source-receptor modeling is to relate particulate matter emissions' levels from emission sources to concentration levels at a receptor. Source modeling uses emission rate, plume buoyancy, source activity and local meteorological data to compute concentrations at a receptor site.¹ Receptor modeling uses measured concentrations at the collector site and apportions these concentrations to known emission sources by a least squares multiple regression analysis on either the particulate mass on different filters or the mass of individual chemical species on a single filter.¹

The source and receptor modeling as described above are two independent methodologies. Source-receptor modeling is a methodology using the basic principles of both types to define a "hybrid or mixed" methodology. This technique is more costly as expected, but preliminary studies show that the results give more interpretation confidence to the investigators when required.⁵

Models Comparison

Typical control strategies for air pollutants use emission inventories for various sources as inputs to Gaussian source (dispersion) models to predict ambient concentrations of total suspended particulate matter, sulfur from sulfur dioxide, and other air pollutants.² In this approach all the pollutants are assumed to be from the source(s) under investigation. Source modeling uses emission rate and dispersion parameters from meteorological data to predict the concentration at a distant site.¹ Some advantages of source modeling are that it can predict the pollution impact of future pollution emissions for a study area² and concentration isopleths can be determined for cancer risk studies.

Receptor modeling uses known chemical compositions of the source and receptor samples to apportion by statistical methods the observed ambient concentrations to source-types, e.g., industrial, transportation, soil.³ The receptor (collector) is located at the site where the particulate matter is collected. Additional pollutants that can be measured by a receptor and not be in the emissions from a source are organic and biological particulate, fugitive process emissions, dust, and others². Other data that receptor modeling can provide is particle size partitioning. Of significant importance is that ambient concentrations are actually measured and not estimated. Receptor modeling is particularly applicable in areas which exceed the National

Ambient Air Quality Standards (NAAQS)⁴ where high concentrations allow many elements to be quantified. A measured concentration has less uncertainty than a concentration from dispersion modeling.

Receptor modeling is not to be a substitute for source modeling, but the two methods enhance each other. A mixed approach seems to be the most promising having the advantages of both models.³ Receptor modeling with reliable trace element data for the source and receptor has accounted for up to 80 percent of all sources contributing.⁵

Receptor Modeling

Particle Size Differentiation

One receptor modeling type is particle size differentiation. Size differentiation is done by dichotomous samplers which selectively sample particles with an aerodynamic particle diameter of 10 microns diameter particles and smaller. This set of particles is partitioned into two diameter size ranges. The coarse particles are 2.5 to 10 microns in diameter and the fine particles are less than 2.5 microns in diameter. These two sizes are usually chemically quite different and have significantly different environmental effects.² Coarse particles are usually from natural sources, (crustal [soil] erosion, volcanoes, and earthquakes) and mechanical-made anthropogenic sources, (industrial site

fugitive emissions, crushing, grinding, and screening operations, and resuspension of particulate matter due to wind activity).² The major concern for coarse particulate is eroding of surfaces.⁶ Fine particles come from high temperature, combustion sources and are of greatest concern in the areas of health, toxicity, and visibility.² In the human body the smaller particle goes deeper into the lungs increasing system ingestion. This size range contains toxic chemical species affecting animal and plant life.^{2,5} In the atmosphere these fine particles scatter light rays causing haze, undergo chemical reactions, and can be transported to remote areas.⁵ The small particle size is attributed to the condensation of high temperature emission releases.^{5,7} The small particle size is indicative of anthropogenic sources of particulate matter.⁵

Chemical Methods

Chemical methods is the other category in receptor modeling and it requires chemical elemental analysis of sources and receptor samples to indicate sample-source combinations. This study uses size differentiation and develops a receptor methodology for source screening from samples' elemental composition data. Figure 1^a shows a box diagram of typical methods involved in receptor modeling.⁵

^aAll tables and figures are given in the Appendixes.

Fundamental Modeling Equations

The fundamental modeling equation is show below.

$$C_{ik} = \sum_{j=1}^P a_{ij} D_{jk} E_{jk}.$$

This equation states that the concentrations of component "i" in the "kth" sample, (C_k), equals the sum of the products of the fractional amount of component "i" in the emissions from source "j", (a_{ij}); the atmospheric dispersion of emissions from source "j" for the "kth" sample, (D_k); and the total emission rate of all components from source "j" which corresponds to sample "k", (E_k).⁴ In source modeling the values of the products of $a_{ij}E_k$ and D_k are from measurements and C_k is calculated. In receptor modeling the values C_k and a_{ij} are from measurements and the value of the D_k and E_k product is calculated. The fundamental equation is changed to the following form.

$$C_{ik} = \sum_{j=1}^P a_{ij} S_{jk} \quad \text{for } i=1,n.$$

This equation states that the concentration of component "i" in the kth sample, (C_k), equals the sum of the products of the composition fractions, (a_{ij}), and the total contribution to the receptor of source "j" in the kth sample, (S_k). The value of "n" is the number of components measured.⁴ This is the principle equation in the chemical mass balance technique.⁴

Equation Assumptions

Several assumptions are required when modeling atmospheric particulate matter.⁴ The assumptions for both model types are listed below.

- 1) Compositions of source emissions are constant.
- 2) Components do not react with each other, i.e., they add linearly.
- 3) "p"-identified sources contribute to the receptor.

Receptor modeling uses the above assumptions and two additional assumptions:

- 4) The number of sources, "p", is less than or equal to the number of components, "n".
- 5) The compositions of all "p" sources (the set of a_{ij} for S_k) are linearly independent of each other.

Source or Receptor Location

The receptor site in source modeling can be any site downwind of the source(s) investigated. When a location's coordinates are input to the model, the source model computes the concentration at that point. The receptor site in receptor modeling is selected downwind of the source(s) investigated and actually measures the components' concentrations at that point only. Multiple receptor sites are possible, but each requires analysis of its collected

samples, separate statistical analysis, and local meteorological data.

Source Contribution Modeling Limitation

This study developed source contribution modeling and is not typical receptor modeling as described above or from EPA methods, but it does evaluate a receptor sample data set. The receptor site was not selected to be downwind of a known emission source(s), but the site selection was made to support the study of Fort Loudon Lake deposition of other pollutants. The site is regarded as a semi-rural area. Without known sources and their related elemental composition profiles, statistical analysis to determine specific source concentration levels are not possible. Using receptor sample elemental profiles, EPA emission source elemental profiles, site area surveillance, and reference material,¹⁶ this study identified probable source-types that may have contributed to the receptor samples. This identification is made without knowledge of the real source(s) emission levels.

III. SAMPLE COLLECTION

Equipment

Total inhalable particulate (PM10) samples were collected with an Anderson Sampler, Inc. automatic dichotomous sampler, series 245 (virtual impactor). The sampler was refitted with a PM10 Sierra-Anderson aerosol sampling inlet, Model 246b. Figure 2 shows the aerosol inlet where the PM10 is separated from the ambient particulate matter. Figure 3 shows the virtual impactor where the particulate matter is partitioned in two size fractions. The PM10 range is less than 1.0 to 10.0 μm . The fine particulate (FP) is less than 1.0 to 2.5 μm and the coarse particulate (CP) is 2.5 to 10 μm . Gelman PTFE teflon membrane filters of 37 mm and 2 μm pore size were used to collect the particulate. Mass determination was made using a Mettler Instruments electronic analytical balance, Model AE163. After dessication, the sample masses were determined to ± 10 μg . The samples were sent by courier in Gelman analyslides for elemental analysis to the NEA/Keystone Laboratory in Beaverton, Oregon.

Monitored Area

The dichotomous sampler was located 8.8 km southwest of Knoxville in the East Tennessee Valley. Figure 4 shows the

monitoring site located in Knox County. This area has semi-industrial development. Knox County's population is about 335,000. The longitude is 83° 58' W. and latitude is 35° 58' N. for Knoxville. The East Tennessee Valley is bordered on the east by the Appalachian Mountains, 600 m to 1800 m elevation, and bordered on the west by the Cumberland Mountains with a crest of about 600 m elevation. The valley between the two mountain ranges is about 65-80 km wide with ridges laying parallel to the mountains. The sampling site has a regular diurnal southwest-northeast wind pattern. The Tennessee River is about 250 m elevation at Knoxville. The sampler placement is about 350 m from the river on a knoll about 260 m elevation in rolling grassland and near cultivated fields. A 4-lane highway (Alcoa Highway) is about 300 m to the east of the sampler. The highway has an average daily traffic volume of 40,000 vehicles per day.

Potential sources for PM₁₀ concentrations are located in most directions from the site. A major aluminum manufacturing plant is to the south about 14 km. A 1700 MW coal-fired power plant is 51 km to the west. A major cement plant is 13.3 km to the north-east. A steel foundry is to the north about 9.7 km. A hospital incinerator is about 5 km to the north. Alcoa Highway is 300 m to the east. A 300 m long, graveled driveway on the east connects the site to the Alcoa Highway.

Gravimetric and Flow Quality Assurance

Dichotomous Sampler

The dichotomous sampler was calibrated at five flow rates twice during the year of sampling. A field audit of the dichotomous sampler was done, initially, and the total flow (16.7 lpm) error was 1.4 percent. The percent error for the coarse flow (1.67 lpm) was -3.0 percent.

Electronic Balance

The Mettler electronic balance was self-calibrated with 100 g ± 0.2 mg at the beginning of each weighing session. A precision test was performed at the beginning and end of each weighing session, where the balance was checked with two weights of 99927 μg ± 10.8 μg and 100124 μg ± 10.6 μg .

Filter Blanks

Field blank Gelman PTFE membrane filters were sent to the analytical laboratory for blank analysis.

Elemental Analysis

The filter samples were sent to the NEA/Keystone Laboratory in Beaverton, Oregon for elemental analysis. Three methods were used for analyzing the samples. X-ray fluorescence spectrometry (XRF) and inductively coupled plasma

spectroscopy (ICP) were used to measure the 36 elements and ion chromatography (IC) was used to measure NO_3 and PO_4 . The analytes are listed in Table 1. A separate analysis sheet for each filter was provided by the laboratory. Each sheet contained mass per filter (μg), percent weight (%wt), and ambient concentration ($\mu\text{g}/\text{m}^3$) for each analyte. Coarse and fine analysis sheets gave the complete sample data for any one sample day, i.e., Figures 5 and 6. One-hundred and twenty sample days had 240 sample profile sheets. The PM_{10} concentration or mass is the sum of the coarse and fine data for that sample day. The sample filters were destroyed in the beryllium analysis and were not available for further analysis.

IV. SAMPLING RESULTS

Fort Loudon Lake Atmospheric Deposition Study

Atmospheric deposition has been identified as a significant factor in ecological contamination of north-eastern inland and coastal waters.⁸ Informed of these studies, the Tennessee Valley Authority is investigating the impact of atmospheric deposition on its reservoir system where water quality problems have been identified. Toxic pollutants, such as, PCB's, pesticides, PCDF's, heavy metals, PCDD's, and nutrient compounds are being researched to determine the role of atmospheric deposition on water quality.⁸ Results from the deposition studies have been presented at the 1992 and 1993 annual meetings of the Air and Water Management Association.^{20, 21} Heavy metal and toxic trace element concentrations were determined by dichotomous sampling and their results are given below.

Ambient Atmospheric Monitoring Technical Paper

In June, 1992, a research paper,⁹ was written and presented at the annual AWMA meeting in Kansas City, Missouri using the same dichotomous receptor sample data as this study. The topics of the paper were seasonal trends of pollutants' concentrations, estimated carcinogenic risks, particulate

matter elemental compositions and annual concentration profiles. The results are comparable to other background sites except that the carcinogenic risk was higher than expected when compared to other data from "background" monitoring sites.

Results

Particulate Matter and Analytes. Size classification and chemical composition can be used to indicate a possible source-type for the particulate matter of 10 microns and smaller, referred to as inhalable particulate (IP).⁵ High temperature combustion sources will contribute largely < 2.5 μm (aerodynamic diameter) particulate, referred to as fine particulate (FP). Typical trace elements found in FP are As, Cd, Ni, Pb, V, Zn, Co, Cr, Hg, Mn, Se, and Sb which come from power-generation fuel, incineration, mobile, industrial, volcano, and forests fire emissions in descending order of their abundance.⁵ Natural sources, e.g., crustal dust, ocean aerosol, biological and soil emanations will contribute mostly > 2.5 μm particulate, referred to as coarse particulate (CP). Major crustal trace elements found in CP are Fe, Mn, Zn, Pb, V, Cr, Ni, Cu, Co, Hg, and Cd in their descending order.⁵ A fourth significant parameter in air pollution monitoring is the fine fraction (FF). This parameter is the fraction of the fine particulate concentration divided by the IP or PM10 concentration.

(1) Meteorological Components. Figure 7 shows the relative shapes of constituents, i.e., average ambient temperature (AAT), wind speed (WS), and rainfall (Rfl), for the same 13 periods (one year) sampled. The constituents' monthly, average concentrations are normalized by dividing each month's average by the maximum month's average for the sampled year for each constituent. The AAT curve has minimum and maximum temperatures of 36.1 and 76.9 °F for January and July, respectively. The WS curve peaks in March at 8.47 kph and is lowest at 1.48 kph in September, 1991. The Rfl's curve has the maximum of 21.8 cm of rainfall for December and several months of about 6 cm of rain per month.

(2) IP and FP Interdependence. The annual mean values for IP, CP, FP, and FF for the particulate matter and each component are reported in Table 2. Monthly concentration averages and the annual mean for IP, CP, FP, and fine fraction (FF) are reported in Table 3. One hundred and twenty sampled days were separated into 13 periods. Eleven periods were one month in time. Partial months of September were sampled at the beginning and end of the schedule. The FF shows that the FP dominates the IP ranging from 57 to 82.4 percent with a mean of 67.8 percent (Note: FF values are calculated from daily concentrations and may not equal monthly concentrations divided by IP concentrations). Figure 8 shows seasonal trends for IP, CP, and FP. A noticeable difference between the FP and CP occurs where the FP increases sharply from April to

July and CP decreases continually for the same period.

(3) Elemental Data Description. Table 3 gives the concentrations and fine fractions measured for all constituents. Annual average concentrations were determined for each element for inhalable particulate, coarse particulate, and fine particulate. Curves of inhalable particulate, coarse particulate, and fine particulate concentrations versus months were graphed (Figure 8). Several components' trends have similar curve shapes. Similarity of curve shapes may mean a common source. Specifically, it was seen that the Fe_P and the Mn_P were quite similar (Figure 9). Fe and Mn are usually found in local soils, but they can be from steel manufacturing emissions⁷, such as from, Florida Steel Co.'s facility located 10 km north of the site. Fe_P 's annual mean concentration was > 70 times Mn_P 's annual mean concentration, i.e., .451 and .0061 $\mu g/m^3$, respectively.

Another set of similar curve shapes are Ca_{CP} , Si_{CP} , Ti_{CP} , Sr_{CP} , and Al_{CP} (Figure 10). Of this group Ca_{CP} and Ti_{CP} match very well. Ca_{CP} 's concentration is > 19 times Ti_{CP} 's concentration. Si, Sr, and Al match well. Si is > 675 times Sr's concentration. Another observation from the component data is that S_P and S_{FP} match very well, meaning that S_P is predominantly composed of S_{FP} (Figure 11). The sulfur curves also match the FP curve .

Comparison of twelve elements, i.e., V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Cd, Hg, and Pb, in this study with

concentrations in three other studies showed that these concentrations are less than or at the lower end of concentration ranges for the studies for rural or background sites.^{5, 10, 11}

Inhalable Particulate Matter Composition. When sampling the ambient atmosphere, there are numerous constituents that may be present, i.e., VOC's, HC's, metallic vapors, biogenic emissions, terrestrial dust, volcanic emissions, sea spray, forest fire emissions, and the endless list of anthropogenic source particulate and elemental matter.⁵ Depending on the objective of the research, an analysis method is selected based on its detection limits capability for the atmospheric constituents.⁵ This study focused on toxic trace elements where heavy metals are the major concern. The XRF analytical method can detect 36 elements of concern. However, most metals in the atmosphere will be in an oxidized form. Table 4 lists the annual average concentration measured for each of 19 elements, plus NO₃ and PO₄. The most probable chemical form of each element was then estimated as it might possibly be found in the atmosphere.^{5, 12} The major constituent was ammonium sulfate. It was over seven times greater than the next highest compound, calcium carbonate. For the 21 compounds, the first five compounds comprised over 52 percent of the IP. The identified mass per cubic meter is estimated by multiplying the analyte's annual mean concentration by the

compound to analyte molecular weight fraction. The table shows that the analyte-compound analysis' estimate is 14.2 $\mu\text{g}/\text{m}^3$. This is a 9.5 $\mu\text{g}/\text{m}^3$ increase compared to using only the elemental composition data. Fifty-nine percent of the chemical composition of IP has been accounted for as having the chemical from given in Table 4. The analytical methods used did not report carbon which may account for much of the "unknown" portion of the composition of the IP.

Carbon Sampling Data. About eight months after the '90-'91 sampling period a second PM10 sampling period was started at the same monitoring site. The samples were collected using the same PM10 dichotomous sampler. The sampling duration was 24 hours beginning at 12:00a. The samples were collected each three days as in the '90-'91 sampling period, but only four samples were selected to be representative of this period. The dichotomous filter load and coincident, acceptable samples collected with two "PUF" samplers at the same site were the factors in selecting the representative PM10 samples. The samples selected were collected on August 19, 27, 31, and September 8, 1992.

The laboratory sample analysis stated the results as organic carbon (1.01 to 4.39 $\mu\text{g}/\text{m}^3$) and elemental carbon (0.81 to 2.07 $\mu\text{g}/\text{m}^3$) in the coarse fraction. It reported the fine fraction results as organic carbon (2.06 to 4.31 $\mu\text{g}/\text{m}^3$) and elemental carbon (2.3 to 4.84 $\mu\text{g}/\text{m}^3$). The total carbon

(organic plus elemental carbon) percent weights for the PM10 (coarse plus fine elemental particulate) were 34.0, 62.8, 19.3, and 24.0 in the order as the above dates. These average 35 percent. The total carbon percent weights for the samples' coarse elemental fractions were 46.2, 64.1, 17.5, and 18.3 listed as above. These average 36.5 percent. The total carbon percents for the samples' fine elemental fractions were 28.4, 61.6, 19.7, and 27.3 listed as above. These average 34.2 percent.

The four selected total carbon samples' percent weights were 6 to 12 times greater than the total carbon percent weights of the field blanks in this sample data set.

Inhalation Unit Cancer Risk. The EPA has defined Unit Cancer Risk (UCR) as the measure of probability of an individual's developing cancer as a result of exposure to a specified unit ambient concentration. This may be understood to mean that an inhalation UCR of 3.0×10^{-4} near a point source implies that if 10,000 people breathe a given concentration of a carcinogenic agent, i.e., $1 \mu\text{g}/\text{m}^3$, for 70 years, three of the 10,000 are likely to develop cancer resulting from this exposure.¹³ The EPA published a list of 75 carcinogenic agents with their unit risk factors in July, 1991.¹⁴

Annual mean IP concentrations were determined for four metals, i.e., Cr, Ni, As, and Cd, and they are identified in the EPA's listing. The UCR results are given in Table 5

(Beryllium was omitted because no detectable concentrations were reported). These concentrations were multiplied by EPA's unit risk factors to calculate the UCR due to each metal. Cadmium has the largest UCR, while nickel has the smallest, i.e., 8.64 and $.192 \times 10^{-6}$ UCR, respectively.

In the cases of chromium and arsenic multi-valent compounds exist. Chromium(VI) and arsenic(III) are the carcinogenic forms. Formerly, approximating Cr(VI) concentration levels were limited to predictions by various modeling approaches.¹⁵ Presently, a sensitive wet impingement method can be used for direct measurement of the low concentrations of Cr(VI) in the ambient background atmosphere.¹⁵ For this study additional analysis would need to be done to approximate the carcinogenic element with respect to its non-carcinogenic species. To approximate the cancer risk due to metals in the IP, 15 percent of the measured Cr and 100 percent of As were assumed to be the carcinogenic species' concentrations. The resulting values are 3.78 and 6.45×10^{-6} UCR, respectively. Cr(VI) was adjusted to 15 percent of measured chromium as an approximate correction factor based on a study in Hudson County, New Jersey for 15 locations at uncontaminated residential sites by Falerios, et al.¹⁵ A relevant point of interest is that the UCR determined from the ambient samples collected from this semi-rural site exceeds 40CFR Ch. I (7-1-91), Part 266 criteria for boiler, incinerator, and furnaces (BIF). According to the EPA rules

for BIF facilities emitting the carcinogenic agents As, Cd, Ni, Be, and Cr, the sum of these carcinogens' concentrations normalized to each agent's risk-specific dose shall not exceed 1 UCR in 100,000 or 10 UCR in 1,000,000.¹⁴ Summing the UCR's for Cr, Ni, As, and Cd give a value of 19 UCR in 1,000,000.

Conclusion

The annual average total inhalable particulate (IP or PM10) concentration measured was $24.3 \mu\text{g}/\text{m}^3$. This is less than half of EPA's annual standard of $50 \mu\text{g}/\text{m}^3$. The average coarse particulate (CP) concentration was $7.9 \mu\text{g}/\text{m}^3$ and the fine particulate (FP) concentration was $16.4 \mu\text{g}/\text{m}^3$. The average fine fraction is 68 percent of the total. Most of the IP source processes are likely to be high temperature and man-made, e.g., fossil-fired boilers, incinerators, cement kilns, mobile. The maximum measured IP concentration was $50.2 \mu\text{g}/\text{m}^3$. This is 33 percent of the EPA's 24-hour standard of $150 \mu\text{g}/\text{m}^3$. Concentrations of 12 elemental constituents tended to be low when compared to other studies for rural or background sites.

The IP chemical composition's concentration was estimated based on the measured elemental analysis and the suspected chemical form (usually oxides) of the particles in the atmosphere. The IP chemical composition accounted for was 59 percent of the total IP ($24.3 \mu\text{g}/\text{m}^3$). The remaining 41 percent was unknown and it's suspected to be mostly carbon from natural and man-made sources. Ammonium sulfate accounted

for 37 percent of the IP concentration.

The seasonal patterns of Al, Ca, Fe, Mn, Si, Sr, and Ti showed similar monthly trends which indicate that they may be from the same source. These elements exhibit a different seasonal trend than the total IP seasonal trend. Figures 10 and 11 for the common soil elements of Ca_{CP} , Si_{CP} , Fe_{IP} , and Mn_{IP} show concentrations declining for the months (Sep-Feb) and does not decline below the February level for the rest of the months (Mar-Sep).

V. CONSTRUCTING THE DATA BASE

A data base was constructed for analysis that included all the air monitoring data, meteorological data, and particulate elemental composition profiles for various air pollution emission source types that could contribute to particulate matter concentrations at the monitoring site. The basis for the selection of the elements, samples, and source types that were evaluated in detail is described below.

Element Selection

There are 36 elements and two compounds as analytes in the laboratory data report and many analytes have zero or less than detection limits concentrations. The zero values were replaced with one half of the "uncertainty limits" reported by the laboratory for that analyte as a means of estimating half of the detection limits. In order to make the analysis more manageable, the number of analytes was reduced from 38 to 18. Reduction of this number of analytes to 18 selected elements was done in the following manner. Elements Al, Si, K, Ti, Mn, and Fe were selected because they were associated in the coarse fraction of the particulate. Elements Pb and Cu were selected because they were associated in the fine fraction of the particulate. Additional elements selected because they are carcinogenic were Cr, Ni, As, and Cd. Finally, other

elements of interest selected because they are commonly found in air samples were C, S, Cl, Ca, Zn, and Br. The group of 18 selected elements for source contribution modeling was C, Al, Si, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Cd, and Pb.

Sample Selection

From the 120 PM10 samples seven were selected for use in modeling. The Annual Average sample was calculated and used because it is the single most representative sample of particulate air pollution measured at the site. The highest coarse fraction sample (besides the highest PM10 sample) was selected because it should best show the contribution of mechanical man-made or natural wind erosion source-types. The highest fine fraction sample (besides the highest sulfur sample) was selected because it should best show the contribution of high-temperature source-types. The highest PM10 sample is of interest for comparing to EPA's National Ambient Air Quality Standard for particulate matter. The highest sulfur content sample was of interest since sulfur is in the coal burned locally and showed the highest concentration of any single element. The highest "As" and "Ni" samples were selected because they are carcinogenic elements. The highest Pb sample was selected because it is a "heavy metal" that has an EPA 3-month NAAQS, and is of concern

because of adverse health effects (brain function) to children.

Source-type Selection

EPA provides a software program named "Speciation," version 1.4¹⁷, for pollutant load estimations. This program is used to determine the elemental composition of emissions from an industry or other source-type or when states need pollutant estimate loads for state pollutant inventories. The data base contains 363 emission elemental source profiles, classified in 23 source-type categories and 16 industry specific categories. The profile gives percent weight data for each element for four particle size ranges. The ranges are 0.0-2.5 μm , 0.0-6.0 μm , 0.0-10.0 μm , and total (0.0-30.0 μm). The number of constituents per profile are about 10 to over 45 depending on the source. Mass fractions for the first three size ranges are given. Source references and general information are given for each profile. Figure 12 is an example of an EPA Speciation data profile. The profile data base, giving source/source-type data, contains 14,560 one-line records in a D-base software format. The software program size is 1.3 megabytes.

The EPA data base,¹⁷ Speciation, has 363 sources and composite sources elemental emission composition profiles cataloged. Composite source profiles are a numerical average

of numerous individual source profiles. These profiles are a representative of a source-type and not a particular emission source's profile. Selection of EPA composites, i.e., source-types, were selected in preference of specific source profiles in hopes that the composites would be more representative of local sources. The selected composites were the Coal Power Plant Composite, Sewage Sludge Incineration Composite, Diesel Heavy Duty Transportation Composite, Unleaded Gas Light Duty Transportation Composite, Earth's Surface-Dust Composite, and Residential Wood Burning Composite. Several specific source profiles were selected when composite profiles were not available. These were: Aluminum Plant-Dross operation, Aluminum Plant-Potline operation, Limestone Kiln Process, Limestone Crustal-Gravel product, Cement Ball Mill operation, and Electric Arc Furnace operation. None of the selected sources or sources-types exhibited high sulfur concentrations as was observed in local samples, so a single element source-type, sulfate as ammonium sulfate ($(\text{NH}_4)_2\text{SO}_4$), was included to account for sulfur. In this case the origin of the ammonium sulfate would be sulfur dioxide emissions which are photochemically converted to ammonium sulfate or other sulfate aerosols in the atmosphere. Other unknown contributors may also be present but not accounted for. For this study the selected specific sources are to be regarded as source-types, like the composites, due to lack of specific source-type profiles.

Data Base Size

The size of the IBM-DOS text files of the samples' laboratory analyte profiles and the D-base files of the EPA emission source elemental composition profiles were very large. The 120 sample IBM-DOS text files totaled to 3.8 kilobytes and the principle 363 source D-base file was 1.3 megabytes. The data reduction of these files was performed with the software "Quattro Pro," version 3.0 and IBM compatible "386" personal computers with math coprocessors.

VI. SOURCE CONTRIBUTION MODELING

Method

Source contribution modeling is a procedure to estimate the relative quantities of different source-types that contribute to the particulate matter in the collected ambient air samples. The time and space factors in emissions dispersion from source to sampler are omitted by comparing the percent weight of each element in the source profile to the sampled values. This procedure identifies the prominent source-types by weighting the contribution of each individual source-type to the profile of elements found in each particulate matter sample. A composite elemental profile of the weighted source-types was analyzed using normal distribution differences to compare the two developed models and the baseline model's predicted values errors to each other and to the sample.

Source of Parameters

This study required the selection of the elements, samples, and source-types that was evaluated from a large data base. The eighteen relevant elements selected from the analyzing laboratory's 38 analytes were selected because of being associated in the coarse or fine fraction, common

elements in air monitoring, and toxicity. The samples were selected primarily because they were the highest concentrations of particulate matter or a particular element. Monitored area surveillance, observations, and personal interviews provided information to select possible source-types. An EPA data base of specific sources and source-types (composite profiles) provided source-type elemental percent weight data. Detailed information about these selections are given in the Chapter V of this thesis.

Estimating the Relative Contribution of Selected Source-types to the Elemental Composition of the Samples

In this study a simple ratio technique is used to estimate the contribution of each selected source-type to the elemental composition of the sample. A numerical illustration is given below to explain this technique.

Definition

Elemental profile step curve fitting - The fraction of one step curve contained in another comparable step curve is determined by dividing the corresponding non-zero components of the curves. For example, the percent weight of the aluminum in a sample B divided by the percent weight of the aluminum from a source A is an estimate of the contribution of

that source to the aluminum found in the sample. If the ratio is less than 1.0 then the ratio represents the fractional contribution of source A to the aluminum found in sample B. If the ratio is greater than 1.0, then some other source must be present to account for the aluminum found in sample B. This process is repeated for each element. The resulting minimum ratio is that maximum fraction that source A contributes to the particulate matter collected in sample B.

Illustration

Figures 13 and 14 are step curves that could represent source-type and sample elemental percent weight values, respectively. In this example, there is an excess of some elements in the sample indicating that the source A could not have accounted for that element in the sample B even if it had contributed 100 percent of the particulate matter. To find the maximum percent contribution of source A contained in sample B use the "step curve fitting" definition from above. A numerical illustration follows:

First, calculate the following fractions (%):

$$B_A/A_A = 7.7/5.5 \times 100\% = 140\%, \quad B_B/A_B = 6.2/8.0 \times 100\% = 77.5\%$$

$$B_C/A_C = 7.5/5.0 \times 100\% = 150\%, \quad B_D/A_D = 2.2/5.8 \times 100\% = 38.1\%$$

$$B_E/A_E = 9.9/2.5 \times 100\% = 396\%$$

Thirty-eight percent is the smallest percent fraction of the group, therefore, the maximum possible contribution of source A to sample B is 38 percent due to the "limiting element," D.

Source A can only contribute up to 38 percent of the total PM10 and only 38 percent of each elemental percent composition present in the source A profile of all the other elements. Elements present at higher percentages in the sample B than these adjusted source A values must be accounted for by some other source. For example, source A can only account for $0.38 \times 2.5 / 9.9 = .096$ (or 9.6 %) of element E; therefore there must be other sources that account for 90.4 percent of element E. This technique of estimating the contribution of each source to measured PM10 is called the "Limiting Element" model.

Assumptions

The collected ambient samples are assumed to comply to the same dispersion principles as source or receptor modeling. Their five basic assumptions are listed in Chapter II of this thesis. Because of different goals of this study, modification of these assumptions are as follows:

- 1) Compositions of source emissions are constant, i.e., processes and other parameters do not vary.

- 2) Components do not react with each other, i.e., they add linearly.
- 3) Only sources from area survey contribute to the receptor.
- 4) Compositions of all sources are linearly independent of each other.
- 5) Elemental composition of local sources is accurately represented by the elemental composition profiles given in the EPA "Speciation" data base.

It is not necessary for all of these assumptions to be completely true to obtain useful information about the sources contributing to local PM10 levels. Successful modeling depends on the model use and accuracy of the measurement data and representativeness of the source profiles.⁴ The methodology presented here is best viewed as a screening technique that sets the upper limits of each source-type contributing to PM10, rather than its' exact contribution.

Models' Differences

Three different models were used to estimate the percent contribution of each of eighteen source-types to measured PM10. These were called (1) the Limiting Element model, (2) the Combined Element model, and (3) the Equal Weight model. The Limiting Element model used the method described above to estimate the maximum contribution of each source-type. The

Combined Element model used the same percent contributions of the Limiting Element model for most of its factors. The other factors in the Combined Elements model were calculated from the sum of the maximum percent weight of all 18 elements times the maximum percent contribution for the limiting element and then divided by the sample's summed percent weight of all 18 elements, providing an alternate maximum estimate of the percent contribution of that source type to the PM10 measured in the sample. The "Combined Elements" model attempts to utilize the data for all 18 elements as a basis for estimating source contributions. Source contributions estimated using the Combined Element model are always less than or equal to the estimates obtained from the Limiting Element model. The Equal Weight model simply assumed that all 18 source-types contributed equally. Normal distribution difference analysis was used to determine which model predicted the measured data best.

Models' Results Table

General

Table 15, described later, is the principle table used to present the study's results. It contains the three models' results for the eight selected samples for comparison between samples and to show performance trends from modeling. The column headings (C to R) list the eight samples and column B

list the 13 selected source-types within their model groups, i.e., Limiting Element, Combined Element, and Equal Weight. In the column of each sample is listed the normal distribution difference results from the composite of the 13 source-types. Note that the Equal Weight model has the same value of 7.692 percent for all samples. For this model the weighting factor is equal for all source-types because all source-types are assumed to contribute equally. The inclusion of the Equal Weight model is to show the relative improvement of the Limiting Element and Combined Element models.

Description and Calculations

The Annual Average sample's complete (unabbreviated) data sheet (Tables 6A-E) is selected to explain the modeling of the thirteen source-types. Figures 15, 16, and 17 shows the percent weight levels for the source-types/composite vs. elements given in Table 6A for the Annual Average sample. The same selected source-types and elements were used in each sample modeled. Table 6A is for the Annual Average sample. The column headings list the elements and calculated items. Column B list the names of the sample, source-types, and their composite. Each model has one sample, 13 source-types, and 18 elements. Using the SEW SLUDGE source-type as an example, beneath its' row (17) of percent weights is listed a row (18) of percent contribution values calculated from the sample's percent weight of 0.1727 for C1 divided by SEW SLUDGE's

percent weight of 1.48 for C1. This is done for each element. Column V lists the maximum percent contribution for each source-type (these are the limiting element values - each row's minimum percent). Column W lists the limiting element that is related to the maximum percent contribution of the source-type. Column X lists the sum (row 8) of the sample's percent weight values row (cell X8 only) or lists the sum of the source-types percent weights row times the source's maximum percent contribution, i.e., column V. Column Y lists the source-type maximum percent contribution times the sum of the source-type percent weights divided by the sum of the sample's percent weights, i.e., source-types of column X divided by cell X8. Column Z lists the smaller of the columns V or Y for each source-type (these are the combined elements values). The composite profile is listed in row 51. Each elemental component of the composite is calculated by summing the products of a weighting factor times its source-type's percent weight for the 13 source-types for each column. The three source-type weighting factors are from the Limiting Element, Combined Element, and the Equal Weight models. These are show in Table 6B - Composites Weight Factors. Other Annual Average sample related tables are Table 6C - Models' Composites, Table 6D - Percent Difference, Table 6E - Percent Difference Statistics, and Table 6F - Selected Samples Elemental Profiles and Reference Data.

Model's Abbreviated Data Sheets

The Annual Average sample's data sheet matrix of elements and source-types was described above (Table 6A). The other seven selected samples would have the same matrix, but the elemental percent weights would be different. This would change the Limiting Element and Combined Elements models' results. Since the focus is on columns V to Z (Table 6A), it is only necessary to show those columns for the remaining samples on an abbreviated data sheet for each one. There are eight abbreviated data sheets and each contains four tables which give details for each sample. This group of data sheets contains Tables 7 to 14. Tables 7A, 7B, 7C, and 7D are abbreviated forms of Tables 6A, 6B, 6C, and 6E. The remaining tables, i.e., Tables 8 to 14, can be expanded to the same forms as Table 6.

Element Percent Weights

The selected samples are listed in Table 6F. The values for row eight in Table 6A comes from this table. Each sample has 18 elements that compose its elemental profile. The samples' percent weights given in the table are for PM10 or total particulate (coarse plus fine elemental fractions). In this table carbon is estimated as 20 percent for all samples and is the largest percentage of all elements in all samples. Carbon was estimated from a later study in August, 1992

described in Chapter IV. Sulfur (besides carbon) is the element with the largest percent weights for seven of the eight selected samples. Nickel is the element with the smallest percent weight in six out of the eight samples. Cadmium, a carcinogen like nickel, is the other element with the smallest percent weight in two out of the eight samples.

Source Contribution Variations

The "Assumptions" section above states principles that are necessary for this methodology to work, i.e., variations should not occur in these areas. Variation in the contribution to the sample can occur for several reasons. One variation in the source's elemental composition profile can occur from some operational procedures being varied in the process of the emission source. The procedure variation may cause some relative elemental quantities to increase or decrease in the source's emissions. A variation in the materials used in a process can also cause source emissions variation altering an emission source's recognizable contribution to a sample.

Another type of variation can result from meteorological conditions varying. For longer periods of time that the wind direction is from the source to the receptor, more emission source particulate will be accumulated on the sample. This variation would determine how much the elemental constituents

in the emission source would be above background or other emission sources. An emission source may not be identified if some of its characteristic elemental constituents are below detection limits. Calm or high wind conditions cause variations in the particle size collected. Soil, storage pile, and haul road conditions can increase the coarse fraction's collection on a sample. Fine particulate can accumulate to a limited degree on coarse particulate and settle out. This could alter the emission source's characteristic elemental profile making it unrecognizable.

Compounds can be made from emission source elements while in transport due to atmospheric reactions. Some of the compounds can be seasonal, e.g., photochemical bonding occurs much greater in the summer and on the sunny days. The variation concern here is that compounds could be too large for collection, i.e., greater than 10 microns or may settle out before transporting to the receptor, modifying the emission source's elemental composition profile.

Seasonal variations can be seen in source contributions to samples from anthropogenic activities, e.g., field or slash burning in the summer and residential heating in the winter by wood or coal. Other examples are forest fires, natural or arson, that occur at summer's end in many cases. It is not uncommon for a million tourists (mobile emissions) to visit the Great Smoky Mountain National Park primarily through the summer.

VII. RESULTS

Selected Sources and Samples

The maximum percent contribution of selected source-types to selected samples are listed in Table 15. This table shows the Limiting Element, the Combined Elements, and the Equal Weight models. Each model has eight columns of selected samples and 13 rows of source-types. The eight selected samples have the highest annual fraction/concentration or average as described by their name. They are High Coarse Fraction (High CF), High Fine Fraction (High FF), High Particulate Matter ≤ 10 micron (High PM10), High Sulfur (High "S"), High Arsenic (High "As"), High Nickel Coarse Fraction (Hi-Ni-Crs), High Lead Fine Fraction (Hi-Pb-Fin), and Annual Average. The Annual Average sample is a calculated average concentration for each of the 38 analytes for the 120 sample days. The thirteen source-types are Sulfate as ammonium sulfate (SULFATE), Coal Power Plant Composite (COAL-PWR), Sewage Sludge Incineration Composite (SEW SLUDGE), Diesel Heavy Duty Transportation Composite (DIESEL FUEL), Unleaded Gas Light Duty Transportation Composite (GASOLN FUEL), Earth's Surface Composite (DUST-EROSN), Aluminum Plant-Dross operation (ALUM-DROSS), Aluminum Plant-Potline operation (ALUM-POTLIN), Limestone Kiln Process (LIME KILN), Limestone Crustal-Gravel product (GRAVEL ROAD), Cement Ball Mill operation (CEM BAL

MIL), Electric Arc Furnace operation (ELEC ARC FN), and Residential Wood Burning Composite (WOOD BURNNG).

Model's Normal Distribution Difference

The normal distribution difference was determined for the Limiting Element, Combined Elements, and Equal Weight models for each selected sample. The percent difference was calculated between the measured and predicted concentration of each of the 18 elements in each sample. The arithmetic mean of these differences is reported as the "mean" value. Also reported are the standard deviation, the median, the maximum and the minimum difference. A positive percent difference in the tables indicate an average over prediction of the elemental composition of the sample by the models, a negative percent difference indicated under prediction. The percent difference statistics are given in Tables 7C to 14C. The Limiting Element model showed an average difference of 70 percent for eight samples with a range of 51 to 115 percent. The Combined Elements model an average of 59 percent for eight samples with a range of 35 to 101 percent. The Equal Weight model showed an average difference of 1236 percent for eight samples with a range 552 to 3728 percent.

The Limiting Element, and Combined Elements models are comparable to one another since most of the Limiting Element maximum percent contributions are in the Combined Elements

model also. The Equal Weight model's percent difference ranges average seventeen times larger than the other models. The Equal Weight model is the baseline model and the other models show considerably less error in their predictions of the samples' percent weights.

Even though the Combined Elements model performance was somewhat better than the Limiting element model, the Combined Elements model was simpler and easier to understand. Because of the higher confidence in the results from the Combined Element model, only results from the Limiting Element model are discussed in detail in this report.

Limiting Element Model Results

Interpretation of Samples

High Coarse Fraction Sample. This sample was collected March 13, 1991. The wind direction was from the West for about five hours, but it is typically in the northeast or southwest directions. An hourly average up to 18 miles per hour was measured during this period. More than thirty-eight percent, the largest percent, was attributed to the DUST-EROSN source-type. For high wind days a soil source-type is expected to be a major contributor to the coarse fraction of an ambient sample. The coarse fraction was 0.729 for this sample.

High Fine Fraction Sample. This sample was collected December 7, 1990. Besides carbon from the DIESEL-FUEL source-type, calcium from the GRAVEL ROAD source-type had the next highest concentration level. Sulfur from the SULFATE source-type was the third highest. Sulfur, calcium, and carbon can be indicators of a high temperature source. The fine fraction of 0.776 indicates that this sample is high temperature source emissions.

High Particulate Matter (PM10) Sample. This sample was collected December 28, 1990. This sample's concentration was $50.2 \mu\text{g}/\text{m}^3$. Its coarse fraction is 0.785. When compared to the High FF and the High CF samples its calcium, sulfur, carbon and aluminum levels are quite smaller. It appears that this sample has a large concentration in the PM10 that was unidentified in the laboratory analysis. The laboratory did not report carbon content which may account for the difference if the air contained a lot of soot from fuel burning. The high coarse fraction indicates that this sample probably is of the natural or mechanically-made origin.

High Sulfur Sample. This sample was collected July 31, 1991. The SULFATE source-type was the major contributor. Source-types DIESEL FUEL, WOOD BURNING, and SULFATE would be expected to be large contributors of sulfur to the sample since sulfur is a major component in organic combustion such

as sulfur dioxide from coal burning boilers. The GRAVEL ROAD and CEM BAL MIL source-types have high contributions (25 to 33 %) to the samples due to calcium and nickel. Nickel is the limiting element in seven of the 13 source-types. This appears to be a definite high temperature source emissions.

High Arsenic Sample. This sample was collected October 17, 1990. It attributes the maximum percent of 81.288 to the SULFATE source-type. Coal burning is also known to contribute to arsenic emissions. Second only to the High CF sample, it has the highest silicon limited maximum percent attribution to the DUST-EROSN source-type. Aluminum and calcium are also very high. These three elements are typical soil components.

High Nickel Coarse Fraction Sample. This sample was collected November 28, 1990. Sulfur and carbon account for most of the PM10. This sample showed the second highest potential contribution of the eight samples due to sulfur dioxide emissions, probably attributed to coal burning. Wood burning and diesel emission both contribute carbon and are indistinguishable. Its coarse fraction is 0.649, which is surprisingly high if the sources are primarily from combustion.

High Lead Fine Fraction Sample. This sample was collected on November 13, 1990. Its maximum percent attributions are to source-types WOOD BURNNG, DIESEL FUEL, SULFATE, and GRAVEL ROAD. Besides the High FF sample, this sample attributes the second highest percent of 1.545 to the SEW SLUDGE sample. Besides the High FF sample, it attributes the second highest percent of 1.694 to the ALUM-DROSS source-type.

Annual Average Sample. This sample was not collected, but was calculated as an average of the year of data from all samples elemental concentrations for the 13 selected elements. The sample is a characteristic representative of the annual sample data set. The annual NAASQ concentration is $50 \mu\text{g}/\text{m}^3$ and this sample's annual concentration is $24.3 \mu\text{g}/\text{m}^3$. Elements aluminum, chlorine, and carbon are limiting elements for two source-types each. This means that the source-types pairs, COAL-PWR/ALUM-POTLIN, DIESEL FUEL/WOOD BURNNG, ALUM-DROSS/LIME-KILN, and GRAVEL ROAD/CEM BAL MIL cannot both contribute 100 percent to the sample. This sample attributes 37.191, 34.542, 6.6, and 6.6 percents to the SULFATE, WOOD BURNNG or DIESEL FUEL ALUM-DROSS/LIME KILN, and GRAVEL ROAD/CEM BAL MIL source-types, respectively, as the major source-types. The minimum percent of 0.289 is attributed to the ELEC ARC FN source-type.

Interpretation of Source-types

Sulfate Source. The source SULFATE could originate from various coal sources as sulfur dioxide gas is converted to ammonium sulfate and other sulfates during dispersion from the source. This source's percent weight is 33 percent and is determined from its compound formula. Since sulfur is the only element in the profile, it is the limiting element, but it is of interest that the highest maximum percent contribution, i.e., 81.288 percent, occurs in the High "As" sample. EPA lists arsenic as a tracer element for coal sources.¹⁸ Also, for this source the second highest value of all contributions is 66.156 percent, and it occurs in the High "S" sample, a characteristic element in coal burning.

Coal Fired Power Plant Source. The COAL-PWR source has a maximum percent contribution of 15.829 percent occurring in the High "As" sample as did the SULFATE source above but the limiting element is Aluminum. Aluminum and silicon are two principle elemental components in typical coal power plant emissions. The High FF sample is indicative of high temperature sources. This source has an annual average maximum contribution of 5.526 percent and is nearly equal to the High FF sample's value of 5.346 percent. Both samples have aluminum as their limiting element. A high coarse fraction sample is indicative of a mechanical or natural

source origin. An unexpected value of 10.523 percent for High CF and 10.881 percent for Hi-Ni-Crs from this high temperature source may be explained by deposition or "washing out" of fine fraction particles on to coarse particles which are then re-entrained and collected on coarse particulate even though they originated from a high temperature source.⁵

Sewage Sludge Source. The SEW SLUDGE source is limited by lead in five of the eight samples. The largest maximum percent contribution of 1.581 percent is in the High FF sample, a high temperature source indicator. Lead is a "heavy metal" that is of medical concern and has an NAAQS of 1.5 $\mu\text{g}/\text{m}^3$ for a 3 month period.¹⁹

Diesel Fuel Source. For the Annual Average, High CF, High FF, and Hi-Pb-Fin samples the contribution by this source is 22.753 percent and carbon is the limiting element. This occurs because an estimated low value for the samples' carbon percent weight is used and the variation between samples is unknown. Another interesting point here is that the High "S" sample has the second highest percent contribution of 22.599 percent from the DIESEL FUEL source and its limiting element is nickel. Also, the High PM10 sample has a value of 11.288 percent. with an limiting element of nickel. For these two cases their concentrations are less than laboratory uncertainty limits. This results in the element nickel being

the limiting element with the lowest percent contribution to the sample. Nickel and vanadium have been used by other investigators as tracers for oil burning sources.¹⁸

Gasoline Fuel Source. This source is a composite of unleaded gasoline fuels. Bromine is the limiting element for seven of the eight samples. In leaded gasolines bromine and lead were tracers for that source-type.¹⁸ This data shows that bromine, a scavenger for lead in leaded gasoline, has not been eliminated but exists at minimal levels. This source's highest percent contribution in the High "As" sample was 9.595 percent.

Dust-Erosion Source. This source's highest percent contribution was 38.473 percent to the High CF sample and it has manganese as its limiting element. The High CF sample's day had high winds, i.e., up to 18 mph. As a natural source, it is expected to have a high concentration in the coarse fraction as this sample does. Soil erosion sources have tracer elements of Al, Si, Ca, Mn, Ti, and Fe. Al, Si, and Mn are the limiting elements for seven of the selected sources.

For the annual average sample this source would have the highest contribution except for the sources with elements sulfur and carbon as limiting elements. These last elements' percent weights are "estimated" items for a source-type and a sample, respectively. This source should have a significant

impact on this site since there are no point sources immediately upwind to the site and this source can be considered a low-level emitter (proportional to the wind speed) and a 24-hour contributor.

It is noticeable that the High PM10 sample had the lowest percent contribution from this source. Inspection of the High PM10 sample's fraction concentrations shows that the coarse fraction concentration was almost four times that of the fine concentration and that the coarse elemental concentrations were generally in the same magnitude as the fine elemental concentrations. This indicates that there is a large unidentified component in the coarse fraction and that component was not a soil erosion source, i.e., Si has only 0.479 percent (from Tables 7A and 7F) maximum contribution to the sample.

Aluminum-Dross Source. This source has chlorine as its limiting element in all of the samples. Chlorine and sodium are tracer elements for a marine source (ocean).¹⁸ The samples High CF and High FF have near equal percent contribution, i.e., 1.176 and 1.581, respectively, from this source and this implies that this source may be more related to background or residual particulate matter. There is an aluminum plant in the sampling area, but usually is not upwind to the site and its contribution would be minimal.

Aluminum-Potline Source. This source has aluminum as the limiting element in six of the eight samples. The largest percent contribution of this source is to sample High CF with a value of 25.810 percent. This percent contribution is almost three times larger than the next sample, i.e., Hi-Ni-Crs' percent of 8.913 percent. The High CF sample's day had high winds, i.e., up to 18 mph. The soil erosion source is the major contributor on that day and the element aluminum is a principle component in that source.

Lime Kiln Source. This source had its highest maximum percent contribution of 16.729 percent to sample Hi-Ni-Crs, the seventh (out of 120 days) "cleanest" day of the year, i.e., PM10 concentration of $8.3 \mu\text{g}/\text{m}^3$. Nickel and chlorine are the only two limiting elements for all eight samples.

Gravel Road Source. This source, i.e., crushed limestone, has calcium as its limiting element for seven of its eight samples. This indicates that calcium is very high in percent weight relative to the other elements in this source. Its highest maximum percent contribution is 33.898 percent and its limiting element is nickel. This source should be a major contributor to the site's samples since it is upwind to the sampler for half of the sampling time, i.e., diurnal periods.

Cement Ball Mill Source. This source is almost the same as the Gravel Road source. It has calcium as the limiting element for the eight samples and its maximum percent contribution is 25.554. These two sources should be regarded as a single source (original assumption) since double counting of seven of the eight samples is likely to be occurring. It is interesting to note that the Gravel Road source values are about 50 percent higher than this source for the eight samples.

Electric Arc Furnace Source. This source had very low maximum percent contributions for the eight samples. Its highest value was 0.456 percent with manganese as its limiting element. This sample has the lowest Annual Average of 0.289 percent. This source is 30 to 40° northwest of the diurnal wind pattern and may show up occasionally in some other samples' concentrations not selected.

Wood Burning Source. This source has the highest percent contribution of 34.542 percent to the Annual Average sample and it has carbon as its limiting element for all eight samples. The major elements in this source are carbon, sulfur, chlorine, and potassium for the selected elements from Table 6A. Carbon and sulfur are expected as products from the combustion of organic materials. Carbon-14 and potassium are listed by EPA as tracer elements for wood burning.¹⁸ In all

samples the amount of the carbon element has been estimated and the same amount was inputed for all selected samples. For the monitored area wood burning by homes is a common practice for heating. Hogged wood fuel at wood products manufacturing industries is another source for this source-type. Forests and field burning may be another wood source-type in the summer months.

VIII.CONCLUSION

The thirteen source-types selected for this study were Sulfate as ammonium sulfate, Coal Power Plant Composite, Sewage Sludge Incineration Composite, Diesel Heavy Duty Transportation Composite, Unleaded Gas Light Duty Transportation Composite, Earth's Surface-Dust Composite, Aluminum Plant-Dross, Aluminum Plant-Potline, Limestone Kiln Process, Limestone Crustal-Gravel, Cement Ball Mill, Electric Arc Furnace, and Residential Wood Burning Composite. The eight 24-hour PM10 samples selected were High Coarse Fraction, High Fine Fraction, High Particulate Matter (PM10), High Sulfur, High Arsenic, High Nickel Coarse Fraction, High Lead Fine Fraction, and Annual Average. The eighteen elements selected were aluminum, silicon, carbon, sulfur, chlorine, potassium, calcium, titanium, chrome, manganese, iron, nickel, copper, zinc, arsenic, bromine, cadmium, and lead.

Three different models were used to estimate the percent contribution of each of eighteen source-types to measured PM10. These were called (1) the Limiting Element model, (2) the Combined Element model, and (3) the Equal Weight model.

Based on the results of the Limiting Element model, the top four major contributors to the Annual Average sample are sulfate from sulfur dioxide emissions (sulfur limited), wood burning sources (carbon limited), diesel fuel burning sources (carbon limited), and soil (silicon limited). The maximum

percent contributions of these source-types to the Annual Average sample are 37.191, 34.542, 22.753, and 8.118 percents, respectively. The wood burning and diesel fuel source-types are limited by the same element of carbon and should be considered as one source-type since double counting of carbon's mass probably occurs. As a one source-type, 22.753 percent would be the maximum percent contribution to the sample (carbon limited), i.e., the smaller of the double counted source-types.

The two minimum contributors to the Annual Average sample are aluminum plant-dross operation (chlorine limited) and electric arc furnace (manganese limited). Their maximum percent contributions to the sample are 0.764 and 0.289 percent, respectively. These were surprising results as there are both an electric arc furnace and an aluminum plant in the area. These two source-types are not in the prevailing upwind direction from the monitoring station which may account for their having only minimal contributions to the ambient samples.

There are three source-types where the limiting elements are the same for all eight samples. Sulfur is the limiting element for the sulfate source-type (sulfur dioxide from coal burning). Chlorine is the limiting element for the aluminum dross source-type. Calcium is the limiting element for the gravel road source-type. This study did not analyze for carbon in the samples. Carbon values from a different study, but the

same site, are used for estimating carbon levels in this study's samples. These estimated carbon levels were the limiting element in several source-types. Carbon should be reported in a study of ambient air monitoring since it could be a major contributor to all atmospheric samples. In this study carbon analysis could have made the results more relevant. Non-carbon containing filters would need to be used instead of PTFE teflon filters.

Without knowing the time and distance that relates to each source-type, this procedure indicates probable relative levels of major source-types contributions to PM10 samples when general knowledge of area industries and natural source-types is known. This procedure should be classified as a screening technique due to its ability to estimate only the maximum (or upper limit) percent contribution of each source and not the exact percent contribution of each source.

IX. RECOMMENDED FUTURE RESEARCH DIRECTIONS

Unit Cancer Risk (UCR) estimates were calculated using the IP elemental analysis of Cr, As, Cd, and Ni and EPA's unit risk factors. The UCR calculated is 19×10^{-6} which is higher than is expected. The UCR might be different if a more accurate value for Cr(VI) were known, since it was estimated as 15 percent of the measured total Cr. Cadmium measurement methods used should have had a lower detection limit to increase the confidence level. Its contribution to the total UCR was 8.6×10^{-6} . The Cr and As carcinogenic species should be studied in more detail to determine representative concentrations of Cr(VI) and As(III) in this area.

The post-study decision to identify the source contributors to the ambient samples limited this study to a screening procedure. Other procedures that would have allowed detailed source identification are to use a different filter medium to analyze for carbon, i.e., PTFE teflon membrane filters contain carbon, to collect meteorological data and the particulate matter samples on the same time interval, to use other sites for simultaneous particulate matter sampling and meteorological data collection, and to use actual source emission samples from the monitored area instead of the EPA emission source data base profiles.

LIST OF REFERENCES

LIST OF REFERENCES

1. **Monitoring and Data Analysis Div.: Receptor Model Technical Series - Overview of Receptor Model Application to Particulate Source Apportionment**, (EPA/450/4-81-016a), U.S. Environmental Protection Agency, Research Triangle Park, 1981, pp 1-13.
2. **Gordon, Glen E.: Critical Review - Receptor Models. Environmental Science Technology 22 (10): pp 1132-1142 (1988).**
3. **Zanetti, Paolo: Air Pollution Modeling.** Boston, Massachusetts: Vanoststrand-Reinhold Pub., 1990, p. 317.
4. **Watson, John G.: Overview of Receptor Model Principles, Air Pollution Control Association 34 (6): pp 619-623 (1984).**
5. **Schroeder, W.H., M. Dobson, D.M. Kane, and N.D. Johnson: Toxic Trace Elements Associated with Airborne Particulate Matter: A Review, Air Pollution Control Association 37 (11): 1267 (1987).**
6. **Miller, G. Tyler, Jr.: Living In The Environment.** California: Wadsworth Publishing Co., 1990. p. 500.
7. **Spengler, J.D. and Thurston, G.D.: Mass and Elemental Composition of Fine and Coarse Particles in Six U.S. Cities, J. Air Pollution Control Assoc. 33 (12): 1162 (1983).**
8. **Tennessee Valley Authority: "Air to Water Impacts Program-Project Plan FY 1991." by N.T. Lee, B.L. Barnard, and W.J. Parkhurst, Tennessee Valley Authority, Muscle Shoals, Ala., 1990. [Plan].**
9. **Benjamin, R.J., T.L. Miller, and W.J. Parkhurst: "Particulate Toxic Trace Element Measurements in Tennessee." Paper (92-77.07) presented at the Air and Waste Management Association, Kansas City, Mo., June, 1992.**
10. **Purghart, B.C. Galli, U.P. Nyffeler, P.W. Schindler, W.A. Van Borm and F.C. Adams: Metals in Airborne Particulate Matter in Rural Switzerland. Atmospheric Environment 24A (8): 2191 (1990).**
11. **Whitby, R., D.E. Gower, and E.W. Savoie: "Ambient Atmospheric Concentrations of Toxic Metal and Toxic Organic Species in New York State Urban Environments," in Proceedings of the 1986 EPA/APCA Symposium on Measurement**

- of Toxic Air Pollutants, VIP-7, Air Pollution Control Association, Pittsburgh, 1986, pp 554-573.
12. **Lodge, J.P., Jr., ed: *Methods of Air Sampling and Analysis*. 3rd ed., Chelsea, Lewis Publishers, Inc., 1989, p 635.**
 13. **Air Risk Information Support Center: *Glossary of Terms Related to Health, Exposure, and Risk Assessment*, (EPA/450/3-88/016), U.S. Environmental Protection Agency, Research Triangle Park, 1989, pp 15-16.**
 14. **"Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities," *Code of Federal Regulations Title 40, Ch. I (7-1-91)*, Part 266, 1991, pp. 468, 484.**
 15. **Falerios, M., Schild K., Sheehan, P., et al: Airborne Concentrations of Trivalent and Hexavalent Chromium from Contaminated Soils at Unpaved and Partially Paved Commercial /Industrial Sites, *J. Air Waste Manage. Assoc.* 42 (1): 40 (1992).**
 16. **M. Lee Smith Publishers & Printers: *1991 Directory of Tennessee Manufacturers*. Nashville, Tenn.: M. Lee Smith Publishers & Printers, 1991.**
 17. **Radian Corporation: *Speciate*, [Computer Software]. Environmental Protection Agency. October, 1991.**
 18. **U.S. Environmental Protection Agency: *Receptor Model Source Composition Library*, (EPA-450/4-85-002), Research Triangle Park, 1984, p. 13.**
 19. **"National Primary and Secondary Ambient Air Quality Standards." *Code of Federal Regulations Title 40, Pt. 50.6*. 1992. pp.698-699.**
 20. **Parkhurst, W.J., B.L. Barnard, and N.T. Lee: "Atmospheric Measurements of Polychlorinated Biphenyls, Dioxins, and Furans near Knoxville, Tennessee." Paper (92-69.08) presented at the Air and Waste Management Association, Kansas City, Mo., June, 1992.**
 21. **Parkhurst, W.J., and B.L. Barnard: "Fort Loudon Lake Toxics Mass Balance Study." Paper (93-WA-73.07) presented at the Air and Waste Management Association, Denver, Colorado, June, 1993.**

APPENDIXES

APPENDIX A. Figures

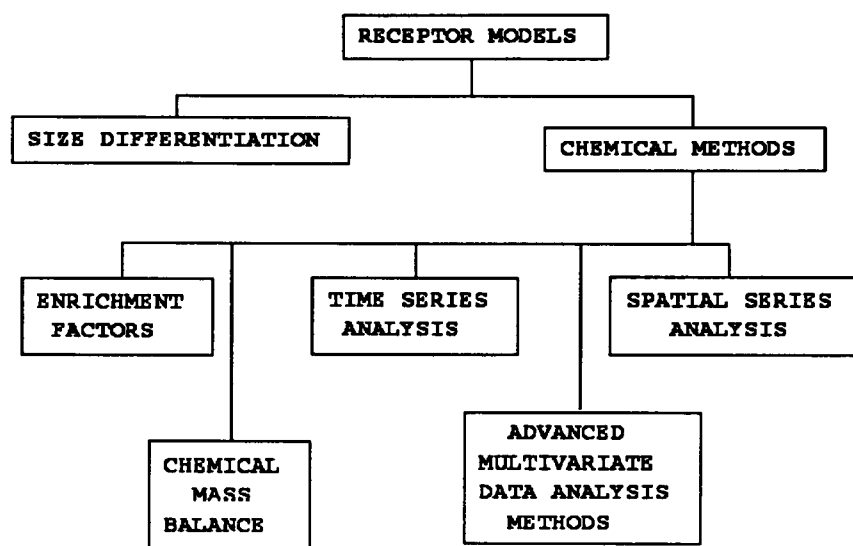


Figure 1. Receptor model types.

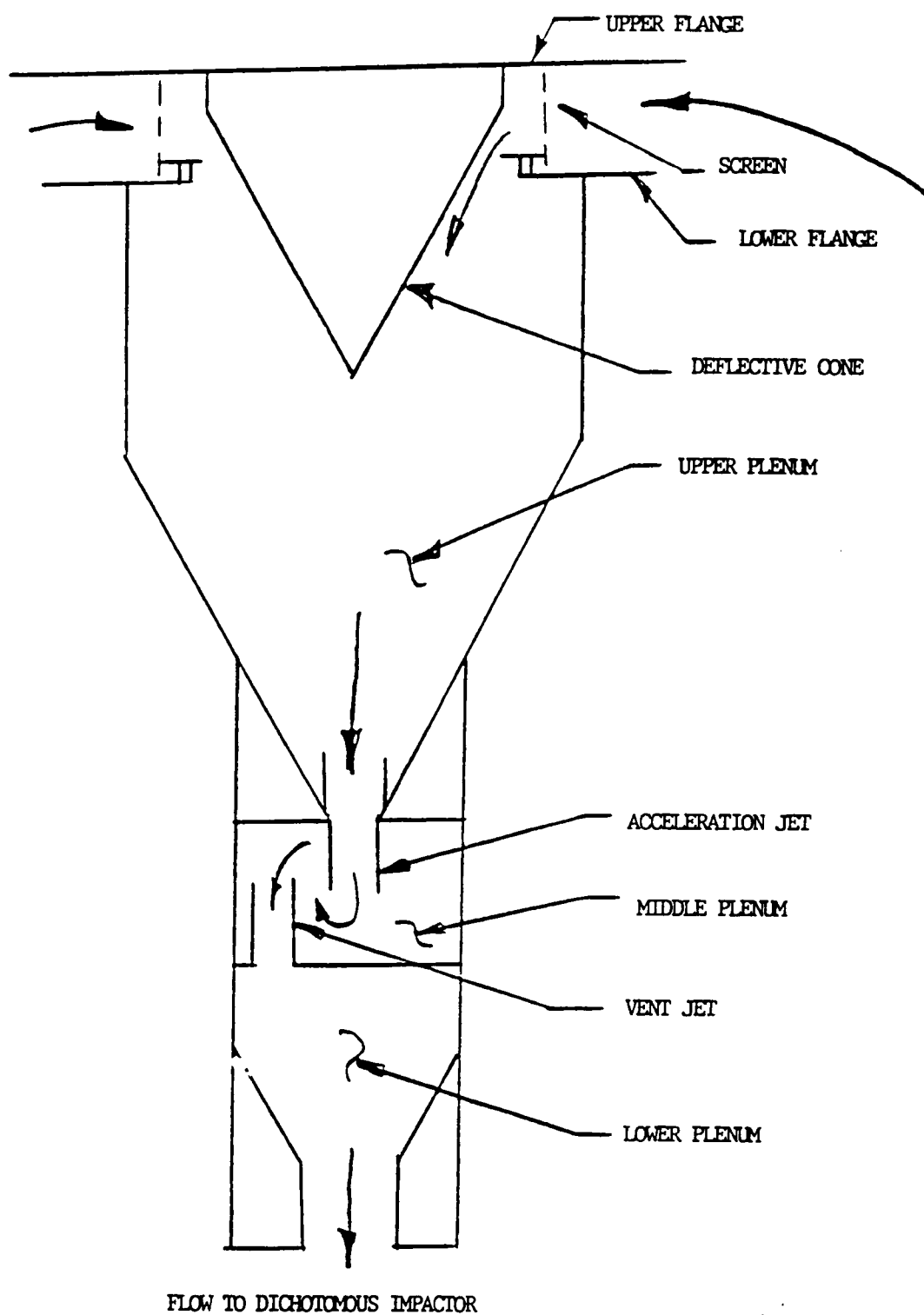


Figure 2. Anderson sampler aerosol inlet.

PRINCIPLE OF OPERATION OF VIRTUAL IMPACTOR

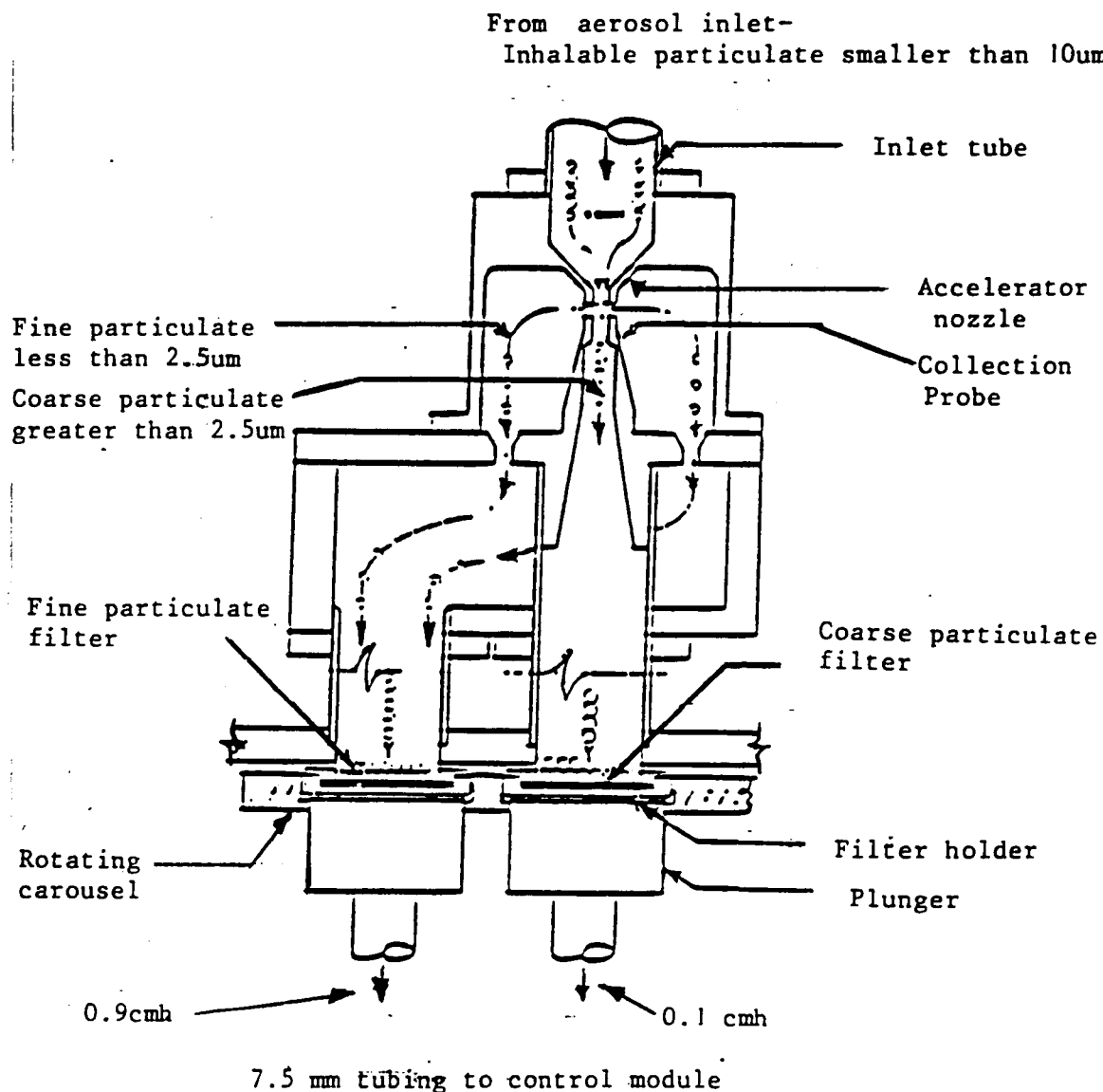


Figure 3. Anderson sampler aerosol virtual impactor.

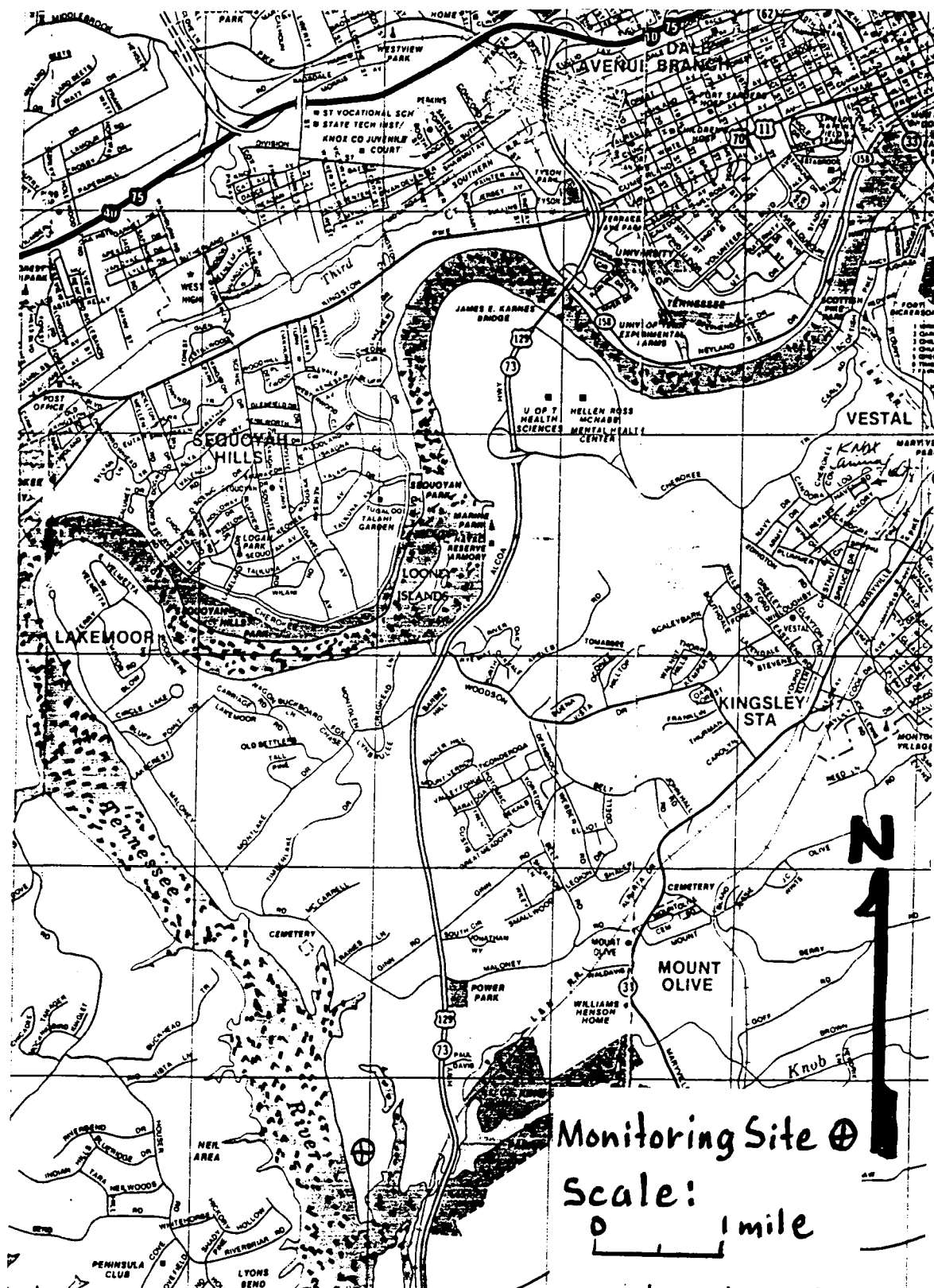


Figure 4. Monitoring site map.

Client: Tennessee Valley Authority Project Number: 307/01
Report Date: 1/10/91 Date Received: 11/30/90
NEA ID: 90-T451 Client ID: CW 9/11/90
Site: Sample Date: 9/11/90
Exposed Area: 6.60 cm2 Deposit Mass: 320.+ 10. ug
Volume of Air Sampled: 20.31 +- 2.031 m3
Suspended Particulates (C): 15.76 +- 1.651 ug/m3

Element	ug/filter	percent	ug/m3
Al	5.1420 +- 0.7029	1.6070 +- 0.2253	0.2532 +- 0.0429
Si	17.9900 +- 2.3830	5.6220 +- 0.7650	0.8858 +- 0.1470
P	0.0000 +- 0.0396	0.0000 +- 0.0124	0.0000 +- 0.0020
S	15.1600 +- 1.7070	4.7380 +- 0.5535	0.7464 +- 0.1124
Cl	0.0000 +- 0.1201	0.0000 +- 0.0375	0.0000 +- 0.0059
K	3.0710 +- 0.3472	0.9597 +- 0.1126	0.1512 +- 0.0228
Ca	29.3900 +- 3.2880	9.1840 +- 1.0670	1.4470 +- 0.2171
Ti	0.7696 +- 0.0429	0.2405 +- 0.0154	0.0379 +- 0.0043
V	0.0178 +- 0.0119	0.0056 +- 0.0037	0.0009 +- 0.0006
Cr	0.0429 +- 0.0073	0.0134 +- 0.0023	0.0021 +- 0.0004
Mn	0.2204 +- 0.0145	0.0689 +- 0.0050	0.0109 +- 0.0013
Fe	11.8400 +- 0.5953	3.7000 +- 0.2190	0.5830 +- 0.0653
Ni	0.0000 +- 0.0073	0.0000 +- 0.0023	0.0000 +- 0.0004
Cu	0.3089 +- 0.0185	0.0965 +- 0.0065	0.0152 +- 0.0018
Zn	0.1551 +- 0.0112	0.0485 +- 0.0038	0.0076 +- 0.0009
Ga	0.0000 +- 0.0046	0.0000 +- 0.0014	0.0000 +- 0.0002
Ge	0.0000 +- 0.0040	0.0000 +- 0.0012	0.0000 +- 0.0002
As	0.0000 +- 0.0119	0.0000 +- 0.0037	0.0000 +- 0.0006
Se	0.0000 +- 0.0046	0.0000 +- 0.0014	0.0000 +- 0.0002
Br	0.0191 +- 0.0053	0.0060 +- 0.0017	0.0009 +- 0.0003
Rb	0.0099 +- 0.0066	0.0031 +- 0.0021	0.0005 +- 0.0003
Sr	0.0442 +- 0.0086	0.0138 +- 0.0027	0.0022 +- 0.0005
Y	0.0000 +- 0.0099	0.0000 +- 0.0031	0.0000 +- 0.0005
Zr	0.0264 +- 0.0132	0.0082 +- 0.0041	0.0013 +- 0.0007
Mo	0.0152 +- 0.0165	0.0047 +- 0.0052	0.0007 +- 0.0008
Pd	0.0000 +- 0.0455	0.0000 +- 0.0142	0.0000 +- 0.0022
Ag	0.0125 +- 0.0601	0.0039 +- 0.0188	0.0006 +- 0.0030
Cd	0.0033 +- 0.0693	0.0010 +- 0.0217	0.0002 +- 0.0034
In	0.0000 +- 0.0818	0.0000 +- 0.0256	0.0000 +- 0.0040
Sn	0.0370 +- 0.0990	0.0116 +- 0.0309	0.0018 +- 0.0049
Sb	0.0000 +- 0.1267	0.0000 +- 0.0396	0.0000 +- 0.0062
Ba	0.0000 +- 0.4620	0.0000 +- 0.1444	0.0000 +- 0.0227
La	0.0000 +- 0.6230	0.0000 +- 0.1947	0.0000 +- 0.0307
Hg	0.0000 +- 0.0073	0.0000 +- 0.0023	0.0000 +- 0.0004
Pb	0.0356 +- 0.0198	0.0111 +- 0.0062	0.0018 +- 0.0010
NO3	8.0000 +- 0.8000	2.5000 +- 0.2600	0.3900 +- 0.0600
PO4	0.0000 +- 2.0000	0.0000 +- 0.6200	0.0000 +- 0.1000
Be	0.0000 +- 0.3800	0.0000 +- 0.1190	0.0000 +- 0.0190

Figure 5. Laboratory coarse results sheet.

Client: Tennessee Valley Authority Project Number: 307/01
Report Date: 1/10/91 Date Received: 11/30/90
NEA ID: 90-T452 Client ID: FY 9/11/90
Site: Sample Date: 9/11/90
Exposed Area: 6.60 cm2 Deposit Mass: 470.+- 10. ug
Volume of Air Sampled: 20.31 +- 2.031 m3
Suspended Particulates (F): 23.14 +- 2.366 ug/m3

Element	ug/filter	percent	ug/m3
Al	0.6217 +- 0.1115	0.1323 +- 0.0239	0.0306 +- 0.0063
Si	1.1110 +- 0.1564	0.2365 +- 0.0337	0.0547 +- 0.0094
P	0.0000 +- 0.0482	0.0000 +- 0.0103	0.0000 +- 0.0024
S	80.3900 +- 8.9960	17.1000 +- 1.9480	3.9580 +- 0.5940
Cl	0.0000 +- 0.5333	0.0000 +- 0.1135	0.0000 +- 0.0263
K	1.3640 +- 0.1564	0.2903 +- 0.0338	0.0672 +- 0.0102
Ca	1.4100 +- 0.1604	0.2999 +- 0.0347	0.0694 +- 0.0105
Ti	0.1148 +- 0.0106	0.0244 +- 0.0023	0.0057 +- 0.0008
V	0.0033 +- 0.0059	0.0007 +- 0.0013	0.0002 +- 0.0003
Cr	0.0482 +- 0.0059	0.0103 +- 0.0013	0.0024 +- 0.0004
Mn	0.0581 +- 0.0073	0.0124 +- 0.0016	0.0029 +- 0.0005
Fe	3.3510 +- 0.1716	0.7129 +- 0.0395	0.1650 +- 0.0185
Ni	0.0158 +- 0.0059	0.0034 +- 0.0013	0.0008 +- 0.0003
Cu	0.1709 +- 0.0119	0.0364 +- 0.0026	0.0084 +- 0.0010
Zn	0.2693 +- 0.0165	0.0573 +- 0.0037	0.0133 +- 0.0016
Ga	0.0000 +- 0.0046	0.0000 +- 0.0010	0.0000 +- 0.0002
Ge	0.0079 +- 0.0040	0.0017 +- 0.0008	0.0004 +- 0.0002
As	0.0112 +- 0.0132	0.0024 +- 0.0028	0.0006 +- 0.0007
Se	0.0046 +- 0.0046	0.0010 +- 0.0010	0.0002 +- 0.0002
Br	0.0462 +- 0.0066	0.0098 +- 0.0014	0.0023 +- 0.0004
Rb	0.0000 +- 0.0073	0.0000 +- 0.0015	0.0000 +- 0.0004
Sr	0.0000 +- 0.0086	0.0000 +- 0.0018	0.0000 +- 0.0004
Y	0.0000 +- 0.0099	0.0000 +- 0.0021	0.0000 +- 0.0005
Zr	0.0066 +- 0.0125	0.0014 +- 0.0027	0.0003 +- 0.0006
Mo	0.0106 +- 0.0172	0.0022 +- 0.0037	0.0005 +- 0.0008
Pd	0.0495 +- 0.0442	0.0105 +- 0.0094	0.0024 +- 0.0022
Ag	0.0000 +- 0.0554	0.0000 +- 0.0118	0.0000 +- 0.0027
Cd	0.0733 +- 0.0706	0.0156 +- 0.0150	0.0036 +- 0.0035
In	0.0000 +- 0.0851	0.0000 +- 0.0181	0.0000 +- 0.0042
Sn	0.0020 +- 0.1043	0.0004 +- 0.0222	0.0001 +- 0.0051
Sb	0.0000 +- 0.1327	0.0000 +- 0.0282	0.0000 +- 0.0065
Ba	0.0000 +- 0.4792	0.0000 +- 0.1019	0.0000 +- 0.0236
La	0.0000 +- 0.6501	0.0000 +- 0.1383	0.0000 +- 0.0320
Hg	0.0000 +- 0.0073	0.0000 +- 0.0015	0.0000 +- 0.0004
Pb	0.1148 +- 0.0218	0.0244 +- 0.0047	0.0057 +- 0.0012
NO3	4.0000 +- 0.4000	0.8500 +- 0.0900	0.2000 +- 0.0300
PO4	0.0000 +- 2.0000	0.0000 +- 0.4300	0.0000 +- 0.1000
Be	0.0000 +- 0.3800	0.0000 +- 0.0810	0.0000 +- 0.0190

Figure 6. Laboratory fine results sheet.

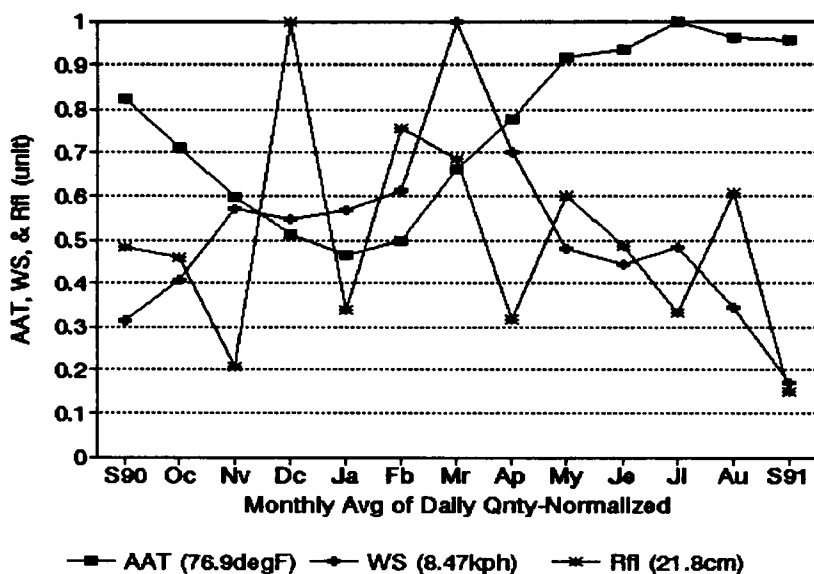


Figure 7. Meteorological components.

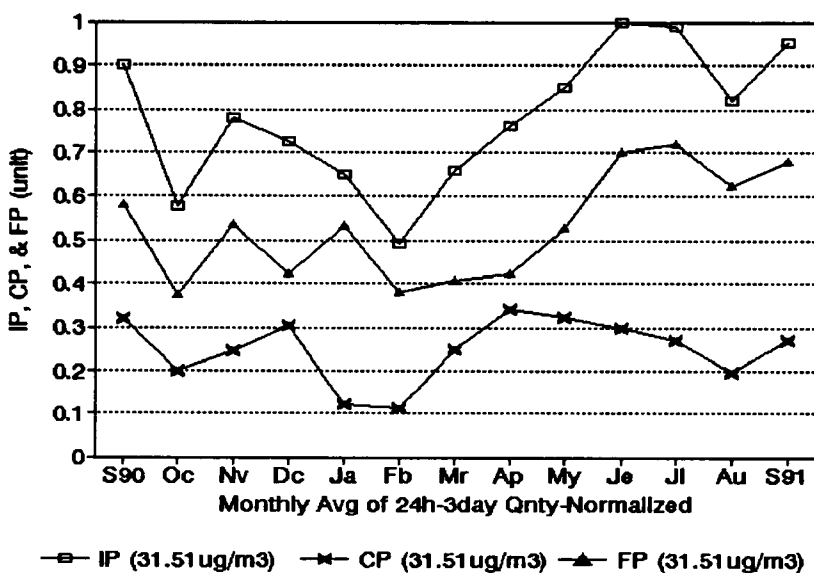


Figure 8. Particulate matter monthly trends.

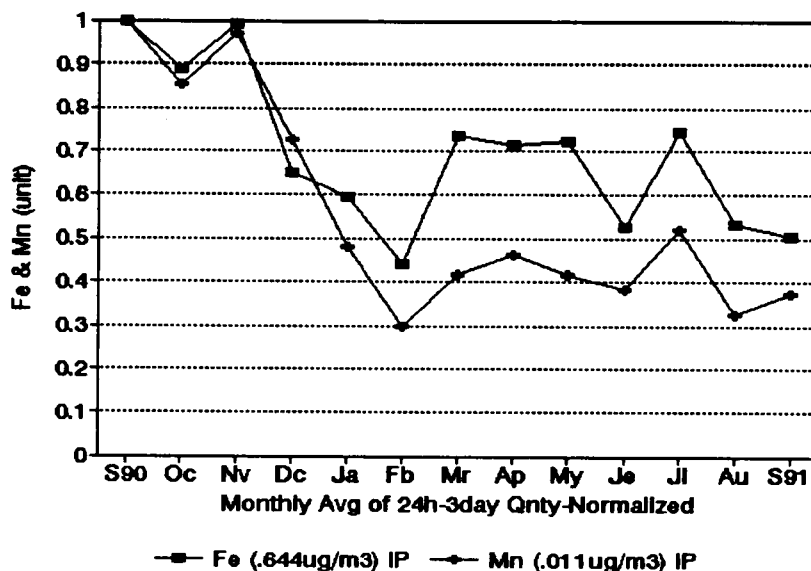


Figure 9. Iron & manganese monthly trends.

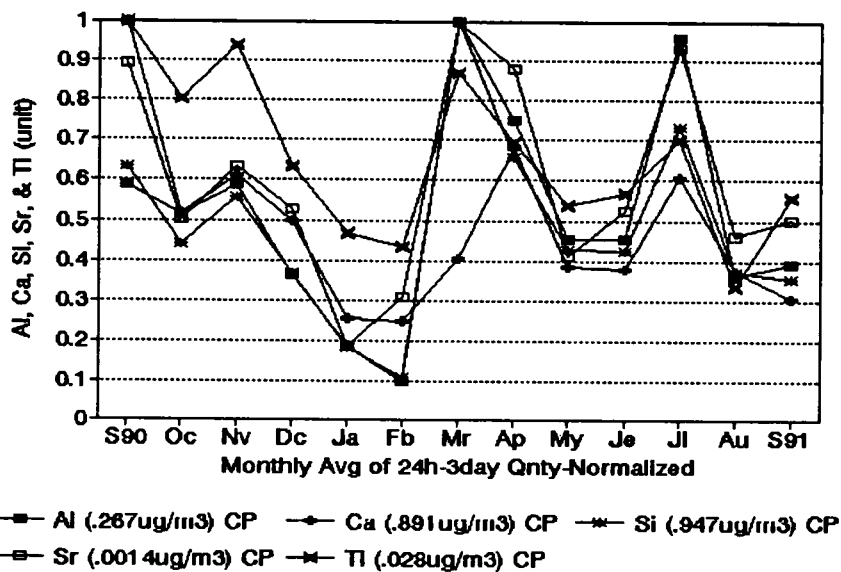


Figure 10. Selected elements' monthly trends.

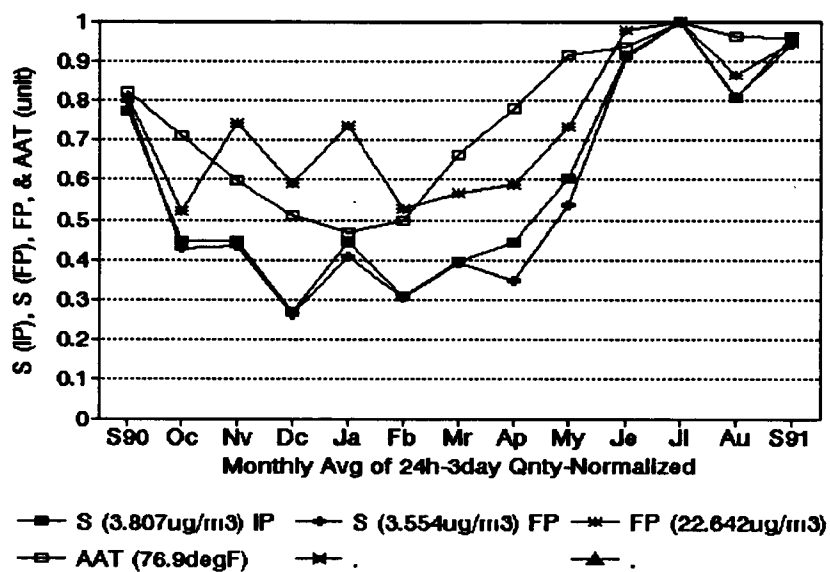


Figure 11. Sulfur's monthly trends.

Profile Name : Coal-fired Power Plant/ESP Composite
Profile Number : 11215
Data Quality : D

Control Device : ESP
Reference(s) : Not specified
Data Source : Profile represents a composite of Profiles
11204, 11205, 11206, 11207, 11208, 11210,
and 11212.

SCC Assignments: 10100201

Mass Fraction Data :
Size Interval (um) - (0-2.5) (0-6) (0-10)
Mass Fraction - 0.290 0.500 0.670

Total Particulate Matter -

Species		0-2.5 um		2.5-10 um		0-10 um		Total Measured	
Num	Sys	%wt	unc{1}	%wt	unc{1}	%wt	unc{1}	%wt	unc{1}
11	Na	0.48	000	0.526	000	0.507	000	0.501	000
12	Mg	1.914	000	2.935	000	2.493	000	2.555	000
13	Al	10.598	000	13.864	000	12.45	000	12.58	000
14	Si	15.789	000	26.426	000	21.822	000	22.604	000
16	S	1.255	000	0.565	000	2.864	000	0.603	000
19	K	1.421	000	1.665	000	1.559	000	1.558	000
20	Ca	2.287	000	2.648	000	2.492	000	2.516	000
22	Ti	0.896	000	1.114	000	1.02	000	1.019	000
23	V	0.058	000	0.062	000	0.06	000	0.061	000
24	Cr	0.05	000	0.05	000	0.05	000	0.049	000
25	Mn	0.047	000	0.041	000	0.044	000	0.044	000
26	Fe	7.239	000	7.73	000	6.089	000	7.534	000
28	Ni	0.019	000	0.018	000	0.018	000	0.017	000
29	Cu	0.022	000	0.021	000	0.022	000	0.021	000
30	Zn	0.156	000	0.151	000	0.153	000	0.149	000
33	As	0.036	000	0.023	000	0.031	000	0.03	000
34	Se	0.011	000	0.008	000	0.009	000	0.009	000
51	Sb	0.004	000	0.004	000	0.004	000	0.004	000
82	Pb	0.033	000	0.032	000	0.032	000	0.032	000
TOTALS:		42.315		57.883		51.719		51.886	

=====

{1} Uncertainty not evaluated.

Figure 12. Particulate matter profile speciation report.

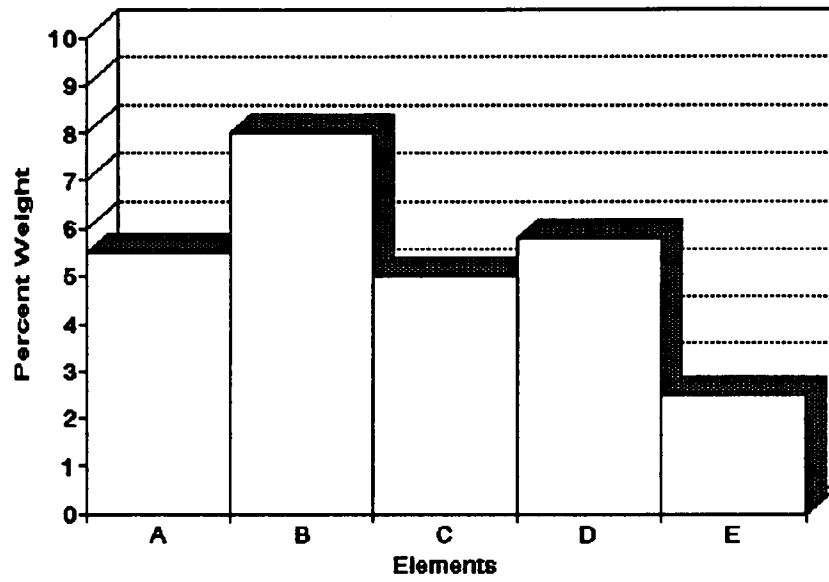


Figure 13. Source A profile.

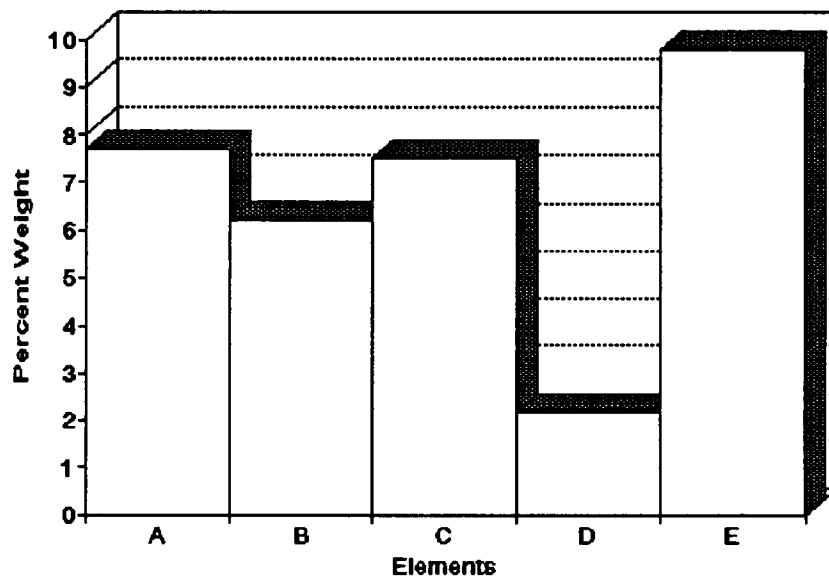


Figure 14. Sample B profile.

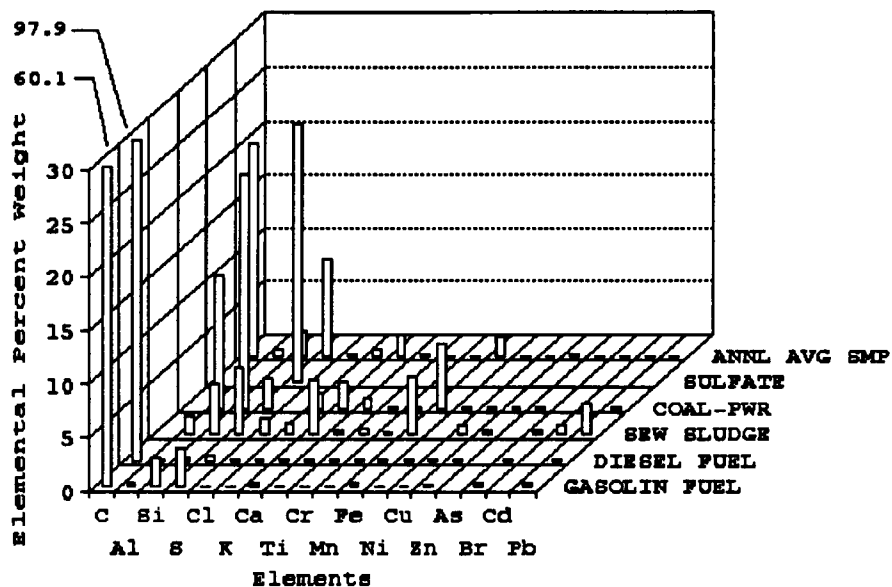


Figure 15. Annual Average sample model - group 1.

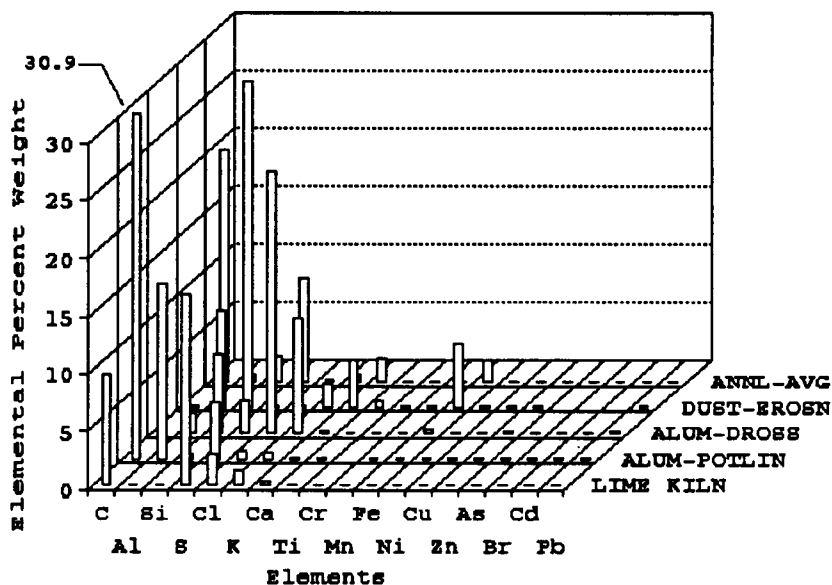


Figure 16. Annual Average sample model - group 2.

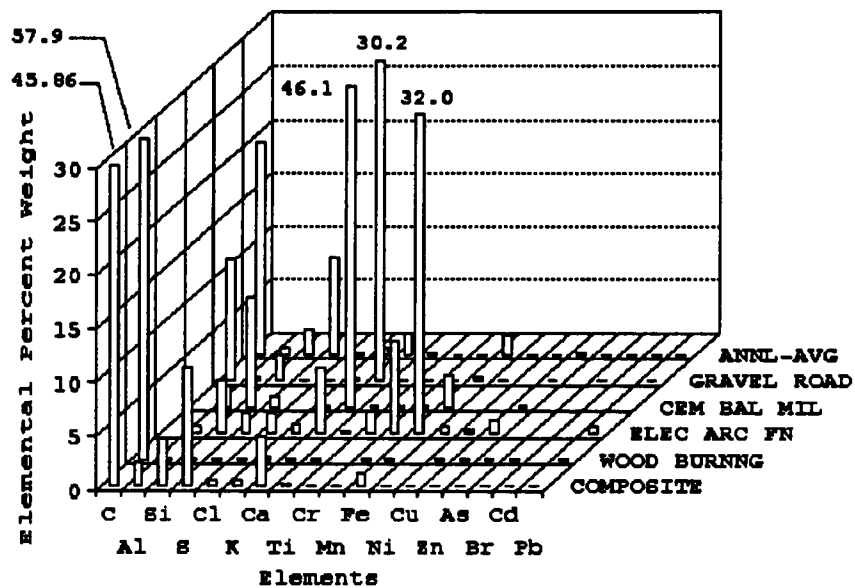


Figure 17. Annual Average Sample Model - Group 3.

APPENDIX B. Tables

Table 1. Monitoring statistics.

Description	Comments
Sampled Period	24-hour duration (12:00a to 12:00a)
Sampling Period	9/11/90 to 9/9/91, incl., 3-day cyc.
Samples Collected	240 (one CP and FP per 24-hours)
Lost Records	2 (9/20/90 and 8/28/91)
Sample miss-scheduled	1 (7/31/91 should be 8/1/91)
Elements from analysis	Element/Compound (MW)
	Al(27), Si(28), P(31), S(32), Cl(35.4),
	K(39), Ca(40), Ti(48), V(51), Cr(52),
	Mn(55), Fe(56), Ni(59), Cu(63.5),
	Zn(65.4), Ga(70), Ge(72.6), As(75),
	Se(79), Br(80), Rb(85.5), Sr(87.6),
	Y(89), Zr(91), Mo(96), Pd(106.4),
	Ag(108), Cd(112.4), In(115), Sn(119),
	Sb(122), Ba(137), La(139), Hg(200.6),
	Pb(207), NO ₃ (62), PO ₄ (95), Be(9)
Analysis Methods	
XRF	Elements Al to Pb (listed above)
IC	Compounds NO ₃ and PO ₄
ICP	Element "Be"

Table 2. Monthly concentrations (μm^3) and ff (dec).

Mth(smps)	IP	CP	FP	FF
Sp90(6)	28.440	10.127	18.308	.613
Oc90(10)	18.160	6.350	11.809	.585
Nv90(10)	24.560	7.748	16.816	.650
Dc90(11)	22.890	9.566	13.357	.633
Ja91(10)	20.470	3.813	16.671	.824
Fb91(9)	15.510	3.550	11.960	.787
Mr91(11)	20.790	7.937	12.850	.667
Ap91(10)	24.010	10.706	13.304	.570
My91(10)	26.790	10.188	16.603	.598
Je91(10)	31.510	9.374	22.133	.702
Jl91(11)	31.150	8.509	22.642	.739
Au91(9)	25.840	6.252	19.585	.753
Sp91(3)	30.000	8.573	21.429	.708
Ann1 Mean:	24.258	7.855	16.406	.678

Table 3. Annual concentration and ff by ranked order.

	($\mu\text{g}/\text{m}^3$)		($\mu\text{g}/\text{m}^3$)		($\mu\text{g}/\text{m}^3$)		(dec)
IP	24.258	CP	7.8550	FP	16.406	FF	0.6780
S	2.1869	Si	0.4673	S	1.9677	S	0.8901
Si	0.5553	Ca	0.4259	NO ₃	0.2400	Br	0.8835
Ca	0.4862	Fe	0.3252	Fe	0.1259	Se	0.8303
NO ₃	0.4515	S	0.2191	Si	0.0880	Pb	0.7748
Fe	0.4510	NO ₃	0.2115	PO ₄	0.0854	Zn	0.6658
Al	0.1669	Al	0.1423	K	0.0789	As	0.6647
K	0.1631	K	0.0841	Ca	0.0603	Sb	0.5952
PO ₄	0.1310	PO ₄	0.0456	Al	0.0246	Mo	0.5855
La	0.0458	La	0.0223	La	0.0239	Ni	0.5839
Cl	0.0419	Cl	0.0192	Cl	0.0226	Y	0.5654
Ba	0.0374	Ti	0.0180	Ba	0.0209	Hg	0.5627
Ti	0.0289	Ba	0.0166	Zn	0.0174	PO ₄	0.5616
Zn	0.0273	Zn	0.0153	Ti	0.0109	Ga	0.5584
Pb	0.0087	Mn	0.0040	Pb	0.0069	Ba	0.5565
Sb	0.0084	Cu	0.0039	Sb	0.0051	Be	0.5556
Sn	0.0078	Sn	0.0033	Sn	0.0045	Ag	0.5543
Cu	0.0071	Sb	0.0033	Cu	0.0033	Ge	0.5513
Mn	0.0061	Cd	0.0023	In	0.0027	Sn	0.5505
In	0.0049	In	0.0023	Br	0.0026	In	0.5496
Cd	0.0048	Be	0.0021	Be	0.0026	Cd	0.5435
Be	0.0046	Pb	0.0018	Cd	0.0025	V	0.5320
Ag	0.0033	P	0.0017	Mn	0.0021	Rb	0.5290
Br	0.0030	Pd	0.0013	Ag	0.0018	P	0.5274
P	0.0028	Ag	0.0013	Pd	0.0014	La	0.5259
Pd	0.0027	Cr	0.0013	P	0.0012	Cu	0.5153
Cr	0.0021	Zr	0.0012	As	0.0011	Pd	0.5138
Zr	0.0017	Sr	0.0008	Se	0.0009	Cl	0.5033
As	0.0015	Mo	0.0004	Cr	0.0008	K	0.4965
Sr	0.0012	As	0.0004	Mo	0.0006	Zr	0.4686
Mo	0.0011	V	0.0004	Zr	0.0006	NO ₃	0.4582
Se	0.0010	Ni	0.0003	Ni	0.0005	Cr	0.4067
V	0.0009	Rb	0.0003	V	0.0004	Sr	0.4025
Ni	0.0008	Br	0.0003	Sr	0.0004	Mn	0.3758
Rb	0.0006	Y	0.0002	Y	0.0003	Ti	0.3035
Y	0.0006	Hg	0.0002	Rb	0.0003	Fe	0.2944
Hg	0.0005	Se	0.0001	Hg	0.0003	Si	0.2009
Ge	0.0003	Ge	0.0001	Ge	0.0002	Al	0.1932
Ga	0.0003	Ga	0.0001	Ga	0.0001	Ca	0.1909
Sum	4.8500	Sum	2.0460	Sum	2.8095	Avg	0.5269

Table 4. IP Analyte and its compound identification.

Analyte (MW)	Compound (MW)	Analyte Annual Conc. ($\mu\text{g}/\text{m}^3$)	IP Est. ($\mu\text{g}/\text{m}^3$, accum % of IP)
S(32)	(NH_4) ₂ SO ₄ (132)	2.187	9.021, 37.2
Ca(40)	CaCO ₃ (100)	.4862	1.216, 42.2
Si(28)	SiO ₂ (60)	.5553	1.190, 47.1
Fe ₂ (112)	Fe ₂ O ₃ (160)	.4510	.6442, 49.8
Al(27)	Al ₂ O ₃ (102)	.1669	.6305, 52.4
NO ₃ (62)	KNO ₃ (101)	.2258	.3678, 53.9
-	NH ₄ NO ₃ (80)	.2258	.2914, 55.0
K(39)	KNO ₃ (101)	.1631	.4224, 56.8
PO ₄ (95)	(NH ₄) ₃ PO ₄ +3H ₂ O (203)	.1310	.2799, 58.0
-	-	-	-
Cl(35.4)	NaCl(58.4)	.0419	.0691, 58.2
Zn(65.4)	ZnO(81.4)	.0273	.0340, 58.4
Sb(122.4)	Sb ₂ O ₃ (292)	.0084	.0201, 58.5
Pb(207)	PbO(223)	.0087	.0094, 58.5
Cu(63.5)	CuO(79.5)	.0071	.0089, 58.6
Mn(55)	MnO(71)	.0061	.0079, 58.6
Cd(112.4)	CdO(128.4)	.0048	.0055, 58.6
Cr(52)	Cr ₂ O ₃ (152)	.0021	.0061, 58.6
As(75)	As ₂ O ₅ (230)	.0015	.0046, 58.6
Se(79)	SeO(95)	.0010	.0012, 58.6
Ni(59)	NiO(75)	.0008	.0010, 58.7
V(51)	V ₂ O ₅ (182)	.0009	.0032, 58.7
Hg(200.6)	HgO(216.6)	.0005	.0005, 58.7
Totals:	-	4.703	14.23, 58.7

Table 5. Unit cancer risk.

Element (MW)	AnnlMean ($\mu\text{g}/\text{m}^3$)	DetLim ($\mu\text{g}/\text{m}^3$)	UntRsk Ftr ($\text{m}^3/\mu\text{g}$)	UntCncr Rsk (10^{-6})
Cr(52)	.0021	.0001	.0120	3.78*
Ni(59)	.0008	.0002	.00024	0.192
As(75)	.0015	.0003	.0043	6.45
Cd(112.4)	.0048	.0017	.0018	8.64
Total:				19.06

* Adjusted for 15% of measured Cr as hexavalent chrome based on Falerios, et al¹⁵.

Table 6A. Annual Average Sample.

Description Elements (Down)		C	Al	Si	S	Cl	K	Ca	Ti	Cr	Mn	Fe	Mi	Cu	Zn	As	Br	Cd	Pb	Sp/ Lin Str Elm -LE		Sup or Src x Col V (unc)	Col V Cell 28 (t)	Salir of Col V or Y
A	B	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
8 Year's Avg		28.00	0.6880	2.2891	9.4152	0.1127	0.6724	2.4043	0.4119	0.0087	0.0251	1.8592	0.0033	0.0293	0.1125	0.0062	0.0124	0.0198	0.0359	M.A.		37.07		
(PM10-1vc)																								
10 Nitrates																								
11 SULFATE																								
14 COAL-PWR																								
15		12.45	21.82	2.06			1.56	2.49	1.02	0.05	0.04	6.09	0.02	0.02	0.15	0.03								
16		5.5	315.2	24.24			43.1	80.5	11.7	17.3	62.9	30.5	16.5	146.3	75.0	20.6								
17 SEN SURGE																								
18		1.8	4.77	6.33	1.40	0.96	5.07	0.44	0.58	0.21	5.38			0.88	0.361		0.38	0.83	2.94					
19		38.2	48.0	142.4	11.7	70.0	39.5	27.1	1.5	12.0	34.6			3.3	31.2		3.3	2.4	1.2	1.22	Pb			
20 DIESEL FUEL																								
21		87.9	0.127	0.178	0.345	0.045	0.013	0.056	0.007	0.007	0.007	0.014	0.003	0.005	0.052		0.009							
22		22.8	541.7	1286.0	2613.1	383.8	5172.0	3579.1	1701.9	123.7	359.2	13280	109.9	585.4	216.4		137.4							
23 GASOLIN FUEL																								
24		60.1	0.3643	2.6403	3.5800	0.0640	0.0287	0.2900	0.0065	0.0095	0.0120	0.2367	0.0070	0.0183	0.2340		0.2425							
25		33.3	180.8	86.7	251.3	265.9	2345.4	672.6	1832.9	91.1	209.6	705.6	47.1	159.6	48.1		5.1							
26 DUST-BROWN																								
27		0.02	8.32	28.2	0.026	0.013	2.09	4.15	0.57	0.01	0.005	5.63	0.008	0.006	0.007									
28		100000	8.3	8.1	34674	1328.7	32.2	48.3	20.9	86.6	26.5	33.0	41.2	487.8	1607.7									
29 ALUM-DROSS																								
30		1.818	6.965	2.783	22.618	10.863	0.153	0.034	0.032	0.013	0.367	0.035	0.049	0.092	0.01	0.062	0.009	0.081						
31		37.8	32.9	323.9	0.8	6.7	1310.0	350.4	27.1	193.4	506.6	9.4	59.7	122.3	61.8	19.9	219.9	44.3	0.76	Cl				
32 ALUM-POWIL																								
33		30.9	15.2	0.34	5	0.8	0.527	0.1	0.002		0.008	0.114	0.014	0.018	0.007	0.022	0.003	0.072						
34		64.7	4.5	673.3	180.3	21.6	127.6	2004.3	5956.8		314.3	1630.9	23.6	162.6	1607.7	28.1	56.2	639.6	49.8	4.53	Al			
35 ALUM-KILN																								
36		9.7	0.064	0.038	16.52	2.618	1.299	0.342	0.004	0.011	0.015	0.041	0.032	0.005	0.006	0.003	0.024	0.015	0.018					
37		206.2	1075.0	6024	54.6	6.6	51.8	586.0	2978.4	78.7	167.6	4534.6	10.3	585.4	1075.7	206.1	51.5	131.9	199.2	6.60	Cl			
38 GRAVEL ROAD																								
39		11.4	0.42	2.4	0.12	0.015	0.27	30.2	0.04	0.001	0.11	0.38	0.002	0.002	0.002		0.001							
40		175.4	163.8	95.4	7512.6	1151.5	249.0	6.6	297.8	865.7	22.9	489.3	164.9		5627.0		1236.7							
41 CEN BAL MILL																								
42		2	10.2	0.80			0.14	46.1	0.14	0.007	0.03	2.94			0.008									
43		34.4	22.4	1024.5			480.3	4.3	85.1	123.7	83.8	63.2			1406.8									
44 ELAC APC																								
45		0.65	5	1.5	1.95	0.92	6.2	0.2	0.2	2.1	8.7	32	0.7	0.28	1.2									
		105.8	45.8	4.0	9.3	32.3	59.6	0.4	0.3	5.8	0.5	5.8	0.5	10.5	9.4									
				</																				

Table 6A. Annual Average sample (continue).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
47	WOOD BUDING	(PM10-1vc)	57.9	0.002	0.021	0.098	0.1	0.289	0.012	0.001		0.001	0.015		0.003	0.027	0.001	0.001		0.002					
48		Sup/Sec(t)	34.5	34001	10901	9199.2	172.7	232.6	16702	11914		2514.6	12395		975.6	416.8	618.4	1236.7		1793.2	34.54	C			
49																									
50	COMPOSITE	(PM10-1vc)	45.86	2.2564	4.4239	10.9373	0.4552	0.5849	4.6232	0.1202	0.0201	0.0502	1.1358	0.0080	0.0178	0.0517	0.0033	0.0225	0.0113	0.0734					
51	(13 Srs)	Sup/Sec(t)	43.6	30.5	51.7	82.4	37.9	115.0	43.4	99.1	43.0	58.1	163.7	41.4	164.8	217.6	188.9	54.9	174.8	48.9	36.49	AI			

53

Table 6B. Composites' weight factors (t).

56	Src	Lin	Ein	Compos	Equal Wt	Lin	Ein	Compos	Equal Wt
57		Compos	Compos	Compos	Compos	Compos	Compos	Compos	Compos
58									
59	B	C	D	E	F	G	H	I	J
60									
61	SULFATE	37.191	24.317	7.692	C	20.0000	45.8601	45.7511	19.8374
62	COAL-PWR	5.526	5.526	7.692	AI	0.6800	2.2564	2.2529	3.3243
63	SEW SUDGE	1.220	1.066	7.692	SI	2.2891	4.4239	4.4161	6.3517
64	DIESEL FUEL	22.753	22.753	7.692	S	9.0152	18.9373	9.7513	5.6546
65	GASOLIN FUEL	5.100	5.100	7.692	CI	0.1727	0.4552	0.4235	2.2772
66	DUST-BROSS	8.118	8.118	7.692	K	0.6724	0.5849	0.5688	1.3969
67	ALUM-BROSS	0.764	0.764	7.692	Ca	2.0043	4.6232	4.6115	7.3208
68	ALUM-POTLIN	4.526	4.526	7.692	Ti	0.1191	0.1202	0.1195	0.1896
69	LIKE KILA	6.598	5.473	7.692	Cr	0.0087	0.0201	0.0191	0.2160
70	GRAVEL ROAD	6.637	6.637	7.692	Mn	0.0251	0.0502	0.0497	0.7108
71	CEM BAL KIL	4.340	4.340	7.692	Fe	1.8592	1.1358	1.1271	4.0429
72	ELAC ARC FN	0.289	0.289	7.692	Al	0.0033	0.0080	0.0076	0.0632
73	WOOD BUDING	34.542	34.542	7.692	Cu	0.0293	0.0178	0.0164	0.0988
74					Zn	0.1125	0.0517	0.0511	0.1651
75					As	0.0062	0.0033	0.0032	0.0051
76					Br	0.0124	0.0225	0.0217	0.0570
77					Cd	0.0198	0.0113	0.0099	0.0659
78					Pb	0.0359	0.0734	0.0687	0.3277
79									

Table 6E. Percent Difference Statistic.

Model	Lin	Ein	Compos	Equal Wt.
Src	Compos	Compos	Compos	Compos
Mean	68.674	55.413	605.733	
S.D.	85.234	83.813	834.274	
Median	87.655	83.355	235.352	
Maximum	227.949	227.443	2776.837	
Minimum	-54.045	-54.598	-37.277	

Table 6F. Percent Difference.

Lin	Ein	Compos	Equal Wt.
Compos	Compos	Compos	Compos
C	129.301	128.755	-0.813
AI	227.949	227.443	383.162
SI	93.254	92.915	177.472
S	21.321	8.166	-37.277
CI	163.516	145.159	1218.358
K	-13.008	-15.399	107.762
Ca	130.664	130.004	265.259
Ti	0.900	0.296	59.127
Cr	132.623	128.916	2394.664
Mn	99.775	97.823	2726.837
Fe	-38.907	-39.375	120.145
Al	141.442	130.532	1814.983
Cu	-39.306	-44.111	237.545
Zn	-54.045	-54.598	46.683
As	-47.062	-47.608	-17.896
Br	82.055	75.160	361.213
Cd	-42.796	-50.083	233.159
Pb	104.457	91.365	812.013

82 Table 67. Selected samples elemental profiles (wetland reference data ($\mu\text{g}/\text{m}^3$)).

84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	1544	1545	1546	1547	1548	1549	1550	1551</
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	--------

Table 7A. Annual Average sample model results.

A	B	C	D	E	F	G	H	I	J
8	Ann-Avry	Year's Avry (PHIO-1-vc)	R.A.				37.07		
9									
10	Mitrazes								
11	SULFATE	(PHIO-1-vc)	R.A.				1.06		
12	(as H2SO4)	Sup/Stc(t)	37.19 S				9.02	24.32	24.32
13									
14	COAL-Pwr	(PHIO-1-vc)							
15		Sup/Stc(t)	5.53 Al				2.69	7.25	5.53
16									
17	SKY SLUDGE	(PHIO-1-vc)							
18		Sup/Stc(t)	1.22 Pb				0.40	1.07	1.07
19									
20	DIESEL FUEL	(PHIO-1-vc)							
21		Sup/Stc(t)	22.75 C				20.21	54.51	22.75
22									
23	GASOLIN FUEL	(PHIO-1-vc)							
24		Sup/Stc(t)	5.10 Br				3.47	9.37	5.10
25									
26	DUST-BROSS	(PHIO-1-vc)							
27		Sup/Stc(t)	8.12 Sl				3.99	10.76	8.12
28									
29	ALUM-DROSS	(PHIO-1-vc)							
30		Sup/Stc(t)	0.76 Cl				0.35	0.93	0.76
31									
32	ALUM-PORTLE	(PHIO-1-vc)							
33		Sup/Stc(t)	4.53 Al				2.41	6.49	4.53
34									
35	LIME KILN	(PHIO-1-vc)							
36		Sup/Stc(t)	6.60 Cl				2.03	5.47	5.47
37									
38	GRAVEL ROAD	(PHIO-1-vc)							
39		Sup/Stc(t)	6.64 Ca				3.01	8.12	6.64
40									
41	CEN BALL MILLS	(PHIO-1-vc)							
42		Sup/Stc(t)	4.35 Ca				2.71	7.32	4.35

Table 7A. Annual Average sample model results (continued).

	C	D	E	F	G	H	I	J
RELAC ABC PA (PH10-1vc)								
Sap/Strc (%)			0.29	0.18	0.49	0.29		
WOOD BURNING (PH10-1vc)								
Sap/Strc (%)			34.54 C	20.20	54.48	34.54		
COMPOSITE (PH10-1vc)								
(13 Strs)			30.49	30.49	30.49	30.49	30.49	30.49

Table 7B. Models' composites (3vt).

Ele	Lin Ele Cub Ele Equal Wt.			
	Sample	Corpos	Corpos	Corpos
	L	M	N	P
C	20.0000	45.8601	45.7511	19.8374
Al	0.6800	2.2584	2.2529	3.3243
Si	2.2891	4.4239	4.4161	6.3517
S	9.0152	10.9373	9.7513	5.6546
Se	0.1727	0.4552	0.4235	2.2772
K	0.6724	0.5849	0.5680	1.3969
X	2.0643	4.6232	4.6115	7.3208
Fl	0.1191	0.1202	0.1195	0.1896
Cr	0.0687	0.0281	0.0191	0.2160
Sn	0.0251	0.0592	0.0497	0.7100
Fe	1.8592	1.1358	1.1271	4.0929
Bi	0.0033	0.0000	0.0076	0.0632
Br	0.0293	0.0178	0.0164	0.0980
Zn	0.1125	0.0517	0.0511	0.1651
As	0.0062	0.0033	0.0032	0.0051
Br	0.0124	0.0225	0.0217	0.0570
Ag	0.0198	0.0113	0.0099	0.0659
Pb	0.0359	0.0734	0.0687	0.3277

Table 7C. Percent Difference Stat.

Item	R	S	T	U
Lin	60.687	55.424	605.776	
Exp	85.241	83.018	834.284	
Med	87.655	83.355	235.352	
Max	227.949	227.443	2726.637	
Min	-54.045	-54.598	-37.277	

Table 7D. Composites' weight factors (z).

Src	V	W	X	Y	Z	Lin Cmb Bin Equal Wt. Compos Compos Compos
SULFATE			37.150	24.317	7.692	
COAL-PWR			5.526	5.526	7.692	
SEN SLUDGE			1.220	1.666	7.692	
DIESEL FUEL			22.753	22.753	7.692	
GASOLINE FUEL			5.100	5.100	7.692	
DUST-ROSEN			8.118	8.118	7.692	
ALUM-ROSEN			0.764	0.764	7.692	
ALUM-PORTIN			4.526	4.526	7.692	
LIME KYLE			6.598	5.473	7.692	
GRAVEL ROAD			6.637	6.637	7.692	
CEN BAL WIL			4.348	4.348	7.692	
CLAYC BAL WIL			0.289	0.289	7.692	
WOOD BURNING			34.542	34.542	7.692	

Table 8A. High Coarse Fraction sample model results.

A	B	C	D	E	F	G	H	I	J
Sup/ Lin Sup or Sup Col B/ Sallr of Src Elm tiles Col F Cell B8 Col F (%) -L2 (vrc) (%) or I J									
8	REC931A	El-Dag-CF	M.A.	47.88					
9		(PM10-vrc)							
10	Nitrates		M.A.	5.47					
11	SULFATE	(PM10-vrc)		1.84	3.91	3.91			
12	(as H2SO4)	Sup/Strc(%)	7.684 S						
13									
14	COAL-Ptr	(PM10-vrc)		5.12	10.87	10.52			
15		Sup/Strc(%)	10.52 Cr						
16									
17	SEW SLUDGE	(PM10-vrc)		0.21	0.45	0.45			
18		Sup/Strc(%)	0.65 Pb						
19									
20	DIESEL FUEL	(PM10-vrc)		20.21	42.92	22.75			
21		Sup/Strc(%)	22.75 C						
22									
23	GASOLIN FUEL	(PM10-vrc)		2.17	4.61	3.19			
24		Sup/Strc(%)	3.19 Br						
25									
26	DUST-BROSS	(PM10-vrc)		18.91	40.16	38.47			
27		Sup/Strc(%)	38.47 Mn						
28									
29	ALUM-DROSS	(PM10-vrc)		0.53	1.13	1.13			
30		Sup/Strc(%)	1.18 Cl						
31									
32	ALUM-POTLIN	(PM10-vrc)		13.72	29.13	25.81			
33		Sup/Strc(%)	25.81 Al						
34									
35	LIME KILN	(PM10-vrc)		3.12	6.64	6.64			
36		Sup/Strc(%)	10.16 Cl						
37									
38	GRAVEL ROAD	(PM10-vrc)		3.84	8.16	8.16			
39		Sup/Strc(%)	8.47 Ca						
40									
41	CEN BAL MIL	(PM10-vrc)		3.47	7.36	5.55			
42		Sup/Strc(%)	5.55 Ca						

Table 8A. High Coarse Fraction sample model results (continued).

C	D	E	F	G	H	I	J
ELC ARC FN (PM10-vrc)							
					0.16	0.33	0.25
		Sup/Strc(%)	0.25 Cr				
WOOD BURNING (PM10-vrc)							
					20.20	42.90	34.54
		Sup/Strc(%)	34.54 C				
COMPOSITE (PM10-vrc)							
(13 Str)		Sup/Strc(%)	23.90 S				

Table 8B. Models' composites (vrc).

Elm	Sample	Compos	Compos	Compos
Lin Elm Cub Elm Equal Vc.				
C	20.0000	51.8497	51.4725	19.8374
Al	3.9231	0.6631	8.6590	3.3243
Si	13.7266	14.2619	14.2421	6.3517
S	1.8432	5.4079	4.3398	5.6546
Cl	0.2660	0.9859	0.6998	2.2772
K	1.6670	1.4975	1.4442	1.3969
Ca	2.5587	7.1133	6.9973	7.3288
Yt	0.2691	0.3446	0.3434	0.1896
Cr	0.0053	0.0220	0.0204	0.2160
Mn	0.0365	0.0810	0.0797	0.7108
Fe	2.6746	3.1713	3.1575	4.0929
Bi	0.0047	0.0153	0.0141	0.0632
Cu	0.0124	0.0193	0.0174	0.0988
Zn	0.0469	0.0566	0.0556	0.1651
As	0.0061	0.0096	0.0095	0.0051
Br	0.0077	0.0215	0.0199	0.0570
Cd	0.0175	0.0078	0.0058	0.0659
Pb	0.0192	0.0688	0.0622	0.3277

Table 8C. Percent Difference Stat.

Item	R	S	T	U
Lin Elm Cub Elm Equal Vc.				
Mean	115.077	101.233	646.667	
S.D.	102.321	92.345	992.973	
Median	121.184	119.299	229.206	
Maximum	318.383	288.279	4004.624	
Minimum	-55.319	-68.006	-53.727	

Table 8D. Composites' weight factors (%).

Src	V	W	X	Y	Z
Lin Elm Cub Elm Equal Vc.					
SULFATE	7.604	3.915	7.692		
COAL-PTR	10.523	10.523	7.692		
SEW SLUDGE	0.652	0.449	7.692		
DIESEL FUEL	22.753	22.753	7.692		
GASOLIN FUEL	3.189	3.189	7.692		
DUST-BROSS	38.473	38.473	7.692		
ALUM-DROSS	1.176	1.129	7.692		
ALUM-POTLIN	25.810	25.810	7.692		
LIME KILN	10.161	6.637	7.692		
GRAVEL ROAD	8.472	8.163	7.692		
CEN BAL MIL	5.550	5.550	7.692		
ELC ARC FN	0.251	0.251	7.692		
WOOD BURNING	34.542	34.542	7.692		

Table 9A. High Fine Fraction sample model results.

A	B	C	D	E	F	G	H	I	J
Sup/ Lin Sup or Sup Col W/ Sallir of Src Elm times Col F Cell BE Coils F (t) -L (tvc) (t) or I I J									
8	REC107	High FF	N.A.	34.73					
9		(PH10-tvc)							
10	Nitrates		N.A.	3.87					
11	SULFATE	(PH10-tvc)		2.94	8.48	8.48			
12		Sup/Strc(t)	12.148 S						
13									
14	COAL-PTR	(PH10-tvc)		2.60	7.49	5.35			
15		Sup/Strc(t)	5.35 Al						
16									
17	SEW SLUDGE	(PH10-tvc)		0.51	1.48	1.48			
18		Sup/Strc(t)	1.58 Pb						
19									
20	DIESEL FUEL	(PH10-tvc)		20.21	58.20	22.75			
21		Sup/Strc(t)	22.75 C						
22									
23	GASOLIN FUEL	(PH10-tvc)		4.90	14.11	7.20			
24		Sup/Strc(t)	7.20 Br						
25									
26	DUST-ZEROX	(PH10-tvc)		3.93	11.32	8.00			
27		Sup/Strc(t)	8.00 Al						
28									
29	ALUM-DROSS	(PH10-tvc)		0.71	2.06	1.58			
30		Sup/Strc(t)	1.58 Cl						
31									
32	ALUM-POYLEIN	(PH10-tvc)		2.33	6.70	4.38			
33		Sup/Strc(t)	4.38 Al						
34									
35	LIME KILN	(PH10-tvc)		1.90	4.33	4.33			
36		Sup/Strc(t)	4.89 Ni						
37									
38	GRAVEL ROAD	(PH10-tvc)		7.10	20.44	15.65			
39		Sup/Strc(t)	15.65 Ca						
40									
41	CEN BAL KIL	(PH10-tvc)		6.40	18.43	10.25			
42		Sup/Strc(t)	10.25 Ca						

Table 9A. High Fine Fraction sample model results (continued).

C	D	E	F	G	H	I	J
ELC ARC PM (PH10-tvc) Sup/Strc(t)							
			0.22 Ni		0.14	0.40	0.22
WOOD BURNING	(PH10-tvc)				20.20	58.16	34.54
	Sup/Strc(t)	34.54 C					
COMPOSITE	(PH10-tvc)						
(13 Str)	Sup/Strc(t)	20.85 Al					

Table 9B. Models' composites (tvc).

Elm	Sample	Compos	Elm	Elm	Elm	Equal	Elm
L	H	N	O	P			
C	20.0000	47.9350	47.8807	19.8374			
Al	0.6656	2.3852	2.3029	3.3243			
Si	2.3705	5.2949	5.2897	6.3517			
S	2.9447	4.7544	4.5688	5.6546			
Cl	0.3575	0.6009	0.5846	2.2772			
K	1.0316	0.6749	0.6667	1.3969			
Ca	4.7258	10.0725	10.0653	7.3208			
Fe	0.1319	0.1314	0.1309	0.1896			
Cr	0.0119	0.0215	0.0209	0.2160			
Mn	0.0430	0.0509	0.0566	0.7108			
Fe	2.1934	1.3316	1.3257	4.0929			
Ni	0.0016	0.0075	0.0073	0.0632			
Cu	0.0233	0.0214	0.0204	0.0988			
Zn	0.1406	0.0582	0.0577	0.1651			
As	0.0093	0.0032	0.0032	0.0051			
Br	0.0174	0.0291	0.0286	0.0570			
Cd	0.0131	0.0141	0.0132	0.0659			
Pb	0.0468	0.0901	0.0869	0.3277			

Table 9C. Percent Difference Stat.

Item	Lin	Elm	Cub	Elm	Equal	Elm
	Compos	Compos	Compos	Compos	Compos	
R	S	T	U			
Mean	67.672	64.620	563.368			
S.D.	109.443	108.019	952.109			
Median	64.184	58.332	197.418			
Maximum	379.554	368.114	3935.630			
Minimum	-65.359	-65.540	-45.339			

Table 9D. Composites' weight factors (%).

Src	Lin	Elm	Cub	Elm	Equal	Elm
	Compos	Compos	Compos	Compos	Compos	
V	W	X	Y	Z		
SULFATE	12.140	8.479	7.692			
COAL-PTR	5.346	5.346	7.692			
SEW SLUDGE	1.581	1.476	7.692			
DIESEL FUEL	22.753	22.753	7.692			
GASOLIN FUEL	7.195	7.195	7.692			
DUST-ZEROX	8.000	8.000	7.692			
ALUM-DROSS	1.581	1.581	7.692			
ALUM-POYLEIN	4.379	4.379	7.692			
LIME KILN	4.890	4.331	7.692			
GRAVEL ROAD	15.648	15.648	7.692			
CEN BAL KIL	10.251	10.251	7.692			
ELC MC PM	0.224	0.224	7.692			
WOOD BURNING	34.542	34.542	7.692			

Table 10A. High PM10 sample model results.

A	B	C	D	E	F	G	H	I	J
Sup/ Lin Sup or Sup Col B/ Sallir of Src Elm Lines Col F Cell BK Cole F (t) -L- (t) or I									
8	REC1228A	High PM10	N.A.	22.46					
9									
10	Nitrates	(PM10-1wt)	N.A.	0.82					
11	SULFATE	(PM10-1wt)		1.49	6.63	6.14			
12		Sup/Strc(t)	6.14 S						
13									
14	COAL-PVR	(PM10-1wt)		0.19	0.84	0.39			
15		Sup/Strc(t)	0.39 AI						
16									
17	SEW SLUDGE	(PM10-1wt)		0.07	0.30	0.21			
18		Sup/Strc(t)	0.21 Cu						
19									
20	DIESEL FUEL	(PM10-1wt)		10.83	44.64	11.29			
21		Sup/Strc(t)	11.29 MI						
22									
23	GASOLIN FUEL	(PM10-1wt)		1.75	5.55	1.83			
24		Sup/Strc(t)	1.83 Br						
25									
26	DUST-BROSS	(PM10-1wt)		0.24	1.05	0.48			
27		Sup/Strc(t)	0.48 SI						
28									
29	ALUM-BROSS	(PM10-1wt)		0.08	0.37	0.19			
30		Sup/Strc(t)	0.19 CI						
31									
32	ALUM-POTLIN	(PM10-1wt)		0.17	0.75	0.32			
33		Sup/Strc(t)	0.32 AI						
34									
35	LIME KILN	(PM10-1wt)		0.33	1.45	1.06			
36		Sup/Strc(t)	1.06 MI						
37									
38	GRAVEL ROAD	(PM10-1wt)		0.21	0.94	0.46			
39		Sup/Strc(t)	0.46 Ca						
40									
41	CEN BAL KIL	(PM10-1wt)		0.19	0.84	0.30			
42		Sup/Strc(t)	0.30 Ca						

Table 10A. High PM10 sample model results (continued).

C	D	E	F	G	H	I	J
ELC ARC FN (PM10-1wt)							
					0.83	0.13	0.85
		Sup/Strc(t)	0.85 MI				
WOOD BURNING (PM10-1wt)							
		Sup/Strc(t)	34.54 C		20.20	89.93	34.54
COMPOSITE (PM10-1wt)							
(13 Str)		Sup/Strc(t)	24.57 AI				

Table 10B. Models' composites (wt).

Elm	Sample	Compos	Compos	Compos	Compos	Compos	Compos	Compos	Compos
L	M	N	O	P					
C	20.0000	31.2747	31.2747	19.8374					
AI	0.0482	0.1741	0.1741	3.3243					
SI	0.1351	0.3640	0.3640	6.3517					
S	1.4895	1.8523	1.8523	5.6546					
CI	0.0419	0.1170	0.1170	2.2772					
E	0.1973	0.1560	0.1560	1.3959					
Ca	0.1398	0.3428	0.3428	7.3208					
TI	0.0110	0.0097	0.0097	0.1896					
Cr	0.0134	0.0036	0.0036	0.2160					
Mo	0.0063	0.0074	0.0074	0.7108					
Fe	0.3071	0.1004	0.1004	4.0929					
MI	0.0003	0.0014	0.0014	0.0532					
Cu	0.0018	0.0042	0.0042	0.0988					
Zn	0.0362	0.0217	0.0217	0.1851					
As	0.0030	0.0006	0.0006	0.0051					
Br	0.0044	0.0070	0.0070	0.0570					
Cd	0.0035	0.0019	0.0019	0.0659					
Pb	0.0204	0.0195	0.0195	0.3277					

Table 10C. Percent Difference Stat.

Item	Lin Elm	Cub Elm	Elm Equal Wt.
	Compos	Compos	Compos
Mean	55.884	55.884	3728.640
S.D.	113.863	113.863	4620.977
Median	21.323	21.323	1571.442
Maximum	386.983	386.983	18548.96
Minimum	-80.892	-80.892	-0.813

Table 10D. Composites' weight factors (t).

Src	V	W	I	T	I
SULFATE	6.145	4.514	7.692		
COAL-PVR	0.387	0.387	7.692		
SEW SLUDGE	0.207	0.207	7.692		
DIESEL FUEL	11.208	11.208	7.692		
GASOLIN FUEL	1.829	1.829	7.692		
DUST-BROSS	0.479	0.479	7.692		
ALUM-BROSS	0.185	0.185	7.692		
ALUM-POTLIN	0.317	0.317	7.692		
LIME KILN	1.058	1.058	7.692		
GRAVEL ROAD	0.463	0.463	7.692		
CEN BAL KIL	0.303	0.303	7.692		
ELC ARC FN	0.048	0.048	7.692		
WOOD BURNING	34.542	34.542	7.692		

Table 11A. High Sulfur sample model results.

A	B	C	D	E	F	G	H	I	J
Sap/ Lin Sap or -ap Col H/ Sulfir of Src Elm times Col F Cell H6 Coils F (t) -LR (twt) (t) or I									
8	REC0731A	EL- S-Flm	N.A.				55.86		
9		(PM10-twt)							
10	Nitrates		N.A.				0.92		
11	SULFATE	(PM10-twt)					16.04	28.71	28.71
12		Sap/Strc(t)					66.16 S		
13									
14	COAL-Perr	(PM10-twt)					1.65	2.95	2.95
15		Sap/Strc(t)					3.39 MI		
16									
17	SEW SLUDGE	(PM10-twt)					0.23	0.42	0.42
18		Sap/Strc(t)					0.72 Pb		
19									
20	DIESEL FUEL	(PM10-twt)					20.07	35.93	22.60
21		Sap/Strc(t)					22.60 MI		
22									
23	GASOLIN FUEL	(PM10-twt)					0.91	1.63	1.34
24		Sap/Strc(t)					1.34 Br		
25									
26	DUST-ROGSH	(PM10-twt)					4.16	7.46	7.46
27		Sap/Strc(t)					8.47 MI		
28									
29	ALUM-DROSS	(PM10-twt)					0.49	0.88	0.88
30		Sap/Strc(t)					1.09 Cl		
31									
32	ALUM-POTLIN	(PM10-twt)					2.57	4.61	4.61
33		Sap/Strc(t)					4.84 MI		
34									
35	LIME KILN	(PM10-twt)					0.65	1.17	1.17
36		Sap/Strc(t)					2.12 MI		
37									
38	GRAVEL ROAD	(PM10-twt)					15.30	27.53	27.53
39		Sap/Strc(t)					33.90 MI		
40									
41	CEN BAL KIL	(PM10-twt)					15.96	28.57	25.55
42		Sap/Strc(t)					25.55 Ca		

Table 11A. High Sulfur sample model results (continued).

C	D	E	F	G	H	I	J
ELFC ARC FR (PM10-twt) Sap/Strc(t)							
					0.06	0.11	0.10
					0.10 MI		
	WOOD BURNING	(PM10-twt)			28.20	36.16	34.54
		Sap/Strc(t)			34.54 C		
	COMPOSITE	(PM10-twt)					
	(13 Str)	Sap/Strc(t)			12.98 Br		

Table 11B. Models' composites (wt).

Elm	Sample	Compos	Elm	Compos	Elm	Equal Wt.
L	M	N	O	P		
C	28.0000	46.2359	45.3443	19.8374		
Al	0.9116	2.5858	2.3708	3.3243		
Si	3.6596	6.7651	6.1989	6.3517		
S	16.0361	17.2369	10.4534	5.6546		
Cl	0.2472	0.4957	0.3260	2.2772		
K	0.7824	0.6313	0.5484	1.3969		
Ca	11.7802	22.5308	20.5342	7.3208		
Ti	0.1374	0.1382	0.1239	0.1896		
Cr	0.0458	0.0132	0.0109	0.2160		
Mn	0.0379	0.0672	0.0583	0.7108		
Fe	2.1256	1.6555	1.5294	4.0929		
Bi	0.0007	0.0052	0.0045	0.0632		
Cu	0.0193	0.0118	0.0087	0.0988		
Zn	0.0787	0.0379	0.0358	0.1651		
As	0.0047	0.0026	0.0024	0.0051		
Br	0.0032	0.0110	0.0093	0.0570		
Cd	0.0109	0.0066	0.0039	0.0659		
Pb	0.0213	0.0453	0.0357	0.3277		

Table 11C. Percent Difference Stat.

Item	Lin Elm	Compos	Elm	Equal Wt.
	Compos	Compos	Compos	
Mean	89.513	62.851	1146.837	
S.D.	164.518	144.293	2217.710	
Median	70.789	42.761	187.148	
Maximum	670.236	565.886	9215.192	
Minimum	-51.926	-64.477	-64.738	

Table 11D. Composites' weight factors (t).

Src	Lin Elm	Compos	Elm	Equal Wt.
	Compos	Compos	Compos	
SULFATE	66.156	28.767	7.692	
COAL-PFR	3.390	2.951	7.692	
SEW SLUDGE	0.724	0.420	7.692	
DIESEL FUEL	22.599	22.599	7.692	
GASOLIN FUEL	1.338	1.338	7.692	
DUST-ROGSH	8.475	7.456	7.692	
ALUM-DROSS	1.093	0.884	7.692	
ALUM-POTLIN	4.843	4.607	7.692	
LIME KILN	2.119	1.166	7.692	
GRAVEL ROAD	33.898	27.527	7.692	
CEN BAL KIL	25.554	25.554	7.692	
ELFC ARC FR	0.097	0.097	7.692	
WOOD BURNING	34.542	34.542	7.692	

Table 12A. High arsenic sample model results.

A	B	C	D	E	F	G	H	I	J	Sap/ Lin Src Elm Lines Col F Cell 86 Col 8 P	Col H/ Sallr of (t) -LE (t) or I
8	REC1017	High "A"	N.A.							60.69	
9		(PM10-1vc)									
10	Nitrates		N.A.							2.87	
11	SULFATE	(PM10-1vc)								19.70	32.47
12		Sap/Str(t)	81.29 S								32.47
13											
14	COAL-PTR	(PM10-1vc)								7.70	12.60
15		Sap/Str(t)	15.83 AI								12.60
16											
17	SEW SLUDGE	(PM10-1vc)								0.06	0.10
18		Sap/Str(t)	0.19 Cd								0.10
19											
20	DIESEL FUEL	(PM10-1vc)								16.37	26.98
21		Sap/Str(t)	18.43 CI								18.43
22											
23	GASOLIN FUEL	(PM10-1vc)								6.54	10.77
24		Sap/Str(t)	9.59 Br								9.59
25											
26	DUST-EROSN	(PM10-1vc)								10.46	17.24
27		Sap/Str(t)	21.29 SI								17.24
28											
29	ALUM-DROSS	(PM10-1vc)								0.02	0.03
30		Sap/Str(t)	0.04 CI								0.03
31											
32	ALUM-DROSS	(PM10-1vc)								0.55	0.91
33		Sap/Str(t)	1.04 CI								0.91
34											
35	LIME KILN	(PM10-1vc)								0.10	0.16
36		Sap/Str(t)	0.32 CI								0.16
37											
38	GRAVEL ROAD	(PM10-1vc)								10.63	17.52
39		Sap/Str(t)	23.44 Ca								17.52
40											
41	CEN BAL KIL	(PM10-1vc)								9.59	15.00
42		Sap/Str(t)	15.36 Ca								15.36

Table 12A. High arsenic sample model results (continued).

C	D	E	F	G	H	I	J
ELEC ARC FN	(PM10-1vc)						
	Sap/Str(t)	0.45 HI					
WOOD BURNING	(PM10-1vc)						
	Sap/Str(t)	0.29 CI					
COMPOSITE	(PM10-1vc)						
(13 Src)	Sap/Str(t)	12.75 CI					

Table 12B. Models' composites (tvc).

Elm	Sample	Compos	Compos	Elm	Equal Wt.
L	M	N	O	P	
C	20.0000	29.7963	28.8906	19.8374	
Al	1.9796	4.3711	3.5964	3.3243	
SI	6.0039	11.9125	9.9369	6.3517	
S	19.7041	20.8600	11.7418	5.6546	
CI	0.0033	0.0651	0.0508	2.2772	
E	1.4149	0.8251	0.6700	1.3969	
Ca	7.0789	15.5153	13.4760	7.3200	
PI	0.2899	0.3175	0.2595	0.1896	
Cr	0.0168	0.0241	0.0216	0.2160	
Mn	0.0635	0.0990	0.0872	0.7100	
Fe	3.7846	2.8851	2.4300	4.0929	
BI	0.0032	0.0100	0.0088	0.0632	
Cu	0.0557	0.0106	0.0088	0.0988	
Zn	0.1406	0.0674	0.0619	0.1651	
As	0.0258	0.0051	0.0041	0.0051	
Br	0.0233	0.0263	0.0250	0.0570	
Cd	0.0016	0.0017	0.0009	0.0059	
Pb	0.0792	0.0542	0.0504	0.3277	

Table 12C. Percent Difference Stat.

Item	Elm	Compos	Elm	Equal Wt.
	Compos	Compos	Compos	
Mean	60.866	35.684	1908.427	
S.D.	160.723	143.815	6230.706	
Median	11.294	0.273	39.522	
Maximum	684.554	560.368	27352.35	
Minimum	-81.047	-84.155	-80.3445	

Table 12D. Composites' weight factors (t).

Src	Elm	Elm	Elm	Equal Wt.
	Compos	Compos	Compos	
SULFATE	81.288	32.469	7.692	
COAL-PTR	15.829	12.685	7.692	
SEW SLUDGE	0.195	0.104	7.692	
DIESEL FUEL	18.433	18.433	7.692	
GASOLIN FUEL	9.595	9.595	7.692	
DUST-EROSN	21.290	17.242	7.692	
ALUM-DROSS	0.037	0.027	7.692	
ALUM-POTLIN	1.037	0.900	7.692	
LIME KILN	0.317	0.161	7.692	
GRAVEL ROAD	23.440	17.521	7.692	
CEN BAL KIL	15.356	15.356	7.692	
ELEC ARC FN	0.448	0.448	7.692	
WOOD BURNING	8.295	7.992	7.692	

Table 13A. High Nickel Coarse sample model results.

A	B	C	D	E	F	G	H	I	J
8	REC1128	RI-RI-Crs	M.A.	43.02					
9									
10	Nitrates		M.A.	3.19					
11	SULFATE	(PH10-1vc)		17.56	29.21	29.21			
12		Sup/Stc(t)	51.84 S						
13									
14	COAL-Pyr	(PH10-1vc)		5.29	12.30	10.88			
15		Sup/Stc(t)	10.88 AL						
16									
17	SEW SLUDGE	(PH10-1vc)		0.10	0.23	0.23			
18		Sup/Stc(t)	0.30 Pb						
19									
20	DIESEL FUEL	(PH10-1vc)		14.18	32.97	15.97			
21		Sup/Stc(t)	15.97 Pb						
22									
23	GASOLIN FUEL	(PH10-1vc)		2.00	4.64	2.93			
24		Sup/Stc(t)	2.93 Pb						
25									
26	DUST-BROSS	(PH10-1vc)		6.59	15.33	13.42			
27		Sup/Stc(t)	13.42 SL						
28									
29	ALUM-BROSS	(PH10-1vc)		0.87	2.03	1.94			
30		Sup/Stc(t)	1.94 CL						
31									
32	ALUM-POWELL	(PH10-1vc)		4.74	11.01	8.91			
33		Sup/Stc(t)	8.91 AL						
34									
35	LIME KILL	(PH10-1vc)		5.15	11.96	11.96			
36		Sup/Stc(t)	16.73 CL						
37									
38	GRAVEL ROAD	(PH10-1vc)		2.87	6.68	6.34			
39		Sup/Stc(t)	6.34 Ca						
40									
41	CEN BAL KILL	(PH10-1vc)		2.59	6.03	4.15			
42		Sup/Stc(t)	4.15 Ca						

Table 13A. High Nickel Coarse sample model results (continued).

	C	D	E	F	G	H	I	J
ELIAC ARC FN (PM10-1wt.)								
Sup/Stc(%)				0.46 Hm		0.29	0.66	0.46
WOOD BURNING (PM10-1wt.)						20.20	46.95	34.54
Sup/Stc(%)				34.54 C				
COMPOSITE (PM10-1wt.)								
(13 Strs)				19.53 Pb				
Sup/Stc(%)								

Table 138. Models' composites (wt).

Lin	Sample Compos	Lin Lin Cub Lin Equal Wt.					
		S	M	O	P		
C	20.0000	40.9005	40.4379	19.8374			
Al	1.3547	4.0212	4.0168	3.3243			
Si	3.7832	7.0547	7.0494	6.3517			
S	12.5549	16.4090	12.6901	5.6546			
Cl	0.4360	1.0663	0.8895	2.2772			
K	1.1521	1.0420	0.9794	1.3969			
Ca	1.9139	4.7858	4.7690	7.3208			
Ti	0.1623	0.2012	0.2007	0.1896			
Cr	0.0119	0.0223	0.0214	0.2160			
Mn	0.0397	0.0709	0.0701	0.7108			
Fe	1.1575	1.7647	1.7588	4.0929			
Ni	0.1658	0.0145	0.0130	0.0632			
Cu	0.0810	0.0126	0.0118	0.0988			
Zn	0.1331	0.0522	0.0516	0.1651			
As	0.0164	0.0063	0.0061	0.0051			
Br	0.0316	0.0173	0.0159	0.0570			
Cd	0.0035	0.0054	0.0041	0.0659			
Pb	0.0088	0.0450	0.0419	0.3277			

Table 13C. Percent Difference Stat.

Measures	R	S	T	U
Lin	58.540	49.730	552.956	
Compas	118.018	112.753	971.126	
Median	53.413	37.816	74.191	
Maximum	441.971	377.538	3630.490	
Minimum	-91.232	-92.153	-68.993	

Table 130. Composites' weight factors (%).

Src	Lin Elm Cdn Elm		Equal Wt.	
	Compos	Compos	Compos	Compos
V	W	X	Y	Z
HULFATE	51.835	29.288	7.652	
COAL-FBR	10.881	10.881	7.652	
HR SLUDGE	0.299	0.225	7.652	
DIESEL FUEL	15.969	15.969	7.652	
ASOLIN FUEL	2.933	2.933	7.652	
NOF-EXOS	13.415	13.415	7.652	
LUM-CROSS	1.936	1.936	7.652	
LUM-POTLIN	0.913	0.913	7.652	
ING KILA	16.729	11.960	7.652	
GRAVEL ROAD	6.337	6.337	7.652	
HR BAL HILL	4.152	4.152	7.652	
ALCAC INC P1	0.456	0.456	7.652	
WOOD BURNING	34.542	34.542	7.652	

Table 14A. High Lead Fine sample model results.

A	B	C	D	E	F	G	H	I	J	Sup/ Ltn Src Eln Clns Col F Cell H6 Cols F (t) -1A (t) or I
8	RAC1113	EL-Pb-Flu	N.A.	38.33						
9										
10	Nitrazes	(Pb10-1vc)	N.A.	3.42						
11	SULFATE	(Pb10-1vc)	4.23	11.04	11.04					
12		Sup/Strc(t)	17.45 S							
13										
14	COAL-Per	(Pb10-1vc)	1.53	5.04	3.97					
15		Sup/Strc(t)	3.97 H1							
16										
17	SEN SLUDGE	(Pb10-1vc)	0.50	1.31	1.31					
18		Sup/Strc(t)	1.54 Cd							
19										
20	DIESEL FUEL	(Pb10-1vc)	20.21	52.73	22.75					
21		Sup/Strc(t)	22.75 C							
22										
23	GASOLIN FUEL	(Pb10-1vc)	3.24	8.44	4.75					
24		Sup/Strc(t)	4.75 Br							
25										
26	DUST-BROSEN	(Pb10-1vc)	4.83	12.61	9.83					
27		Sup/Strc(t)	9.83 Al							
28										
29	ALUM-DROSS	(Pb10-1vc)	0.77	2.00	1.69					
30		Sup/Strc(t)	1.69 Cl							
31										
32	ALUM-POTLIN	(Pb10-1vc)	2.86	7.46	5.38					
33		Sup/Strc(t)	5.38 Al							
34										
35	LIME KTLA	(Pb10-1vc)	0.76	1.99	1.99					
36		Sup/Strc(t)	2.48 H1							
37										
38	GRAVEL ROAD	(Pb10-1vc)	6.29	16.42	13.88					
39		Sup/Strc(t)	13.88 Ca							
40										
41	CEN BAL MIL	(Pb10-1vc)	5.68	14.81	9.49					
42		Sup/Strc(t)	9.49 Ca							

Table 14A. High Lead Fine sample model results (continued).

C	D	E	F	G	H	I	J
ELAC ABC PB (Pb10-1vc)							
Sup/Strc(t)	0.11 H1						
WOOD BUILDING (Pb10-1vc)							
Sup/Strc(t)	34.54 C	20.20	52.70	34.54			
COMPOSITE (Pb10-1vc)							
(13 Str)	Sup/Strc(t)	13.67 H1					

Table 14B. Models' composites (wt).

Eln	Sample	Compos	Compos	Compos	Compos	Compos	Compos	Compos	Compos	Compos
L	N	M	N	O	P					
C	20.0000	46.3410	46.2935	19.8374						
Al	0.3179	2.4778	2.4732	3.3243						
Si	2.9459	5.2883	5.2767	6.3517						
S	4.2297	5.5512	4.8673	5.6546						
Cl	0.3832	0.5873	0.5510	2.2772						
E	0.3240	0.6637	0.6600	1.3969						
Ca	4.1988	9.0213	9.0075	7.3288						
Ti	0.1799	0.1248	0.1238	0.1896						
Cr	0.0215	0.0179	0.0165	0.2160						
Mn	0.0580	0.0456	0.0450	0.7188						
Fe	4.1541	1.2675	1.2545	4.0929						
Bi	0.0008	0.0058	0.0056	0.0632						
Cu	0.1588	0.0283	0.0181	0.0988						
Zn	0.1835	0.0409	0.0401	0.1651						
As	0.0075	0.0030	0.0029	0.0051						
Br	0.0115	0.0228	0.0217	0.0570						
Cd	0.0128	0.0135	0.0115	0.0659						
Pb	0.1549	0.0088	0.0737	0.3277						

Table 14C. Percent Difference Stat.

Item	Ltn Eln	Cub Eln	Equal Wt.	Compos	Compos	Compos
Mean	51.000	46.395	656.955			
S.D.	161.354	158.156	1775.385			
Median	-5.685	-15.282	93.113			
Maximum	631.542	611.786	7856.146			
Minimum	-86.561	-87.969	-34.475			

Table 14D. Composites' weight factors (%).

Src	Ltn Eln	Cub Eln	Equal Wt.	Compos	Compos	Compos
SULFATE	17.449	11.036	7.692			
COAL-Per	3.969	3.969	7.692			
SEN SLUDGE	1.545	1.366	7.692			
DIESEL FUEL	22.753	22.753	7.692			
GASOLIN FUEL	4.751	4.751	7.692			
DUST-BROSEN	9.830	9.830	7.692			
ALUM-DROSS	1.694	1.694	7.692			
ALUM-POTLIN	5.381	5.381	7.692			
LIME KTLA	2.481	1.990	7.692			
GRAVEL ROAD	13.877	13.877	7.692			
CEN BAL MIL	9.491	9.491	7.692			
ELAC ABC PB	0.113	0.113	7.692			
WOOD BUILDING	34.542	34.542	7.692			

Table 15. Models' Results.

Samples ->	REC0313A	REC1207	REC1228A	REC0731A	REC1017	REC1128	REC1113	Annual	Sel Srcs Max %										
	High CF	High PF	High PM10	High "S"	High "As"	Hi-Ni-Crs	Hi-Pb-Fin	Average	Contrib Range										
PM10									Min Max										
Conc (ug/m3)	42.3	42.1	50.2	29.5	21.7	8.3	25.7	24.3											
Fine Fraction	0.271	0.776	0.215	0.92	0.204	0.351	0.615	0.678											
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
11																			
12	"LIMITED ELEMENT" Model - Src's maximum percent contribution to Smp with limiting element (%).																		
13																			
14	SULFATE	7.604 S	12.148 S	6.145 S	66.156 S	81.288 S	51.835 S	17.449 S	37.191 S	6.145	81.288								
15	COAL-PWR	10.523 Cr	5.346 Al	0.387 Al	3.390 Ni	15.829 Al	10.881 Al	3.969 Ni	5.526 Al	0.387	15.829								
16	SEW SLUDGE	0.652 Pb	1.581 Pb	0.207 Cu	0.724 Pb	0.195 Cd	0.299 Pb	1.545 Cd	1.220 Pb	0.195	1.581								
17	DIESEL FUEL	22.753 C	22.753 C	11.288 Ni	22.599 Ni	18.433 Cl	15.969 Pb	22.753 C	22.753 C	11.288	22.753								
18	GASOLN FUEL	3.189 Br	7.195 Br	1.829 Br	1.338 Br	9.595 Br	2.933 Pb	4.751 Br	5.100 Br	1.338	9.595								
19	DUST-EROSH	38.473 Mn	8.000 Al	0.479 Si	8.475 Ni	21.290 Si	13.415 Si	9.830 Al	8.118 Si	0.479	38.473								
20	ALUM-DROSS	1.176 Cl	1.581 Cl	0.185 Cl	1.093 Cl	0.037 Cl	1.936 Cl	1.694 Cl	0.764 Cl	0.037	1.936								
21	ALUM-POTLIN	25.810 Al	4.379 Al	0.317 Al	4.843 Ni	1.037 Cl	8.913 Al	5.381 Al	4.526 Al	0.317	25.810								
22	LIME KILN	10.161 Cl	4.890 Ni	1.058 Ni	2.119 Ni	0.317 Cl	16.729 Cl	2.481 Ni	6.598 Cl	0.317	16.729								
23	GRAVEL ROAD	8.472 Ca	15.648 Ca	0.463 Ca	33.898 Ni	23.440 Ca	6.337 Ca	13.877 Ca	6.637 Ca	0.463	33.898								
24	CBM BAL MIL	5.550 Ca	10.251 Ca	0.303 Ca	25.554 Ca	15.356 Ca	4.152 Ca	9.091 Ca	4.348 Ca	0.303	25.554								
25	ELEC ARC FN	0.251 Cr	0.224 Ni	0.048 Ni	0.097 Ni	0.448 Ni	0.456 Mn	0.113 Ni	0.289 Mn	0.048	0.456								
26	WOOD BURNNG	34.542 C	34.542 C	34.542 C	34.542 C	8.295 Cl	34.542 C	34.542 C	34.542 C	8.295	34.542								
27																			
28																			
29	Percent Difference Statistics.																	Average	
30																			
31	Mean	115.68	67.67	55.88	89.51	60.87	58.54	51.00	60.69	69.98									
32	S.D.	102.32	109.44	113.86	164.52	168.72	118.02	161.35	85.24	127.94									
33	Median	186.85	222.46	193.94	361.08	382.80	251.60	359.05	141.00	262.35									
34	Maximum	318.38	379.55	306.98	670.24	684.55	411.97	631.54	227.95	453.90									
35	Minimum	-55.32	-65.36	-80.89	-51.93	-81.05	-91.23	-86.56	-54.05	-70.80									
36																			
37																			
38																			
39	"COMBINED ELEMENTS" Model - Least of LE model or Src Wt./Smp Wt. (%).																		
40																			
41	SULFATE	3.915	8.479	6.145	28.707	32.469	29.208	11.036	24.317	3.915	32.469								
42	COAL-PWR	10.523	5.346	0.387	2.951	12.685	10.881	3.969	5.526	0.387	12.685								
43	SEW SLUDGE	0.449	1.476	0.207	0.420	0.104	0.225	1.306	1.066	0.104	1.476								
44	DIESEL FUEL	22.753	22.753	11.288	22.599	18.433	15.969	22.753	22.753	11.288	22.753								
45	GASOLN FUEL	3.189	7.195	1.829	1.338	9.595	2.933	4.751	5.100	1.338	9.595								
46	DUST-EROSH	38.473	8.000	0.479	7.456	17.242	13.415	9.830	8.118	0.479	38.473								
47	ALUM-DROSS	1.129	1.581	0.185	0.884	0.027	1.936	1.694	0.764	0.027	1.936								
48	ALUM-POTLIN	25.810	4.379	0.317	4.607	0.908	8.913	5.381	4.526	0.317	25.810								
49	LIME KILN	6.637	4.331	1.058	1.166	0.161	11.960	1.990	5.473	0.161	11.960								

Table 15. Models' Results (continued).

Samples ->	REC0313A	REC1207	REC1228A	REC0731A	REC1017	REC1128	REC1113	Annual	Sel Srcs Max %										
	High CF	High PF	High PM10	High "S"	High "As"	Hi-Ni-Crs	Hi-Pb-Pin	Average	Contrib Range										
PM10									Min Max										
Conc (ug/m3)	42.3	42.1	50.2	29.5	21.7	8.3	25.7	24.3											
Fine Fraction	0.271	0.776	0.215	0.92	0.204	0.351	0.615	0.678											
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
61																			
62 GRAVEL ROAD	8.163	15.648		0.463	27.527	17.521	6.337	13.877	6.637	0.463	27.527								
63 CEM BAL MIL	5.550	10.251		0.303	25.554	15.356	4.152	9.091	4.348	0.303	25.554								
64 ELEC ARC FN	0.251	0.224		0.048	0.097	0.448	0.456	0.113	0.289	0.048	0.456								
65 WOOD BURNNG	34.542	34.542		34.542	34.542	7.992	34.542	34.542	34.542	7.992	34.542								
66																			
67 Percent Difference Statistics.																		Average	
68																			
69 Mean	101.23	64.62		55.88	62.85	35.68	49.73	46.39	55.42	58.98									
70 S.D.	92.34	108.02		113.86	144.29	143.81	112.75	158.16	83.82	119.63									
71 Median	178.14	216.83		193.94	315.18	322.26	234.85	349.88	141.02	244.01									
72 Maximum	288.28	368.11		306.98	565.89	560.37	377.54	611.79	227.44	413.30									
73 Minimum	-68.01	-65.54		-80.89	-64.48	-84.16	-92.15	-87.97	-54.60	-74.72									
74																			
75																			
76 "EQUAL WEIGHT" Model - Srcs contribute equally by factor of 100 % / 13 (%).																			
77																			
78 SULFATE	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
79 COAL-PWR	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
80 SEW SLUDGE	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
81 DIESEL FUEL	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
82 GASOLN FUEL	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
83 DUST-EROSN	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
84 ALUM-DROSS	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
85 ALUM-POTLIN	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
86 LIME KILN	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
87 GRAVEL ROAD	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
88 CEM BAL MIL	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
89 ELEC ARC FN	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
90 WOOD BURNNG	7.692	7.692		7.692	7.692	7.692	7.692	7.692	7.692										
91																			
92																			
93 Percent Difference Statistics.																		Average	
94																			
95 Mean	646.67	563.97		3728.65	1146.84	1988.43	552.86	656.96	605.78	1236.27									
96 S.D.	992.97	952.11		4620.98	2217.71	6230.79	971.13	1775.38	834.28	2324.42									
97 Median	2029.18	1990.48		9274.89	4639.97	13716.35	1849.74	3945.31	1382.06	4853.50									
98 Maximum	4004.62	3935.63		18548.96	9215.19	27352.35	3630.49	7856.15	2726.84	9658.78									
99 Minimum	-53.73	-45.34		-0.81	-64.74	-80.34	-68.99	-34.48	-37.28	-48.21									

VITA

Robert Jan Benjamin was born in Harriman, Tennessee on January 21, 1943. He completed elementary and junior high schools in Harriman and Knoxville, Tennessee and finished high school at H.B. Plant High School in Tampa, Florida in 1961. Completing his undergraduate education on a part-time basis, he received his Bachelor of Science degree at the University of South Florida at Tampa, Florida in August, 1970.

He was employed by the Tennessee Valley Authority from 1970 to August 1988 as a mechanical design engineer on nuclear power plant projects. In September, 1989 he entered the University of Tennessee and in December, 1993 he received his Master of Science degree in Environmental Engineering.