

Copyright Warning & Restrictions

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be “used for any purpose other than private study, scholarship, or research.” If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of “fair use” that user may be liable for copyright infringement,

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

Please Note: The author retains the copyright while the New Jersey Institute of Technology reserves the right to distribute this thesis or dissertation

Printing note: If you do not wish to print this page, then select “Pages from: first page # to: last page #” on the print dialog screen

The Van Houten library has removed some of the personal information and all signatures from the approval page and biographical sketches of theses and dissertations in order to protect the identity of NJIT graduates and faculty.

ABSTRACT

Title of Thesis: TRENDS IN METAL (Pb, Ni, Zn, As, AND Se) CONCENTRATIONS IN THE NEW JERSEY AIR ENVIRONMENT

Geoffrey Ejiofor: Master of Science, 1986

Thesis Directed by: Dr. Joseph W. Bozzelli, Professor

The trend and atmospheric concentrations of five trace elements (Pb, Zn, Ni, As and Se) were studied at Newark (urban site) and Ringwood (rural site), New Jersey, during January - September 1985, whilst the Hackensack Meadowlands, New Jersey were monitored during October 1985-March 1986. The analytical procedure involved collection of the airborne particulates on a glass fiber filter using a non-dichotomous high volume sampler. The samples were digested and analyzed using the atomic absorption spectrophotometer. It was ascertained that Newark and Meadowlands exhibited higher average concentrations of Zinc and Lead than Ringwood. It was concluded all the metals originated mostly from regional pollutant transport at the Ringwood site, while Lead and to a lesser extent Zinc, Nickel, Arsenic and Selenium arose mainly from local vehicular and industrial sources at the Newark site. In the Meadowlands, Lead and Zinc were assumed to be from local sources around the area; such as nearby highway with heavy traffic, plus the active landfills. Ni, As and Se were assumed to be from regional transport due to wind direction effect at the site. The decreased level of lead can be attributed to mandatory use lead free gasoline in late model cars.

TRENDS IN METAL (Pb, Zn, Ni, As and Se)
CONCENTRATIONS IN THE NEW JERSEY AIR ENVIRONMENT

by

Geoffrey Ike Ejiofor

Thesis submitted to the faculty of the Graduate School of the
New Jersey Institute of Technology in partial
fulfillment of the requirements for the degree of
Master of Science

1986

Blank Page

APPROVAL SHEET

Title of Thesis: Trends in Metal (Pb, Ni, Zn, As and Se) Concentrations in the New Jersey Air Environment

Name of Candidate: Geoffrey Ejiofor
Master of Science, 1986

Thesis and
Abstract Approved:

Joseph W. Bozzelli, Ph.D
Professor of Chemistry
Department of Chemical
Engineering and Chemistry

Date

Barbara B. Kezbekus, Ph.D
Professor of Chemistry
Department of Chemical
Engineering and Chemistry

Date

Howard S. Kimmel, Ph.D
Professor of Chemistry
Department of Chemical
Engineering and Chemistry

Date

VITA

Name: Geoffrey Ike Ejiofor.

Permanent address: 9 Summit Street, Apt C3, East Orange, NJ, 07017

Degree and date to be conferred: Master of Science, 1987

Date of Birth:

Place of Birth:

Secondary Education: Oraukwu High School (1976).

<u>Collegiate Institutions attended</u>	<u>Dates</u>	<u>Degree</u>	<u>Date of Degree</u>
New Jersey Institute of Technology	1984-1987	M.S.	1987
State University of New York College at Buffalo	1982-1984	B.A.	1984
Institute Of Management and Technology Enugu-Nigeria	1977-1981	Dip.	1981

Major: Engineering Science

ACKNOWLEDGMENTS

I wish to express my gratitude to Dr. Joseph W. Bozzelli for his generosity and cooperation with regard to time and attention towards me throughout the entire course of the project. I would also like to thank him for his financial and moral help. In addition, I have to express my gratefulness to Paul Galluzz of The Hackensack Meadowlands Environmental Center for providing me with their air sampler. Ms. Nancy Bae is credited with the typing of the paper and computer analysis. Finally, I am dedicating this thesis to my parents for given me the opportunity to acquire the education and knowledge.

TABLE OF CONTENTS

Chapter	Page
ACKNOWLEDGMENT	ii
I INTRODUCTION	1
1.1 Background	1
1.2 Objective	5
II PUBLISHED RESEARCH	7
2.1 Source Apportionment Analysis	7
2.2 Urban and Rural Relationship	9
2.3 Seasonal Variations	11
2.4 Potential Health Effect at Published Levels	12
III EXPERIMENTAL METHODS	14
3.1 Sample Collection	14
3.2 Sampling	15
3.3 Atomic Absorption Analysis	17
3.4 Operating Principles	21
3.5 Analytical Methods	22
IV RESULTS AND DISCUSSION	25
4.1 Overall Averages	25
4.2 Monthly Averages	33
4.3 Quarterly Averages	49
4.4 Averages by Day of Week	60
V CONCLUSIONS	65
5.1 Error Analysis	65

TABLE OF CONTENTS (continue)

Chapter		page
APPENDIX 1	NEWARK SITE	69
APPENDIX 2	RINGWOOD SITE	74
APPENDIX 3	HACKENSACK MEADOWLANDS SITE	79
NOTES		82
BIBLIOGRAPHY		85

LIST OF TABLES

Tables		Pages
3-1	U.S. Environmental Protection Agency Priority Pollutants (Metals)	14
3-2	Spectrophotometric Conditions of Each Metal	20
4-1	Average Concentrations of Each Metal by Sampling Site and the Ranges	26
4-2	Monthly Average Concentrations by Sites ..	36
4-3	3 Month Average Concentrations by Sites ..	51
4-4	Overall Average Concentrations by Day of Week by Sites	63
5-1	Minimum Detectable Quantities	67
5-2	Summary of Error Analysis	68

LIST OF FIGURES

Figures		Pages
3-1	Calibration Curve for Lead	18
3-2	Calibration Curve for Arsenic	24
4-1	Overall Average Concentrations by Sites	30
4-2	Monthly Average Concentrations by Metals ...	39
4-3	Quarterly Average Concentrations by Metals .	55

CHAPTER 1

INTRODUCTION

1.1 Background

During the last two decades, there has been an increasing interest in air pollution studies throughout the world, and a large amount of work has been carried out to assess the environmental pollution by heavy metals. Few systematic studies have been made of trace elements in atmospheric aerosols at rural sites and urban areas. The concentrations of trace elements on airborne particulates serve as indicators of the sources of atmospheric materials and are used in receptor modeling to study the histories of air masses. Compounds of the metals are, of course, very widespread in the environment (1), mainly as minerals. Many of the minerals are located in the soils; but also lakes, rivers, oceans and the air. They occur both as a result of natural processes and of man made activities. The atmosphere is recognized as an important contributor to the geochemical cycling of many trace elements. (2)

The determination of toxic element concentrations in airborne particulates will establish background and individual event levels for these species in regions throughout the state of New Jersey. The primary sources of inorganic atmospheric aerosols are wind-blown continental dust, sea spray, biological activity and anthropogenic

emissions.(3) The first three activities represent primarily natural sources of metals to the atmosphere, while the anthropogenic emissions is the highest source for As,Se,Ni and Pb. The importance of anthropogenic sources to the atmospheric burden is best demonstrated on Pb, for which combustion of gasoline and smelter operations contribute most of the atmospheric emissions (4). The behavior of trace elements in the atmosphere depend on their chemical nature and size distributions and these two characteristics are mostly dependent on the originating sources and ambient atmospheric conditions. Whilst urban concentrations of metal such as of lead are well established, there are far fewer data upon the concentrations of other metals such as Zinc, Nickel, Arsenic and Selenium in urban air. Data upon the concentrations of these four elements in rural area are even more scarce. In urban areas, Zinc, Arsenic, Selenium and other chalcophile elements are usually associated with coal fired plants or sulfide ore smelters (5) while Nickel is an indicator of oil combustion. Although, receptor models have been most used on an urban scales, Husain and Samson (1979) showed that trace elements including toxic ones as Arsenic, Selenium, Nickel and Zinc could be transported by air masses from pollution source over long distance to rural regions (6). It is now well established that many high-temperature combustion and smelting operations emit particles containing toxic elements such as Arsenic, Selenium, Nickel, Zinc, and

Lead. Many of these elements are enriched in ambient urban aerosols by as much as 100 to 1000 fold over their natural crystal abundance (7).

Lead has been a common contaminant in the urban environment. In a monumental survey of lead in the atmosphere of three urban communities conducted by the U.S. Department of Health Education and Welfare, it was reported that downtown area of those cities had higher concentrations of lead than the outlying area of the cities sampled. (8)

The analysis of these elements was made easy due to use of the sophisticated instrumentation, including high-volume air pollution samplers and atomic absorption spectrophotometer. Advances in technology continue to press the limits of pollutant detection. Homes, schools and offices environment are now in the spotlight. The relationship between indoor and outdoor airborne particles has been reviewed by Anderson (9) (1972) and Benson et al (10) (1972). They concluded that indoor and outdoor particulate concentrations are about equal. But, Thompspon, Hensel and Kats (1973) found that indoor particulate levels were heavily influenced by traffic from outdoors, especially in schools. (11)

Complaints of undefined illness, unexplained diseases and fatigue may serve to focus attention on levels of these trace elements in indoor environments. The steady increased quantity of Lead in the city environment due to heavy industrialization and auto exhaust was one of the well

recognized environmental problems. Although it is now decreasing due to increased use of unleaded gasoline. Inhaled lead is an important contribution to the total human lead exposure, even though the amount of lead orally ingested is considered to be higher than that inhaled. The reason for the concern regarding inhaled lead is that the physiological absorption of lead from respired particulate is much more efficient than that from ingested material.

In the developed countries, the effect of lead on human population has been an important research subject for more than a decade. Medical research thrusts in these countries have been in the area of both clinical and subclinical effects of lead on human population (12). Under normal conditions, more than 90% of the lead retained in the body is in the skeleton (13). Lead poisoning results from very high level of lead in the human body, particularly in the soft tissue, and it most often affects the blood, kidneys and nervous system. Without clearcut answer to the questions concerning the consequences of such inadvertent exposure, the public is resigned to a state of understandable anguish. Although, other heavy metals such as Zinc, Nickel, Arsenic, and Selenium are widely dispersed throughout the environment and in the biosphere, their concentrations in harmful forms are rarely such as to give rise to anxiety.

1.2 Objective

The objective of this study is to apply a perspective that includes quantitative analysis and trends of airborne toxic metal in an urban and rural areas. The work involves analysis of the airborne samples collected in a glass fiber filter for 24 hours once every sixth day in order to determine the concentrations and the trends of the metal in an urban and rural areas. The urban site is Newark, New Jersey which was sampled for 9 months (from January to September 1985). It is a representative of a different kind of population-industrial-commercial interface. The rural site is in Ringwood, New Jersey, which was also sampled for 9 months (January to September 1985). It is considered a northeastern regional background location. The third site was the administrative building roof top of the Environmental Center, Hackensack, Meadowlands which is approximately equidistant between an active landfill and the highway. The sampling was done for 6 months (October 1985 to March 1986). This area is unusual in that there is no significant industrial, commercial or municipal emission of metals in the locality (14). Although extensive analyses have already been conducted on these data as examinations of seasonal variations, pollution episodes, interurban

differences and source apportionment on some metals, this paper will focus on Arsenic, Selenium, Nickel, Zinc and Lead metals.

CHAPTER 2

PUBLISHED RESEARCH

2.1 Source Apportionment Analysis

The behavior of trace metals in the atmosphere depend on their chemical nature and size distribution. These two characteristics are mostly dependent on their sources and the ambient atmospheric conditions (15). In 1981 (Wolff and Korsog) (16) conducted a study on total suspended particulate during the months of June, July and August in Detroit, Michigan because of the belief that the highest TSP values are generally observed during these months. Their studies centered on determination of major chemical constituents in inhalable particulate matter, contributions of the fine particulate species to the TSP and in trying to identify the major sources of particulate matter. The week of 15-21 July 1981 was selected for elemental analysis for the reason that the week contained one of the most severe pollution episodes during the study period in terms of low visibility and high ozone in the city of Detroit, Michigan. Moreover, just before and immediately after this 4-day episode, two of the clear periods in terms of visibility were observed. The area was heavily loaded with diversity of industries such as coal and oil fired boilers, foundaries, incinerators, coke

ovens, cement plants, iron and steel plants, motor vehicle manufacturing processes chemical plants and oil refineries. So, these posed a problem in determining the principal sources of the particulates.

In their study (17), they found out that fine particulate mass was loaded moderately with Nickel (Ni) most likely representative of fuel oil combustion, and also showed high loading for Zn which suggests that this is an incineration term. They estimated that Zn comprised about 2% of fine particulate mass from incinerators. The components in the coarse particle mass were heavily loaded with Pb which might represent motor vehicle emission. The estimated vehicular contribution to fine particles was 7.3%. In combination with other metals, As and Se were attributed to be the constituents of fly ash produced from coal combustion. The concentrations of AL, Si, and K elements in fly ash from coal-fired power plants increased markedly with decreasing particle size.

2.2 Urban and Rural Relationship

Harrison and Williams (18) studied the concentrations of airborne metals such as Pb and Zn present in rural and urban sites in order to examine relationships statistically between metals at each site. It was seen that the mean Pb levels were more than an order of magnitude higher at the urban site than at the rural site. Also, there was an increased level of Zn at the urban site. This confirmed the major vehicular source of Pb and lesser source of Zn at the urban site. It was found that Zn was present in tire tread samples at the slightly higher concentration. So higher levels of Lead and Zinc observed in high traffic density area, support the hypothesis that automobiles are a likely source of Pb and Zn. Although the atmospheric concentration of these were higher in city area compared with the suburbs, they apparently exhibit no other significant trends. The significant correlation for urban Zn with rural Zn could result from facile transport of airborne Zn arising from urban area. An explanation for these correlation may lie in the differences between the meteorological conditions associated with more polluted air masses. In the case of Pb at the rural sites, atmospheric transport from distant sources again seemed to be the dominant influence. It is notable that the difference between urban and rural Pb sectorial concentrations is higher for some areas. This might be suggestive of the types of

meteorological effects mentioned. Thus atmospheric variations affecting dispersion, such as changes in atmospheric mixing depth, could produce a more marked effect upon Pb compared with Zn. Supposing that the airborne Zn from a local source at the urban site was in coarse particle from tire wear, and tend to be deposited close to the source. Conversely, Pb emitted as fine particles from vehicle exhausts could remain airborne over longer distance.

2.3 Seasonal Variations

In published study conducted by Harrison and Williams (1982) (19) on airborne Lead and Zinc at rural and urban sites, their results showed a high variability for all the metals at both sites. It showed that the mean levels of Pb and Zn were higher during the "winter" months (Oct.-March) than during the "summer" (April-September). At the rural area this effect was more marked for Zn than for Pb. They attributed two sets of factors which may have produced this seasonal fluctuations. Firstly, they said that the atmospheric emission rates of the metals may be greater in winter, due to increased burning of fossil fuels. They also noted, however, that this should be relatively unimportant for airborne Pb, where the predominant motor-vehicle source should be virtually constant throughout the year. Secondly, they suggested seasonal meteorological variation may have been important; temperature inversion layers within the atmosphere are more persistent in winter than in summer. This, they said should restrict vertical mixing of the atmosphere during the winter, and thereby produce higher concentrations of airborne metals near ground level.

Another study (McInnes 1978) (20) said that an increase of airborne concentration during winter is especially characteristic of "industrial" pollutant metals.

2.4 Potential Health Effect at Published Levels

Health scientists have paid more attention to assessment of health risks from exposures to outdoor air pollutants. In their studies, they consider: time variations in concentrations of pollutants and number of persons affected. Alimentary and respiratory tracts have been identified as a major routes by which lead enters the body. Stephen Hall (21) (1972) found out that under normal condition, more than 90% of the lead retained in the body is in the skeleton. With the passage of time absorbed lead becomes progressively more deeply buried in the bone matrix. This develops a potentially dangerous pool of exchangeable lead which can persist for months or even years. The effect of excessive amount of lead in the blood is anemia and in severe case it may lead to kidney failure. The Lead effect on the central nervous system results to convulsions or swelling of the brain. Similarly, repeated bouts of lead poisoning can also cause permanent brain damage.

Chronic lead poisoning results from a slow buildup of lead over a period of years or as after effects by slow build up of acute poisoning. Chronic lead poisoning, however, often without symptoms, is difficult to diagnose and may only be recognized after irreversible damage has been done. Acute lead poisoning has easily recognizable symptoms, and if treated in time, permanent damage can be avoided.

The minimum blood concentration of lead below which it is most unlikely that poisoning will occur is 80 ug of lead per 100 ml of blood for adults. In children, the threshold is much lower. Nickel and Zinc are of similar toxicity to Lead, but with the exception of isolated instances have been found in much lower concentrations than Lead. The poisonous effect of Arsenic and Selenium on human beings has been increasingly recognized. Arsenic poisoning produces diseases of the nerves and skin, leading to serious tissue damage because of destruction of the capillary system.. Selenium, on the other hand is an essential trace element which occurs in nature in small quantities, but is toxic in high concentrations

CHAPTER 3
EXPERIMENTAL METHOD

3.1 Sample Collection

Airborne particulates collected at Newark and Ringwood sites were taken by New Jersey Department of Environment Protection personnel. The samplings were done once every sixth day for 24 hours. The Meadowland samplings were done by the author for the same time period and day.

Table 3.1

United States Environmental Protection Agency Priority
Pollutants (metals)

Antimony	Sb
Arsenic	As
Beryllium	Be
Cadnium	Cd
Chromium	Cr
Copper	Cu
Lead	Pb
Mercury	Hg
Nickel	Ni
Selenium	Se
Silver	Ag
Thorium	Th
Zinc	Zn

3.2 Sampling

Airborne particulates at the Meadowland site were collected with high-volume samplers. Each sampler consisted of General Metal Works (22) (GMW) 2000 or Staplex (23) TF 1a Hi-vol Assemblies that were outfitted with 102 mm diameter filters.

Each sampler was fitted with a circular, umbrella-type dust and rain cover to prevent large, non-respirable particulates from being collected. This system helps in elimination of non-uniformities in sample collection with wind direction.

The filter materials used were glass fiber type which can collect 99.9% of all particulates up to 0.3 μm and can permit an average air flow of 25 cfm. The filters were dessicated (2 days), weighed and inserted immediately into the sampler before it was turned on, and after completion of the run, they were unloaded into a polythene envelope for immediate storage. They were later put inside a dessicator for four days in order to dry off the water contents and yield a dry particulates weight.

The sampler used in Hackensack Meadowland was calibrated with a differential pressure oil manometer. Slight changes in volume flow of air from beginning to end of sample collection were at times, observed. The pumps can collect particles of

35 um and under in size. The mean flow was calculated by averaging the initial and final flows. The total volume of air sampled was then calculated by multiplying the average flow by the number of minutes sampled

$$[(\text{meter}^3 / \text{minute}) \times (\# \text{ minutes}) = \text{meter}^3 \text{ volume}].$$

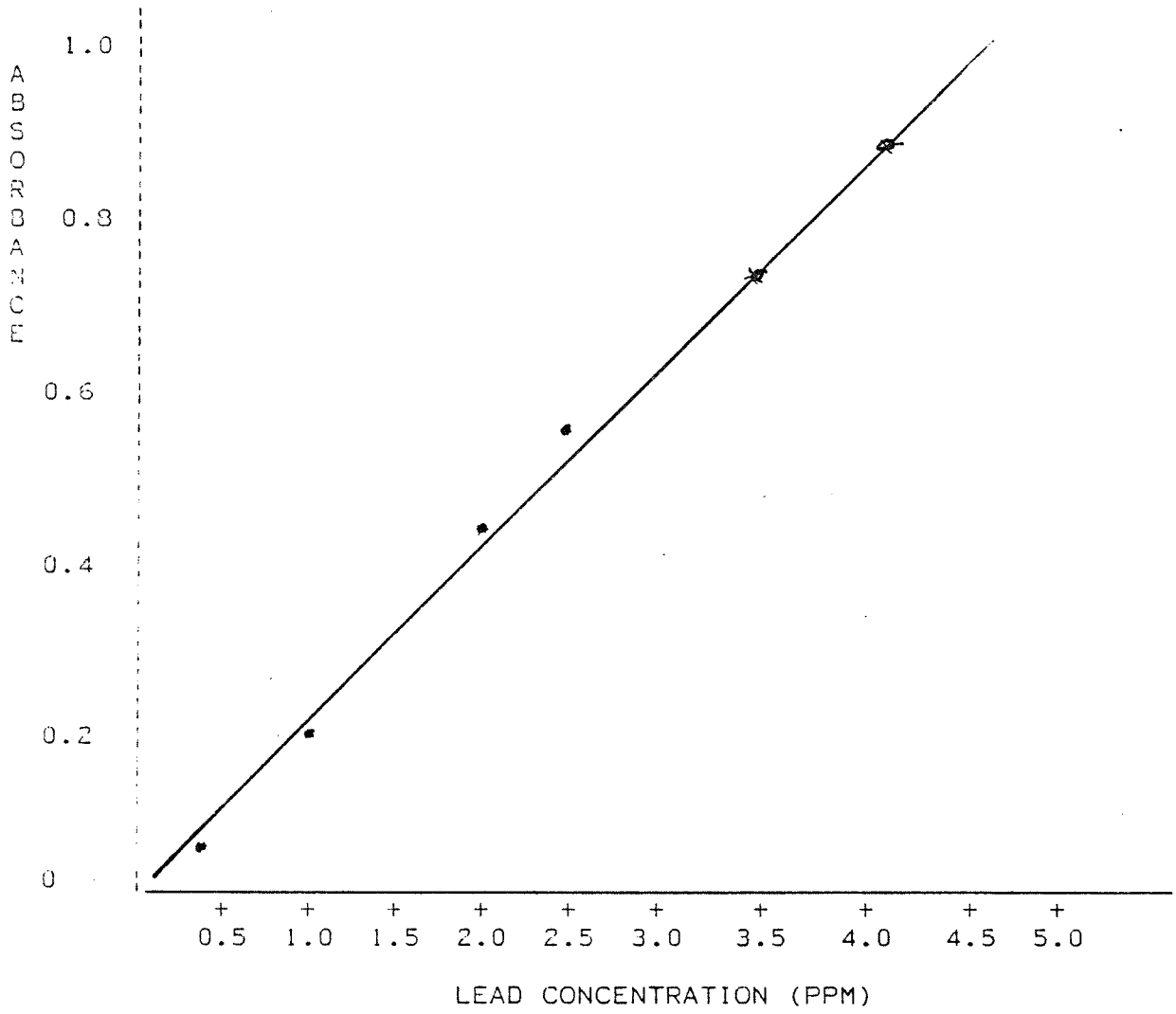
New Jersey Department of Environment Protection samples were collected with an automated sampler which monitored the outlet flow with a pressure transducer which transmitted a signal to a recorder for a continuous log. The pump can collect inhalable particulate matter of less than 10 um.

3.3 Atomic Absorption Analysis

Since determination of metallic element in a sample matrix was a complex process, a sensitive and selective method of analysis was desirable. The major breakthrough in the development of the use of measurement of atomic absorbance as an analytical technique came in the 1950's when Sir Alan Walsh realized that it was possible to use a line source which emitted very narrow lines at the same wave length than a continuum source. This atomic absorption spectrophotometer was tuned each day before the analysis was carried out. The tuning process involves burner alignment, optimization of lamp alignment and frequency. A Varian atomic absorption spectrophotometer, model 12 was used.

A calibration absorbance curve was prepared from standard metal solutions each time analysis was carried out. When samples were run, the standards were checked at the beginning and end of each metal analysis. In an analysis of a group of samples for a metal, all the spectrophotometric conditions were first optimized, the standards run and a graph of absorbance versus concentration plotted to verify the linear relationship. The zero reading was checked after each absorbance measurement and standards run to check for instrumental drift. Commercial standards (Fisher Scientific, Springfield, NJ) for each metal were purchased in concentrations of 1,000 ppm and were diluted with "super

FIGURE 3.1
LEAD CALIBRATION CURVE



water" (double deionized water - distilled) using calibrated pipets and volumetric flasks. The absorbance was directly proportional to the standard concentration and showed a linear relationship in accordance with Beer's law. A least square fit to this line was calculated using the standards data which were valid for AA(0,0) plots. The slope from this least squares calculation was then used to determine the concentration from the sample absorbance readings. Figure 3.1 shows a typical absorption curve for the lead standard. The spectrophotometric conditions for each metal and lamp are listed in Table 3.2. The line source commonly used is hollow-cathode lamp and flame is air-acetylene flame.

Table 3.2

Spectrophotometric Conditions for Each Metal

Element	Wavelength(nm)	Spectral Band Pass(nm)	Lamp
			Current (MA)
Arsenic *	193.7	1.0	8
Lead	217.0	1.0	5
Nickel	232.0	0.2	10
Selenium *	196.03	1.0	10
Zinc	213.86	0.5	5

* Hydride Generation Method

3.4 Operating Principles

As the instrument is turned on and the necessary parameters and units are set to the required positions, a light source (hollow cathode lamp) emits the spectrum of the metal being determined. A characteristic line from this spectrum is capable of being absorbed by atoms of the same metal if they are present in the sample. The liquid sample is converted to a fine aerosol by a nebulizer and the aerosol is reduced to the constituent atoms in a flame. The flame lies in the light path between the lamp and the line detector (monochromator and photomultiplier tube). If any of the metal is present in the sample, absorption of the characteristic line will provide an accurate measure of the concentration of the metal. The analytical precision is typically around 1% relative.

3.5 Analytical Methods

Prior to analysis for Pb, Zn, Ni, As and Se, samples of airborne particulates were extracted by digesting the particulates from the filter paper in an acid solution (mixture of 40% H₂O, 50% HNO₃ and 10% HCL) and three drops of 30% H₂O₂. The extraction process involved, cutting up the glass fiber filter into pieces and placing them in a 300 ml pyrex flask and adding 20 ml of acid solution. The acid-filter mixture was heated to boiling for twenty minutes and acid solution decanted through a polymeric filter into a 50 ml volumetric flask. The process of boiling and decanting was repeated and the flask rinsed with super water twice and filtered into the 50 ml volumetric flask. The super water was used to dilute the volume to mark. The sample was stored in the plastic volumetric flask and analysis performed with the atomic absorption spectrophotometer using a Varian Model 12 with an air-acetylene flame.

Known blank filter of identical material was taken through the whole procedure. This allowed background metal impurities which could originate from the filter paper, acids and glassware to be subtracted from the metal concentration analysis. Blank values of the filter paper and the reagent used are always small.

All the samples and standard solutions prepared were not analysed the same way for all metals. Arsenic and Selenium

were analysed differently from the Lead, Zinc and Nickel. The Arsenic and Selenium are hydride forming elements and they were analysed by a technique called hydride generation. The absorption cell was heated by the standard air/acetylene flame of the AA instrument. The hollow cathode beam passes through the quartz windows of the absorption cell so that the flame is not in the optical path and therefore, produces no noise or absorbance. During the analysis, 20 ml of prepared sample or standard was first acidified with hydrochloric acid and a reducing agent, sodium borohydride solution was added. As the solution mixture was stirred, the hydride gas was evolved and was passed into the heated quartz cell by directing an inert gas (N₂) through the reaction vessel. The passed gas dissociated into metallic element at the high temperature and absorbed radiation from the hollow cathode lamp. The required dissociation temperature is about 800 Celsius. As the gas was purged through the cell, the integration/read control of the atomic absorption spectrophotometer automatically triggered at the Peak signal time. The results can be read in peak height just as they are in conventional AA. Figure 3.2 shows typical absorption curve for Arsenic standard.

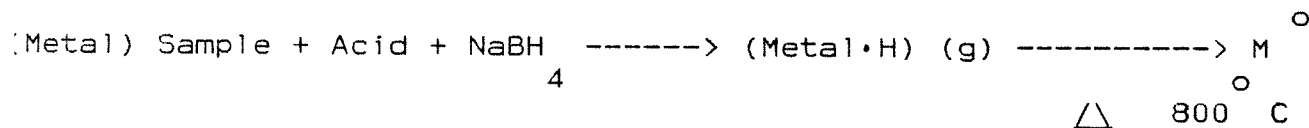
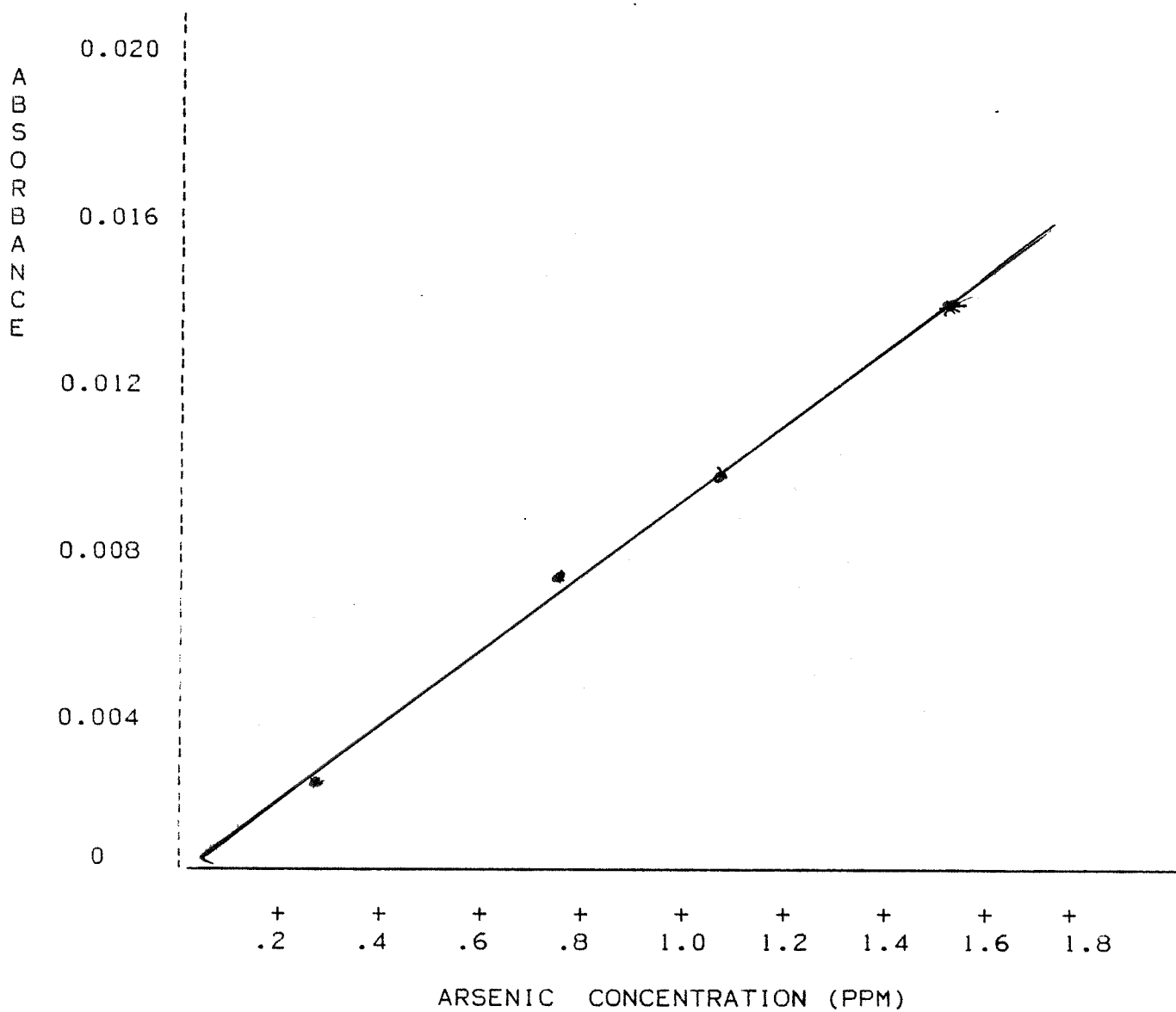


FIGURE 3.2
ARSENIC CALIBRATION CURVE



CHAPTER 4

RESULTS AND DISCUSSION

The concentrations of the airborne metals As, Pb, Ni, Se and Zn in the air at three locations in New Jersey are listed in the appendix section by sites and dates. The first listing contains the metal concentrations in microgram per cubic meter (ug/m^3) for the Newark site which was sampled from January-September 1985 while the second contains that of Ringwood site which was also sampled from January to September 1985. The third listing contains the concentrations of the metals from the Meadowland site. The sampling was from October 1985-March 1986. In the Newark site, the highest concentration of individual metals are as follows: Pb-1.67; Zn-3.33; Ni-0.61; As-0.053 and Se-0.081 ug/m^3 . In the Ringwood site, the highest concentration are: Pb-0.87; Zn-0.78; Ni-0.19; As-0.013 and Se-0.013 ug/m^3 while in Meadowlands the concentrations are: Pb-2.68; Zn-2.63; Ni-1.23; As-0.039 and Se-0.034 ug/m^3 .

4.1 Overall Averages

According to Table 4.1, the overall averaged concentrations of each metal for each sampling site is presented in microgram per cubic meter along with their ranges. The data are based on sampling duration of 24 hours for 9 months except the Meadowland site which was sampled for 6 months.

TABLE 4.1

3

Overall Average Concentrations (Ug/m³)
for each site

TOXIC METALS	NEWARK	RINGWOOD	MEADOWLAND *
Arsenic	0.026	0.0075	0.018
Lead	0.78	0.68	1.25
Nickel	0.22	0.045	0.59
Selenium	0.022	0.0077	0.014
Zinc	1.16	0.38	1.32

* Sampled for six months

3

Range of Concentrations (Ug/m³)

TOXIC METALS	NEWARK	RINGWOOD	MEADOWLAND
Arsenic	0.00-0.053	0.00-0.013	0.00-0.039
Lead	0.61-1.67	0.04-0.87	1.12-2.68
Nickel	0.00-0.61	0.00-0.19	0.00-1.23
Selenium	0.00-0.081	0.00-0.013	0.00-0.034
Zinc	0.47-3.33	0.00-0.78	1.11-2.63

The overall average concentration of lead detected in each site is below the EPA (quarterly average) air quality standard of 1.5 ug/m^3 . The Newark site had the average concentration of 0.78 ug/m^3 slightly higher than the Ringwood site which has the average of 0.68 ug/m^3 based on nine months sampling. The Meadowland site had the highest concentration of Lead 1.25 ug/m^3 .

The metal Zinc is found to be in high concentration at the Newark site (1.15 ug/m^3) compared to Ringwood (0.38 ug/m^3) for 9 months sampling programme. Meadowland site had the highest concentration (1.32 ug/m^3).

However, there is no corresponding elevation for airborne Arsenic and Selenium. Indeed, the average As and Se concentrations at the Newark during the 9 month sampling program (0.026 ug/m^3 and 0.022 ug/m^3 respectively) are higher than the corresponding values at Ringwood (0.0075 ug/m^3 and 0.0077 ug/m^3 respectively). The average concentrations of As and Se at Meadowlands based on 6 month sampling (0.028 ug/m^3 and 0.014 ug/m^3 respectively) are higher than the corresponding Ringwood site.

Moreover, there is a substantial enhancement of airborne Ni concentration at the Newark site (0.22 ug/m^3) relative to the Ringwood site (0.045 ug/m^3). Meadowlands again showed a higher concentration of 0.59 ug/m^3 than the Newark and Ringwood.

The overall average concentrations of each metal for each site are illustrated graphically in figure 4.1. From the graphs the Newark site has the highest concentration of Arsenic and Selenium. They show a very close relationship.

The high concentration at the site might be attributed to the emissions from a coal-fired power plant in this industrial area. Moreover, Ringwood exhibited the lowest concentration of all the metals. It might be due to remoteness of the area, where the possible sources of emission are rare. Based upon this, the wind directions will have had a greater influence on the regional transport of the metal to the site thereby contributing a significant pollutants.

The Newark and Ringwood showed closely related concentrations of lead. In case of rural site, atmospheric transport from distance sources again seems to be the dominant influence contributing to the local source. However, burning of leaded gasoline had been the major contributor of lead in the atmosphere. The Meadowland site exhibited the highest concentration of Lead, Nickel and Zinc. The high concentration of Lead might be attributed to the closeness of the sampling site to the landfill and high density traffic road.

Fuel oil combustion seems to be contributing to presence of Nickel in the atmosphere. Since Nickel is usually in fine particles, regional transport must influence its concentration.

The high concentration of Zinc metal shown at Meadowland site must have confirmed the emission of Zinc from active landfill activities. Greenberg (24) et al (1982) estimated that Zinc comprised about 12% of total particulate in refuse

incineration. Moreover, automobile tire wears contributes significantly to Zinc presence in the atmosphere. Since landfill and highway are close to the sampling site, the high loading of Zinc could be attributed to their presence.

The Arsenic, Nickel, Selenium and Zinc were all about three to four times higher in Newark and Meadowlands than in Ringwood. Lead was about twice as high in Meadowlands as Newark.

FIGURE 4.1
OVERALL AVERAGE CONCENTRATION $\mu\text{g}/\text{m}^3$
FOR EACH SITE

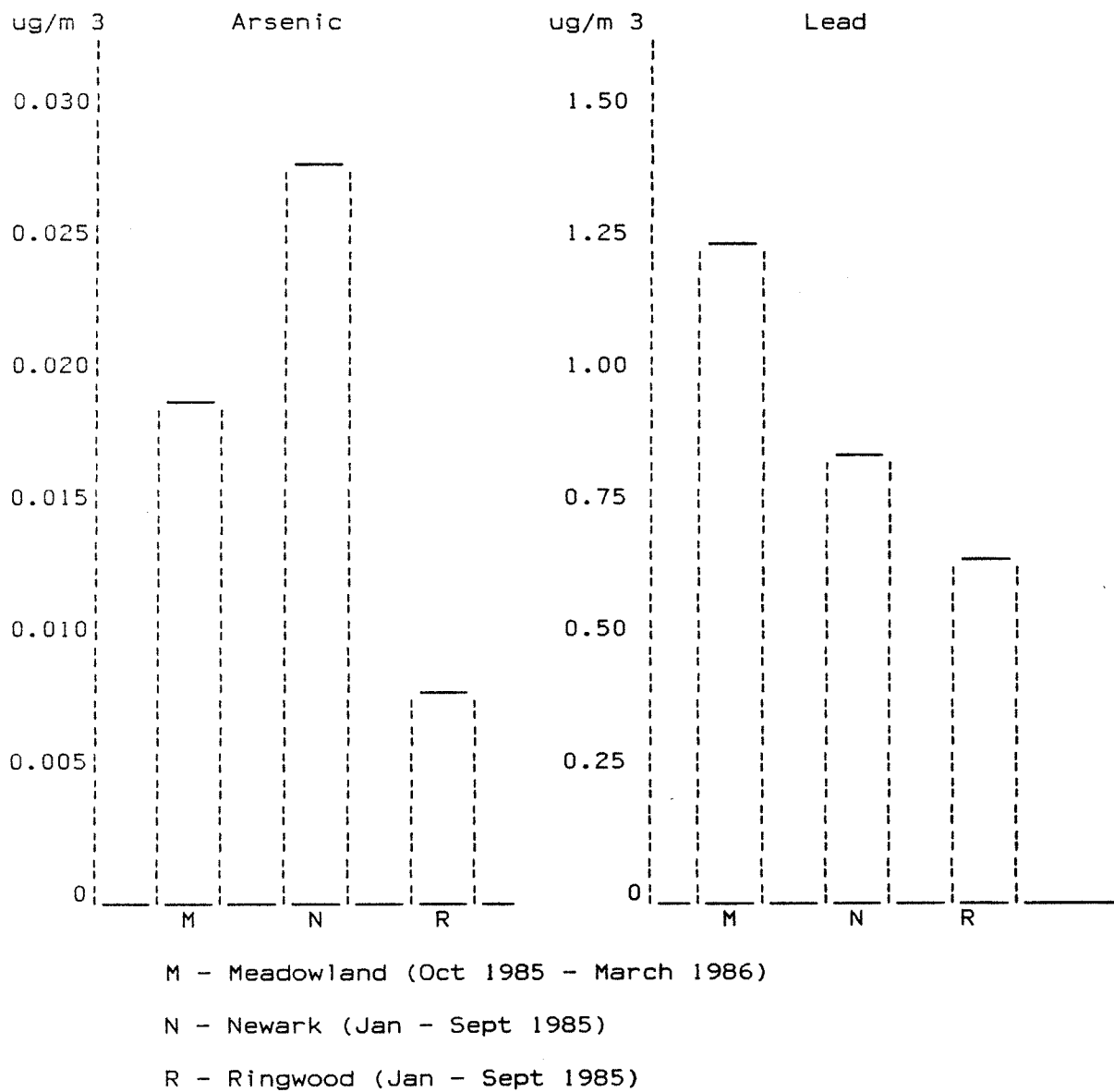
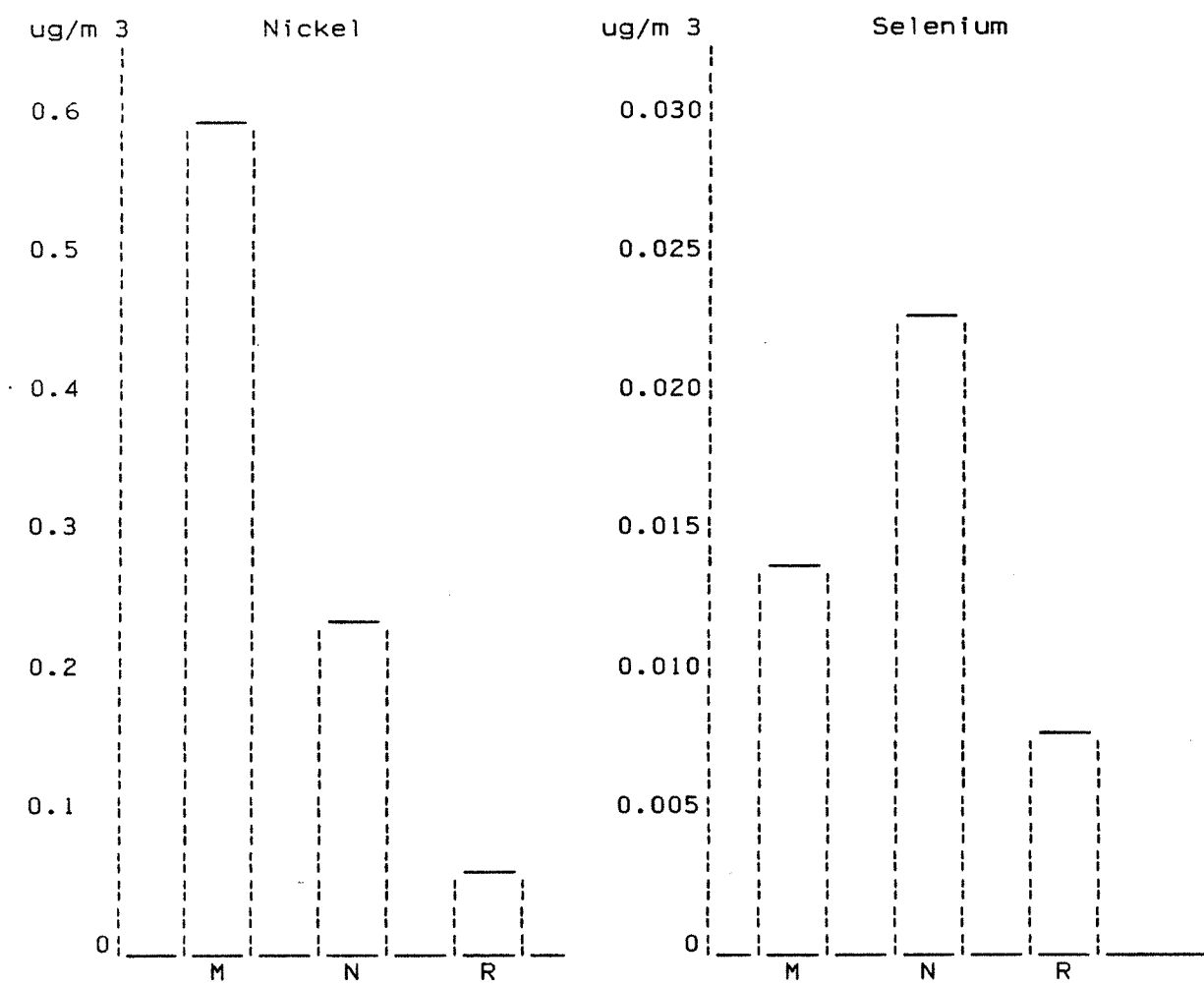


FIGURE 4.1 (Continue)
OVERALL AVERAGE CONCENTRATION $\mu\text{g}/\text{m}^3$
FOR EACH SITE

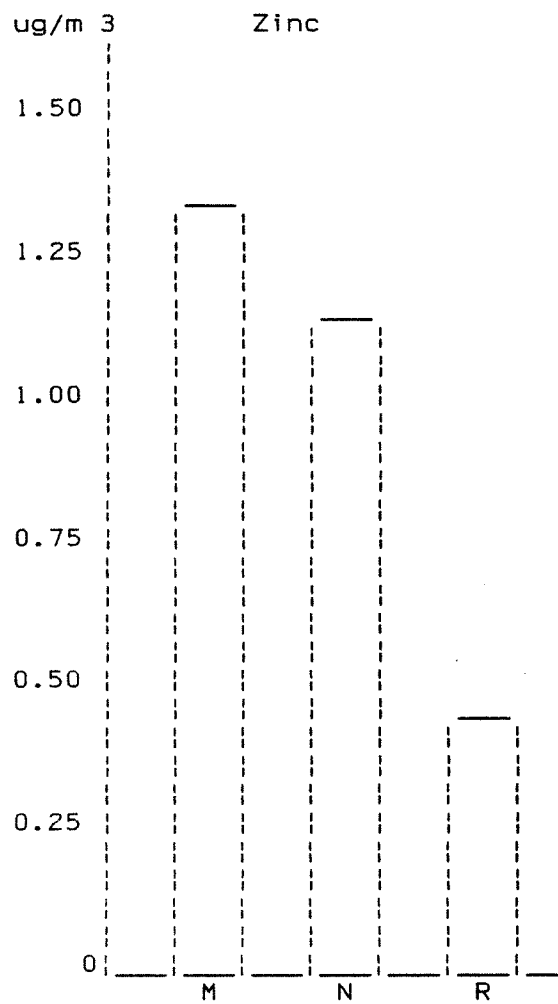


M - Meadowland (Oct 1985 - March 1986)

N - Newark (Jan - Sept 1985)

R - Ringwood (Jan - Sept 1985)

FIGURE 4.1 (Continue)
OVERALL AVERAGE CONCENTRATION $\mu\text{g}/\text{m}^3$
FOR EACH SITE



M - Meadowland (Oct 1985 - March 1986)

N - Newark (Jan - Sept 1985)

R - Ringwood (Jan - Sept 1985)

4.2 Monthly Averages

The monthly average of metal concentrations for each site is listed in Table 4.2 and graphically shown in Figure 4.2.

Newark Site: From the graphs plotted, Pb demonstrates relatively constant high concentrations from Jan-May and down from June-Sept. During the two separate time periods, levels were relatively constant.

The consistent levels of Se throughout the sampled periods in Newark may be due to continuous background from industrial emissions and transport. It exhibited highest value in January.

The concentrations of Ni were found to fluctuate slightly. The months of April, May, July and Sept observed lower levels of Ni while the peak level was observed in June at a value of 0.34 $\mu\text{g}/\text{m}^3$.

As was observed to show a relatively constant concentration values throughout with slightly higher values during the periods of June to August.

The Zinc exhibited constant high values throughout the period with exception of March, April and June where the values were lower. At this site and at the Meadowlands, Zinc exhibited higher concentrations than Lead and must result from more local industrial or vehicle sources.

Ringwood Site: The values of Arsenic, Selenium, Nickel and Zinc are almost half that of Newark.

The Arsenic concentrations are relatively constant throughout the period with the highest value being 0.010 $\mu\text{g}/\text{m}^3$

3

in month of February and lowest 0.006 ug/m³ in April and June.

Pb concentrations are moderate and consistent throughout the months with exception of Sept which showed a low value of 0.38 ug/m³.

Nickel concentrations are low and similar to As and Se. It exhibited a low values throughout with slight elevations in April, August and September showing higher values. Ni in Ringwood is about one tenth the values of Newark and Meadowlands.

Selenium concentrations was relatively constant with little or no variation throughout the months.

Zinc observed relatively high concentrations with slight fluctuations. The lowest was shown in the month of February.

The atmospheric concentrations of these metals are moderate in the suburb compared with the city, and they exhibit no significant trends. Contributions from specific local sources in this rural area does not appear to be significant in comparison to that transported.

Meadowlands Site: The Meadowlands area showed higher monthly average concentrations for the areas sampled.

Pb was observed to be constantly high throughout, with highest value of 1.57 ug/m³ in the month of November.

As concentrations were relatively constant with slight variation. Highest value was in the month of February while lowest was in the month of December. December was sampled for only two weeks. These values might not be a true representative of the concentrations.

The Ni concentrations showed slight variations with the highest value being in the month of March and lowest during

December with a value of 0.36 ug/m^3 .

Se exhibited relatively constant values throughout the months with the highest in December and lowest in March with a value of 0.008 ug/m^3 .

The concentrations of Zn were again relatively high throughout the periods. Higher values were observed from December through March, while November showed the lowest concentration value. The average value is similar to Lead and one might consider the possible toxic effect of Zinc.

The possible reason for higher concentrations in the Meadowlands is due to dust from the extensive landfill activities and proximity of major traffic arteries of NJ Rt 3, Rt 17 and Turnpike.

TABLE 4.2

Newark Site

Toxic Metals	Monthly Average Concentrations (ug/m ³)								
	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.
Arsenic	0.023	0.018	0.026	0.026	0.023	0.037	0.034	0.031	0.021
Lead	1.1	0.78	0.80	0.92	0.90	0.56	0.55	0.72	0.60
Nickel	0.30	0.28	0.26	0.12	0.17	0.34	0.18	0.28	0.12
Selenium	0.039	0.013	0.020	0.019	0.016	0.025	0.020	0.013	0.025
Zinc	1.21	1.67	0.71	0.76	1.34	0.65	1.35	1.12	1.68

TABLE 4.2 (Continue)

Ringwood Site

Toxic Metals	Monthly Average Concentrations (ug/m ³)								
	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.
Arsenic	0.009	0.010	0.007	0.006	0.007	0.006	N/A	0.009	0.007
Lead	0.67	0.79	0.82	0.71	0.70	0.75	N/A	0.67	0.38
Nickel	0.010	0.008	0.008	0.054	0.012	0.025	N/A	0.072	0.039
Selenium	0.006	0.007	0.006	0.010	0.010	0.009	N/A	0.008	0.006
Zinc	0.47	0.13	0.36	0.50	0.40	0.32	N/A	0.52	0.30

N/A - Not Analysed

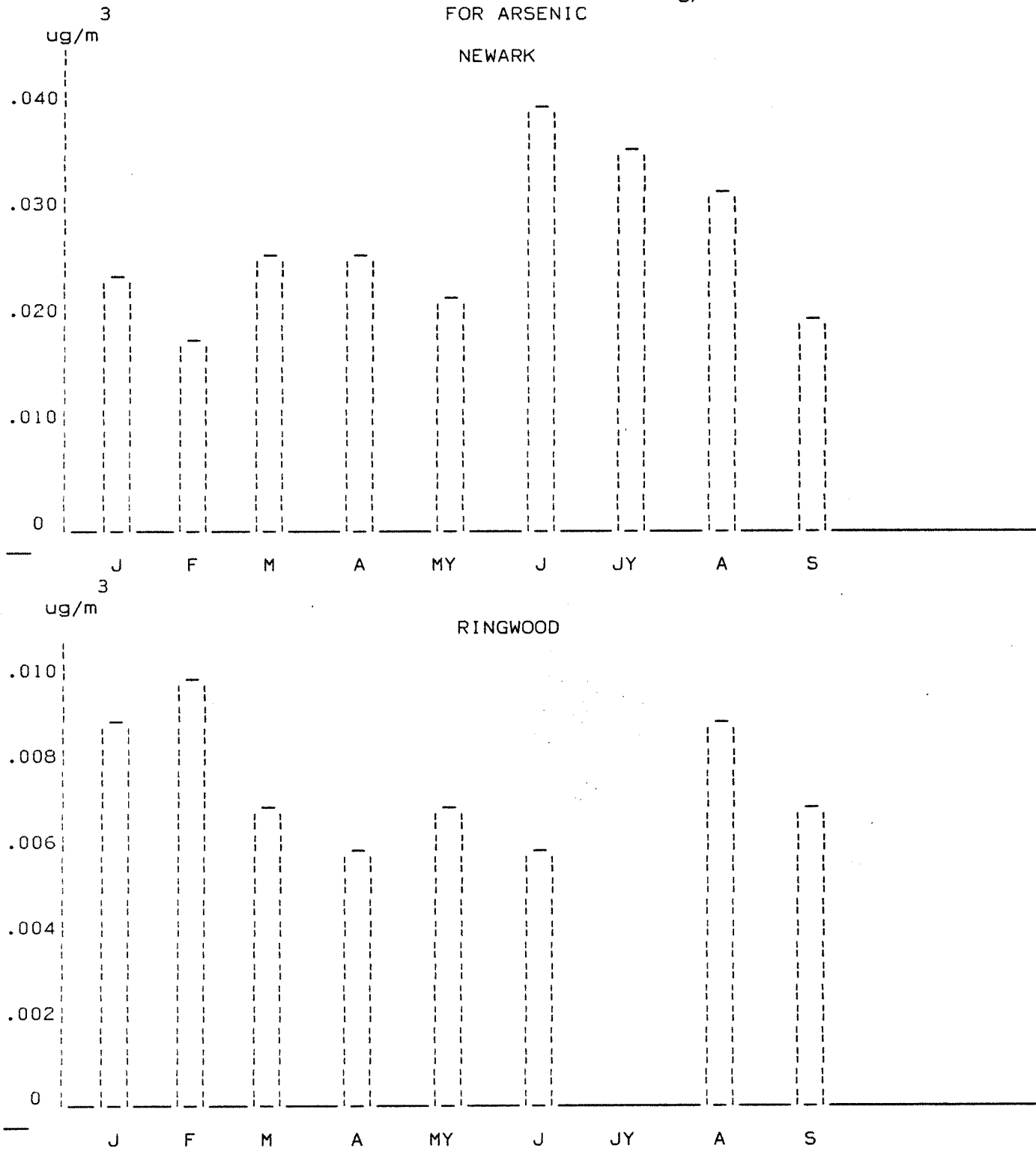
TABLE 4.2 (Continue)

Meadowland Site

Toxic Metals	Monthly Average Concentrations (ug/m ³)					
	Oct.	Nov.	*Dec.	*Jan.	Feb.	Mar.
Arsenic	0.020	0.018	0.013	0.017	0.021	0.019
Lead	1.01	1.57	1.28	1.33	1.20	1.21
Nickel	0.48	0.60	0.36	0.71	0.48	0.90
Selenium	0.012	0.015	0.041	0.014	0.016	0.008
Zinc	0.98	0.60	1.65	1.92	1.43	1.58

* Two Weeks Sampling

FIGURE 4.2
MONTHLY AVERAGE CONCENTRATION $\mu\text{g}/\text{m}^3$
FOR ARSENIC



Monthly Average: Jan-Sept 1985 for Newark and Ringwood

FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION ug/m
FOR ARSENIC

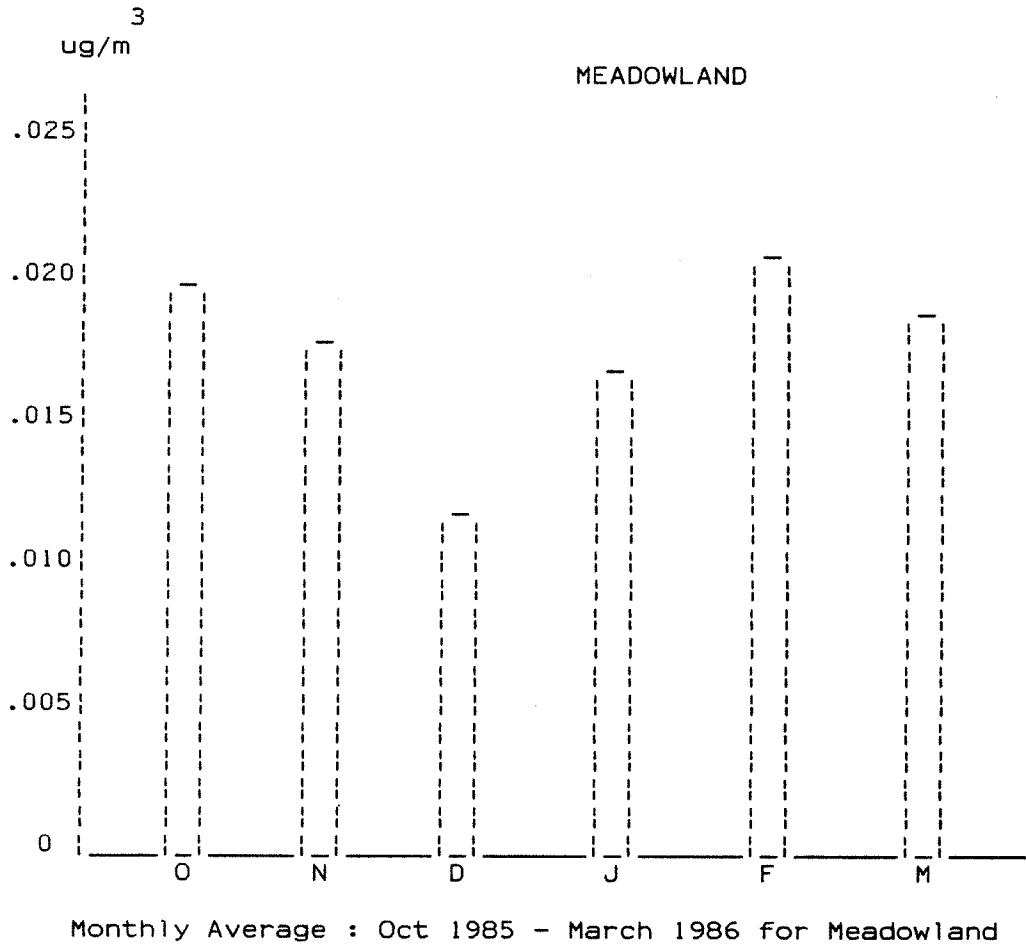
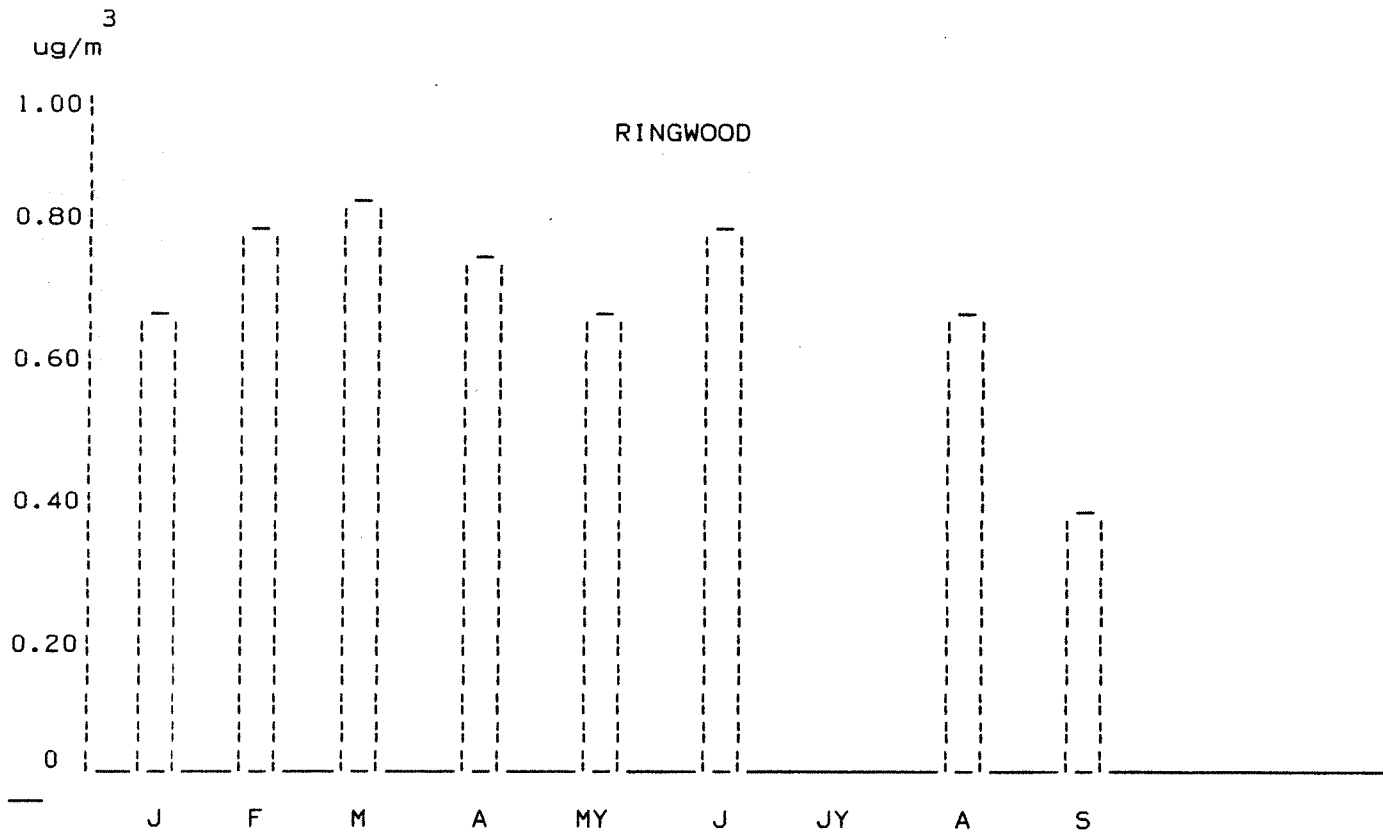
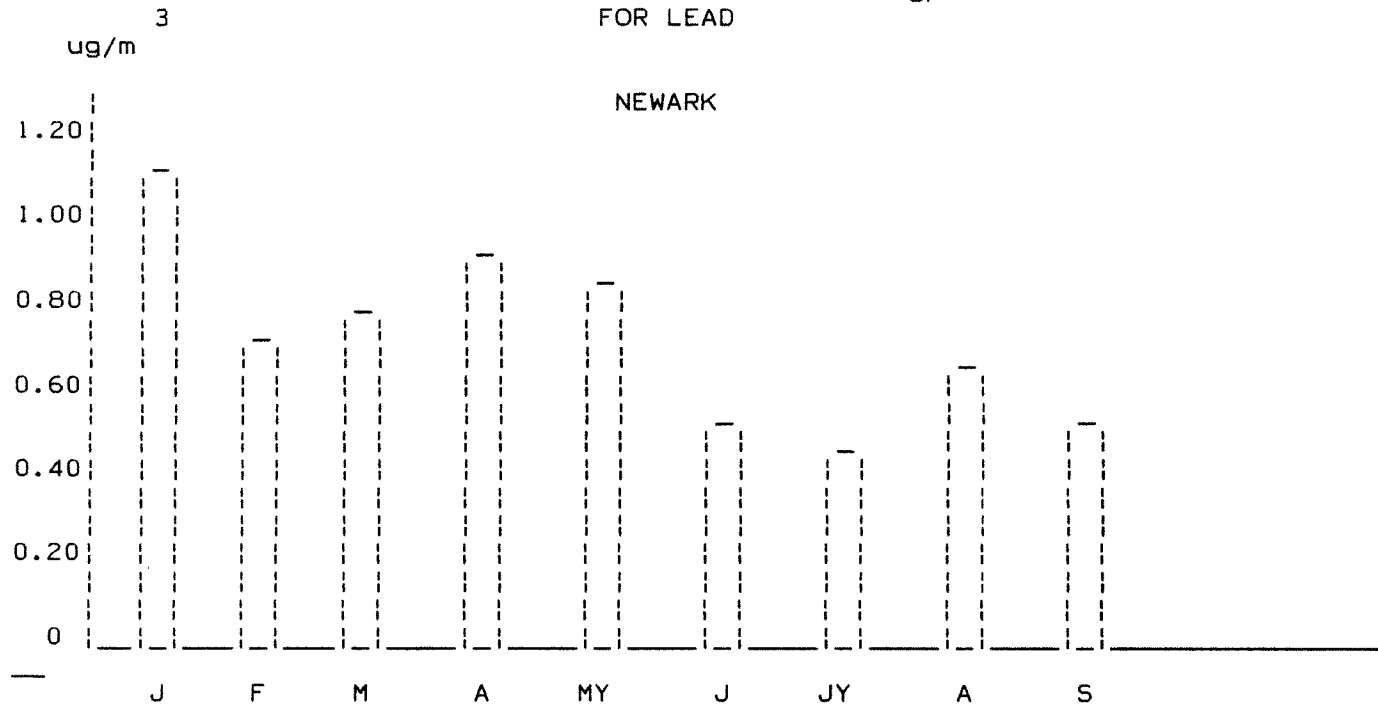


FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION $\mu\text{g}/\text{m}^3$
FOR LEAD



Monthly Average: Jan-Sept 1985 for Newark and Ringwood

FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION $\mu\text{g}/\text{m}^3$
FOR LEAD

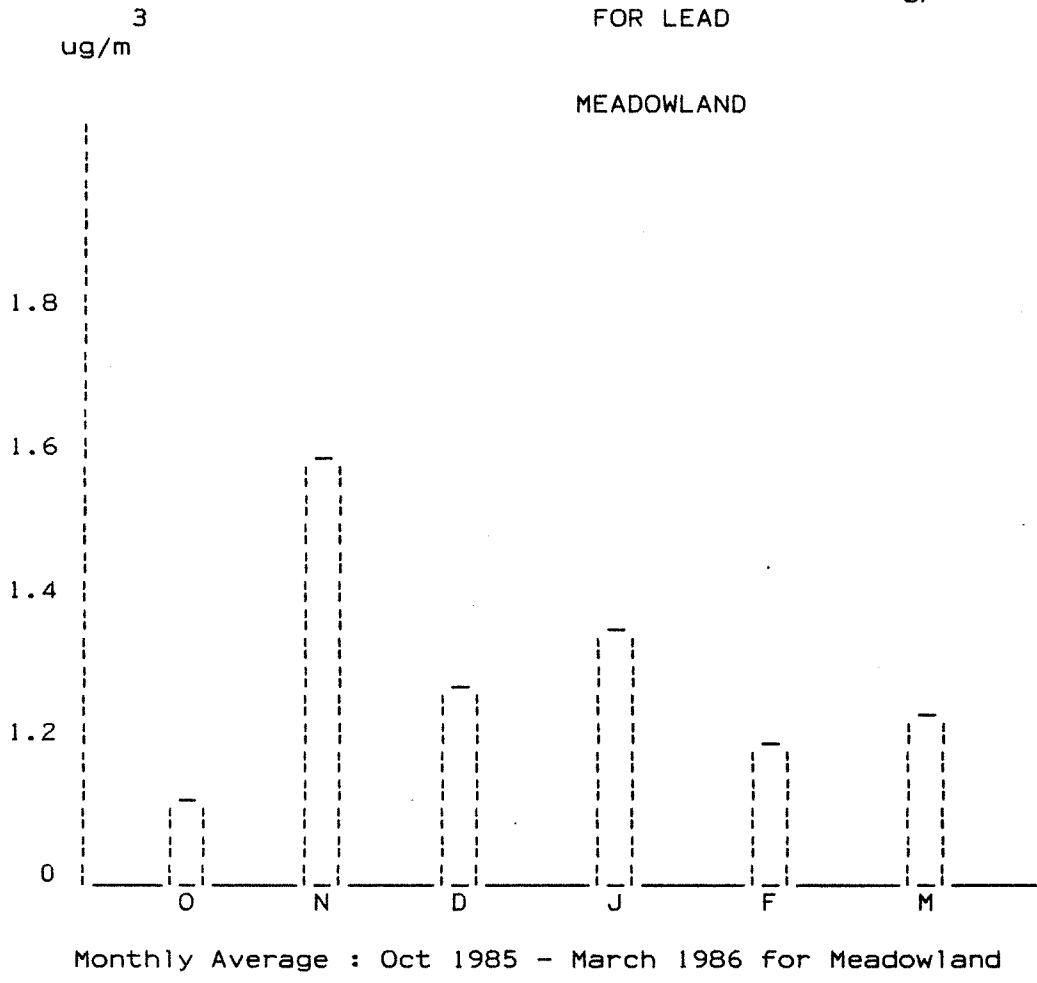
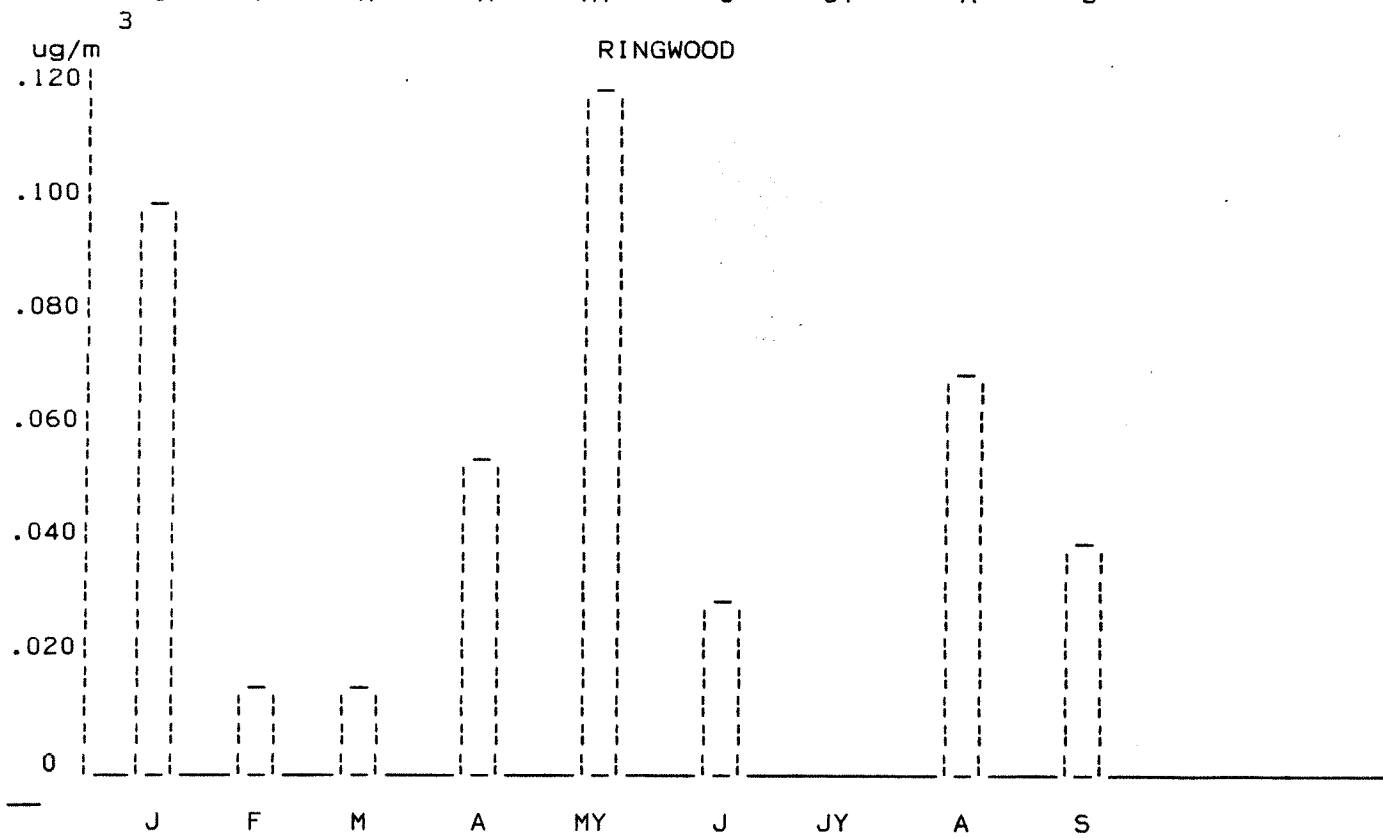
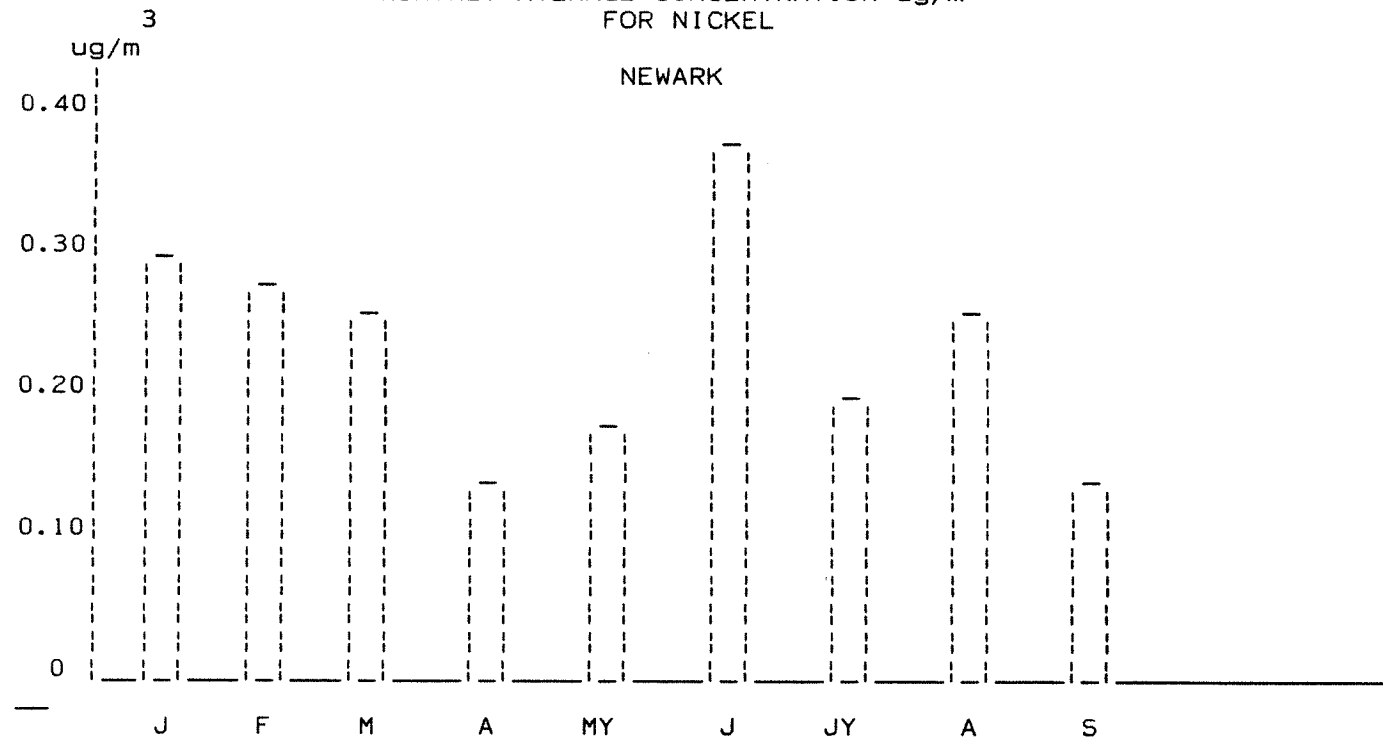


FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION ug/m
FOR NICKEL



Monthly Average: Jan-Sept 1985 for Newark and Ringwood

FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION ug/m³
FOR NICKEL

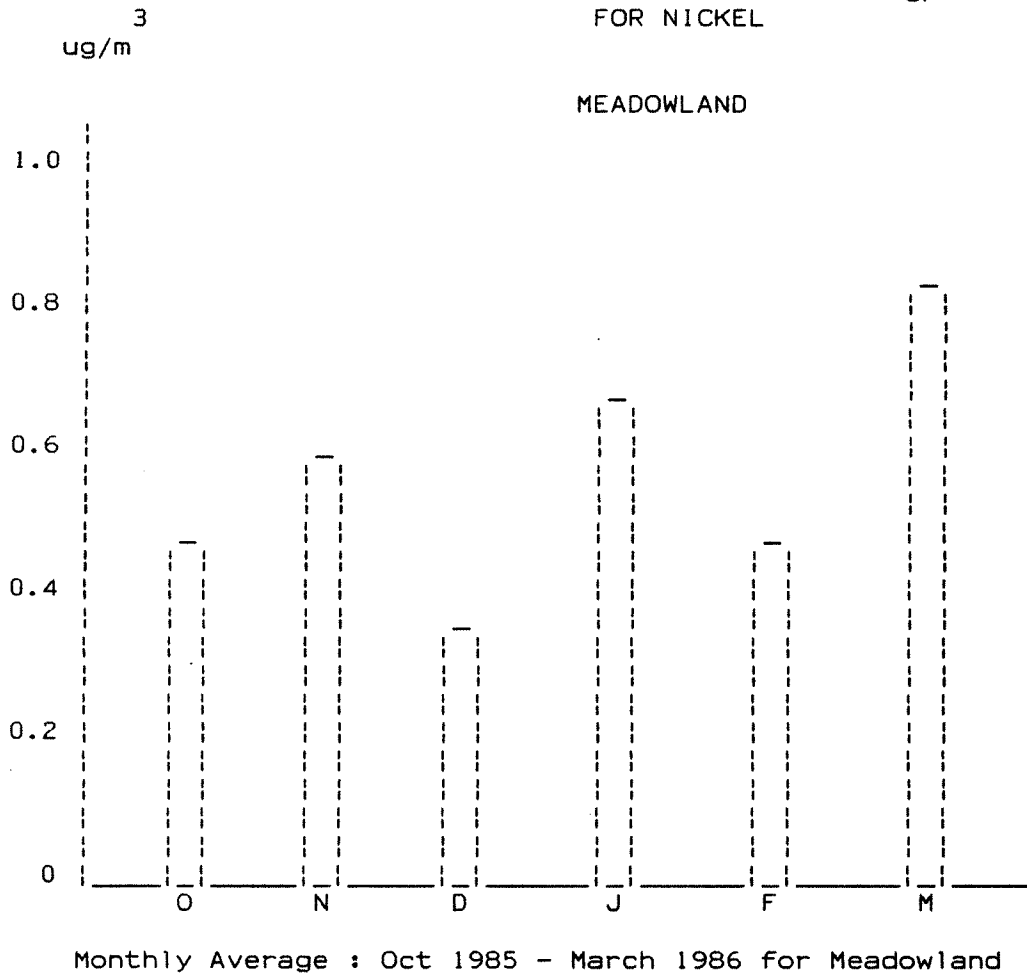
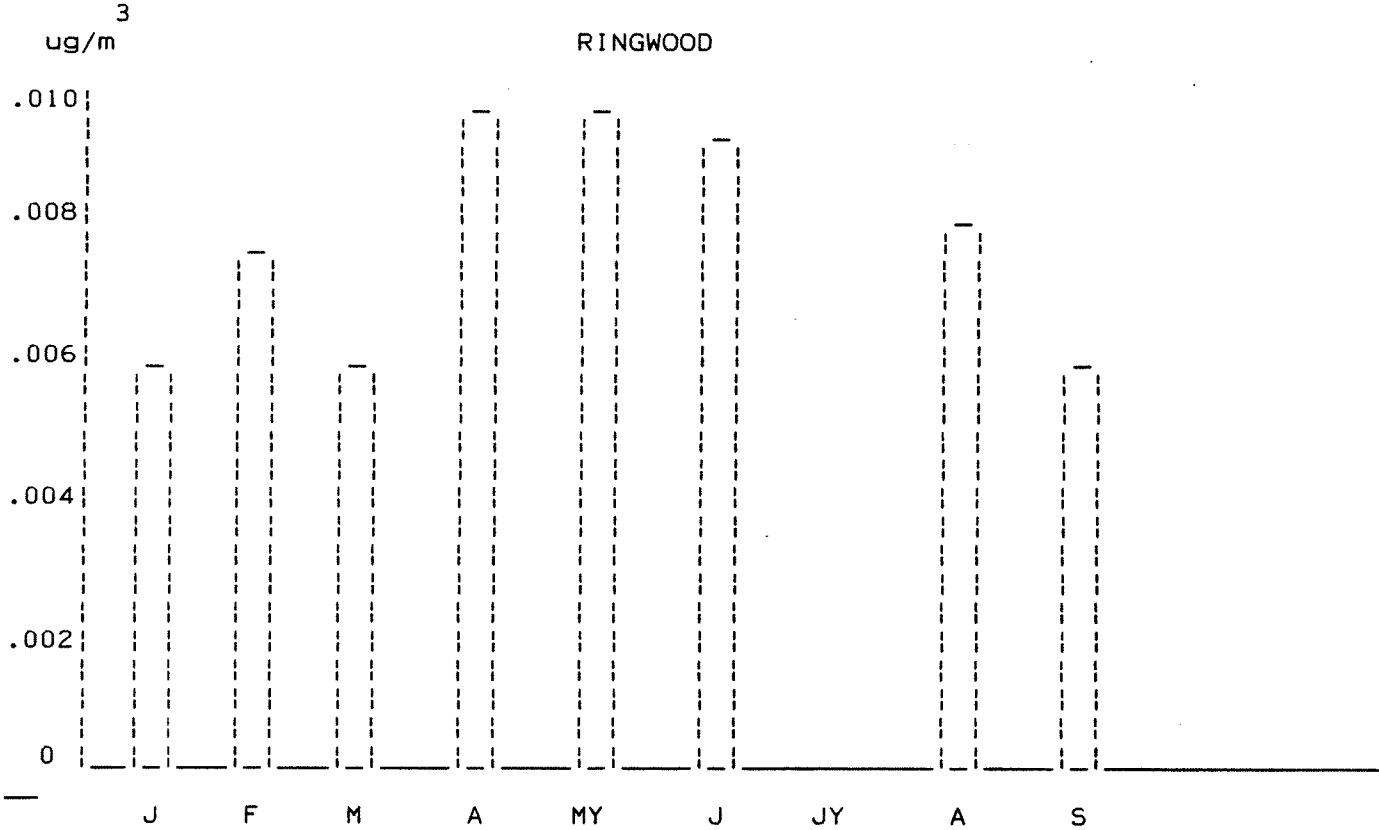
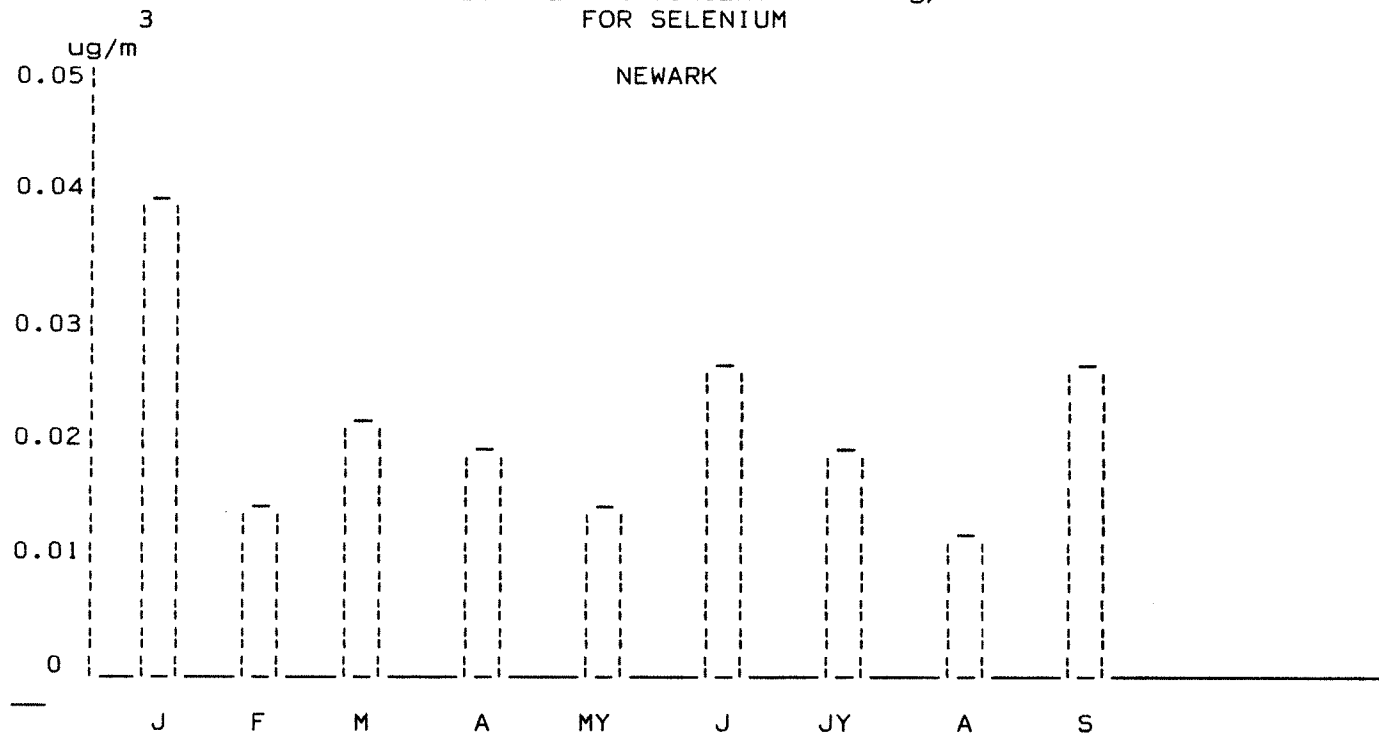


FIGURE 4.2 (Continue) 3
 MONTHLY AVERAGE CONCENTRATION ug/m
 FOR SELENIUM



Monthly Average: Jan-Sept 1985 for Newark and Ringwood

FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION ug/m³
FOR SELEUNIUM

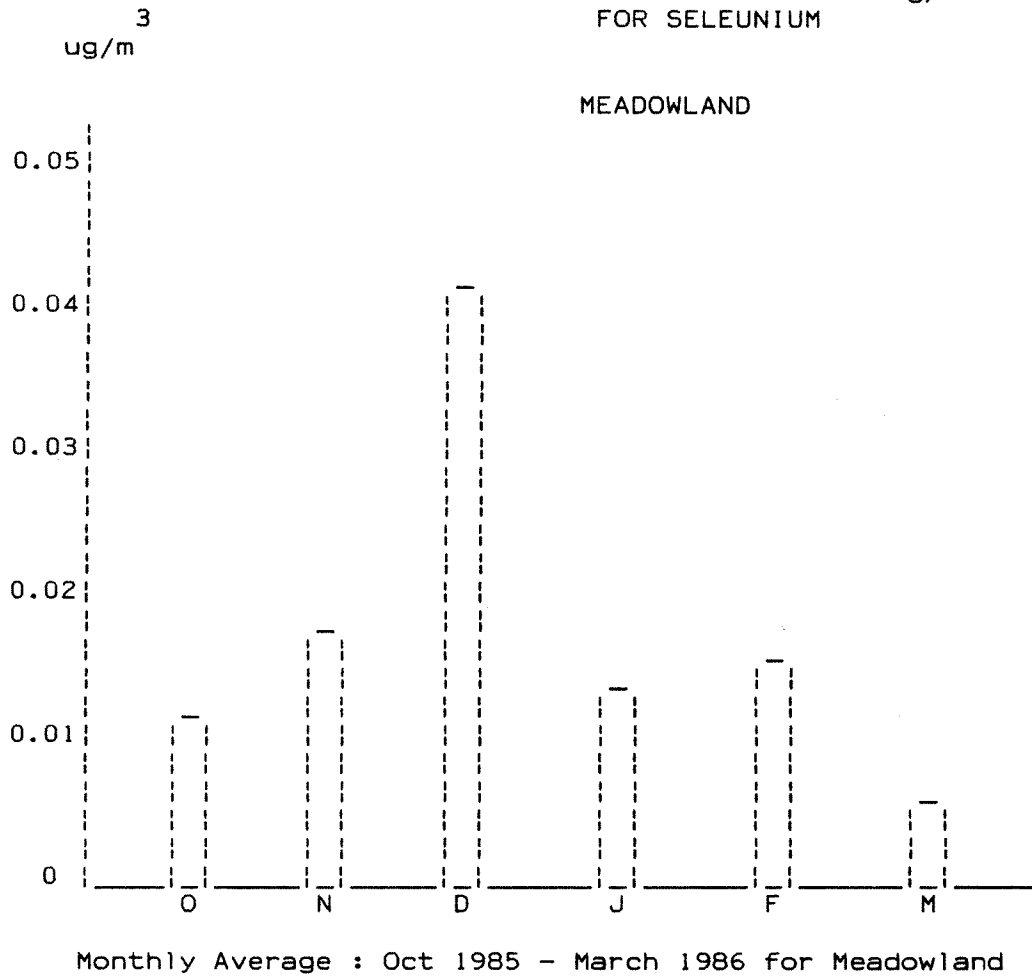
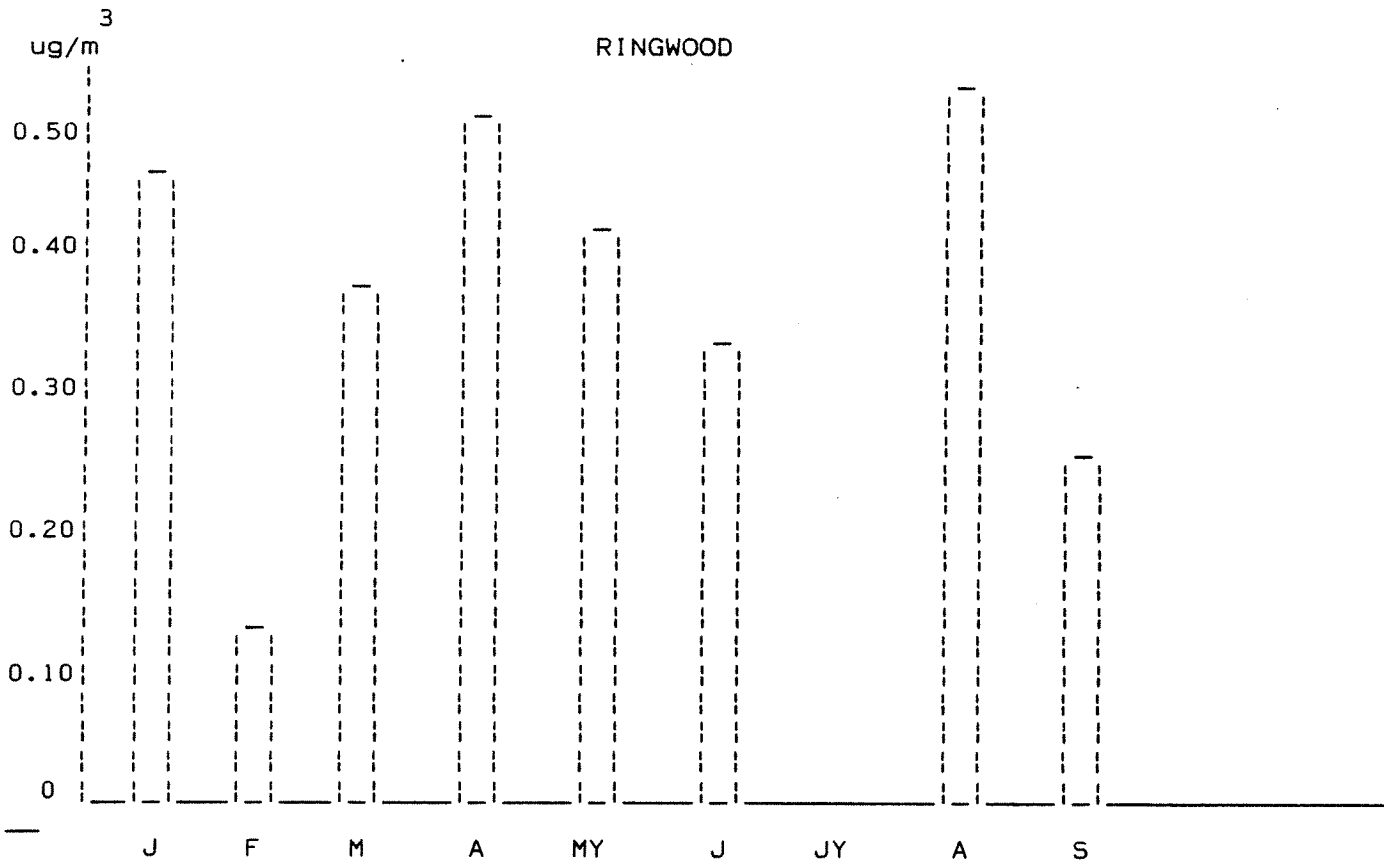
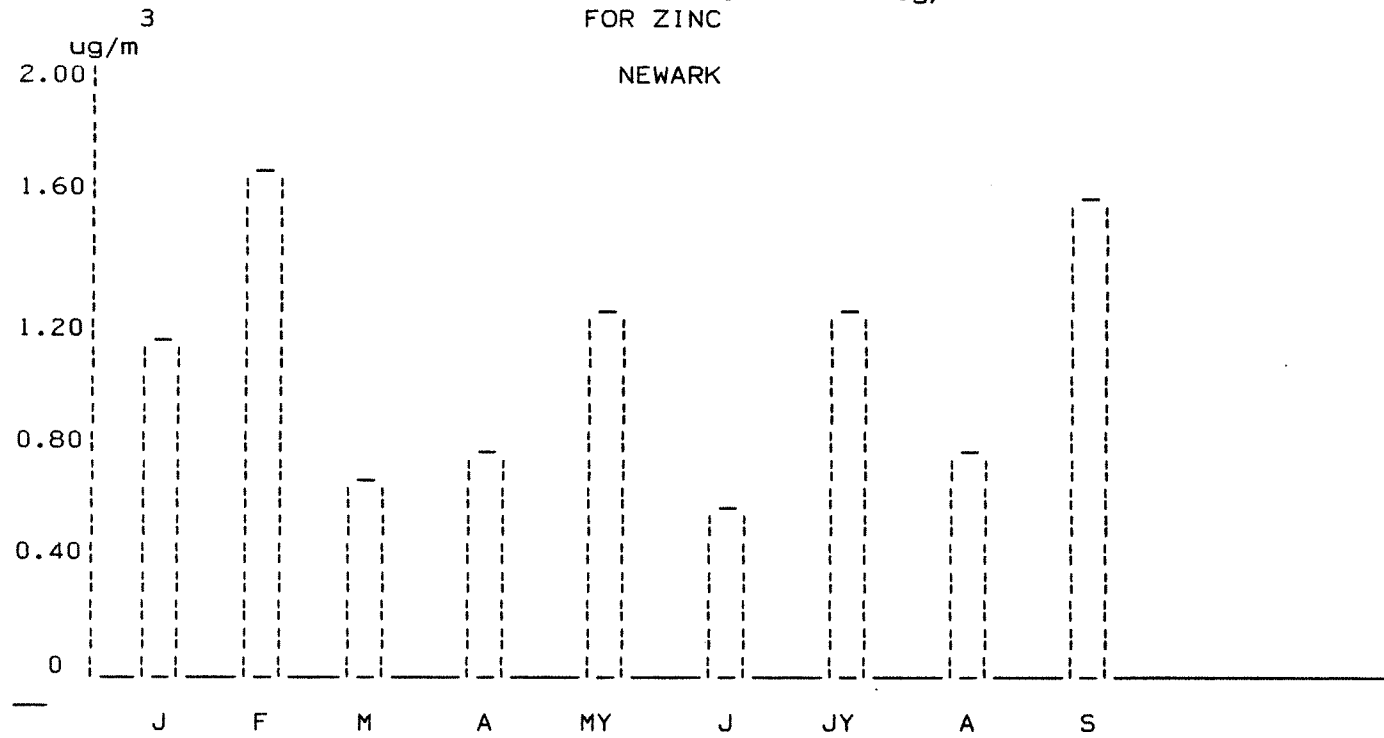
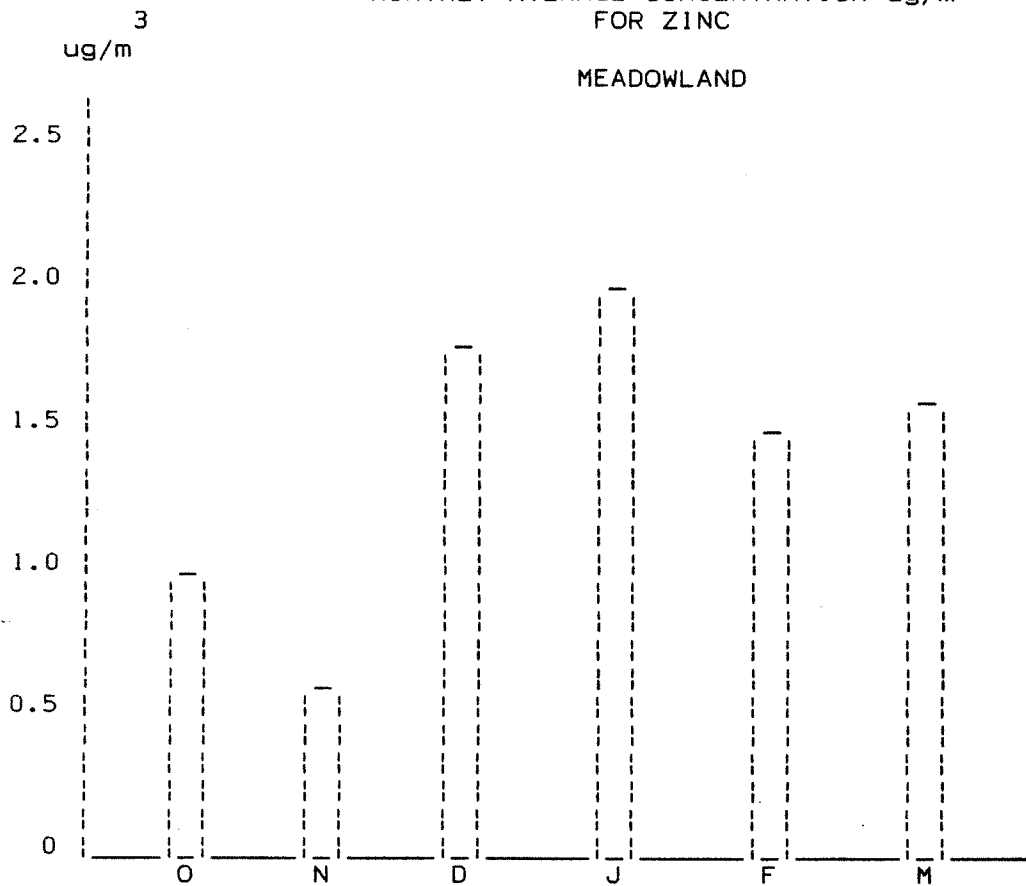


FIGURE 4.2 (Continue) 3
 MONTHLY AVERAGE CONCENTRATION ug/m³
 FOR ZINC



Monthly Average: Jan-Sept 1985 for Newark and Ringwood

FIGURE 4.2 (Continue) 3
MONTHLY AVERAGE CONCENTRATION ug/m
FOR ZINC



Monthly Average : Oct 1985 - March 1986 for Meadowland

4.3 Quarterly Averages:

The quarterly average concentrations for metals at each site are illustrated in Figure 4.3 while the data are listed in Table 4.3.

Newark Site: Newark showed high concentrations of Pb during the quarters of winter and spring, but decreased in the quarter of July to Sept (summer). This trend could be attributed to increased emission rate during the winter due to increased combustion of fuel.

Arsenic concentrations showed relatively constant values with slight variations. It observed the highest value during the July-Sept quarter.

The concentration of Ni was slightly higher during the winter period (Jan-March) than the rest of the quarters with a value of 0.28 ug/m³.

Relatively, constant quarterly average concentrations of Selenium was observed in Newark, with a very small drop during the April-June quarter.

Higher concentrations of Zn were observed in winter and summer which approached quarterly limit for Lead. But, there was a slight drop during the quarter of April-June (spring).

Ringwood Site: The quarterly average concentrations of most metals in the Ringwood area are significantly below the values in the city.

Pb values were observed to be relatively constant with a slight drop during the summer.

Arsenic demonstrated a constant values throughout the quarter.

Ni concentrations fluctuated slightly with July to Sept quarter showing the lowest value.

A constant quarterly average concentrations of Selenium was observed.

A constant average values of Zn concentrations were exhibited at Ringwood site throughout the periods. There was a slight drop in concentration during the winter.

The low values of the metals in the Ringwood site may be attributed to the remoteness of the area and lack of major vehicular sources..

TABLE 4.3

Newark Site

Toxic Metals 3 - Month Average Concentrations (ug/m³)

	<u>Jan - March</u>	<u>April- June</u>	<u>July - Sept.</u>
Arsenic	0.023	0.028	0.029
Lead	0.90	0.81	0.62
Nickel	0.28	0.20	0.20
Selenium	0.025	0.019	0.021
Zinc	1.16	0.96	1.36

TABLE 4.3 (Continue)

Ringwood Site

Toxic Metals 3 - Month Average Concentrations (ug/m)³

	<u>Jan - March</u>	<u>April- June</u>	<u>*July - Sept.</u>
Arsenic	0.008	0.007	0.008
Lead	0.76	0.72	0.68
Nickel	0.069	0.071	0.056
Selenium	0.007	0.009	0.007
Zinc	0.33	0.40	0.41

* Excluding July

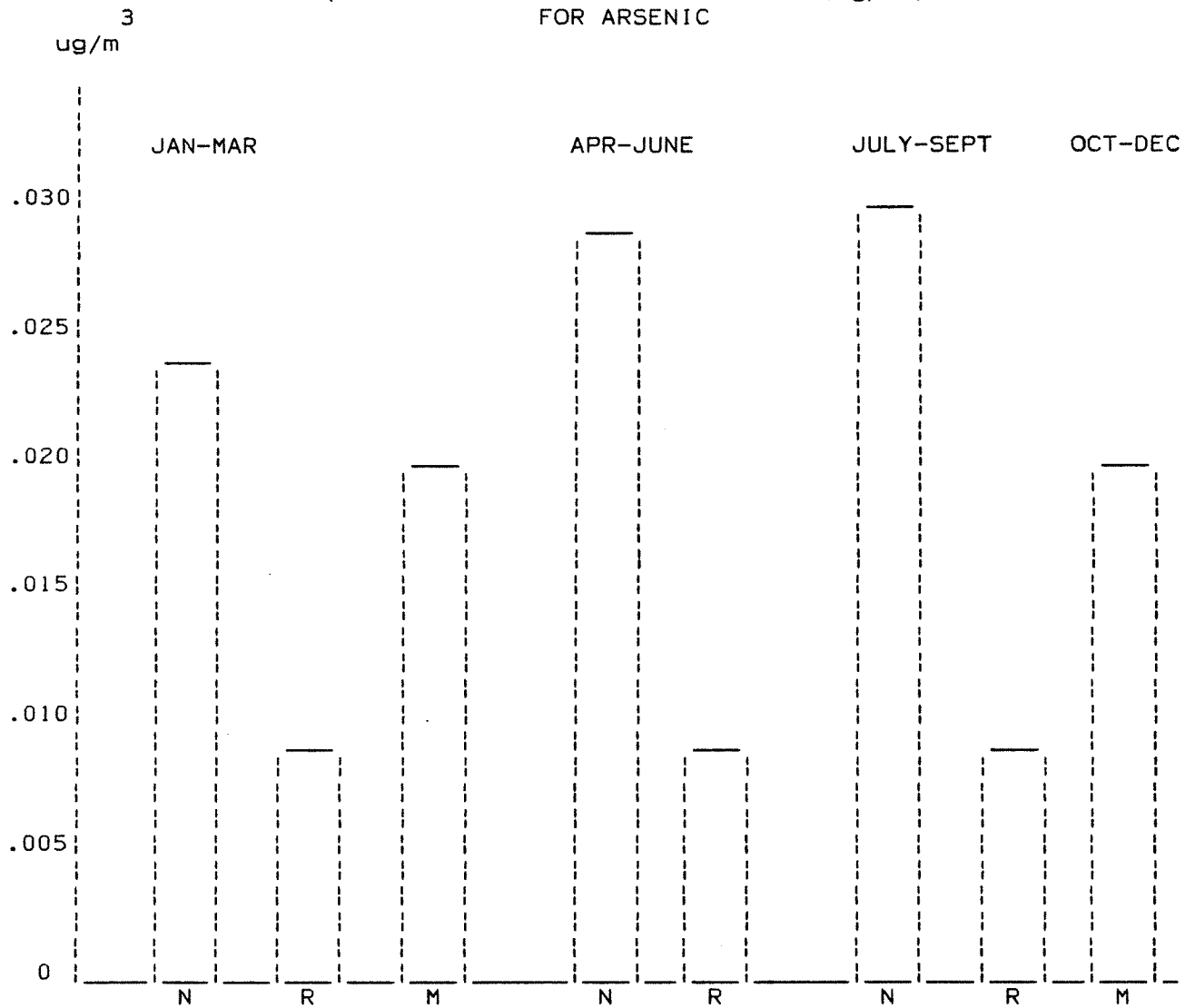
Meadowlands Site: The Meadowlands site showed relatively constant quarterly average concentrations of Pb throughout the periods.

As also showed similar constant values and the value of Selenium was similar with little or no variation.

Nickel concentration was significantly up in winter as was Zn with a high value of 1.60 $\mu\text{g}/\text{m}^3$.

The high concentrations in Meadowlands site during the winter can be attributed to landfill activities in the area during the winter and temperature inversions which are more persistent in winter than summer.

FIGURE 4.3
QUARTERLY AVERAGE CONCENTRATION (ug/m)
FOR ARSENIC



N - Newark (Jan - Sept 1985)

R - Ringwood (Jan - Sept 1985)

M - Meadowland (Oct 1985 - March 1986)

FIGURE 4.3 (Continue)

3
QUARTERLY AVERAGE CONCENTRATION (ug/m³)
FOR LEAD

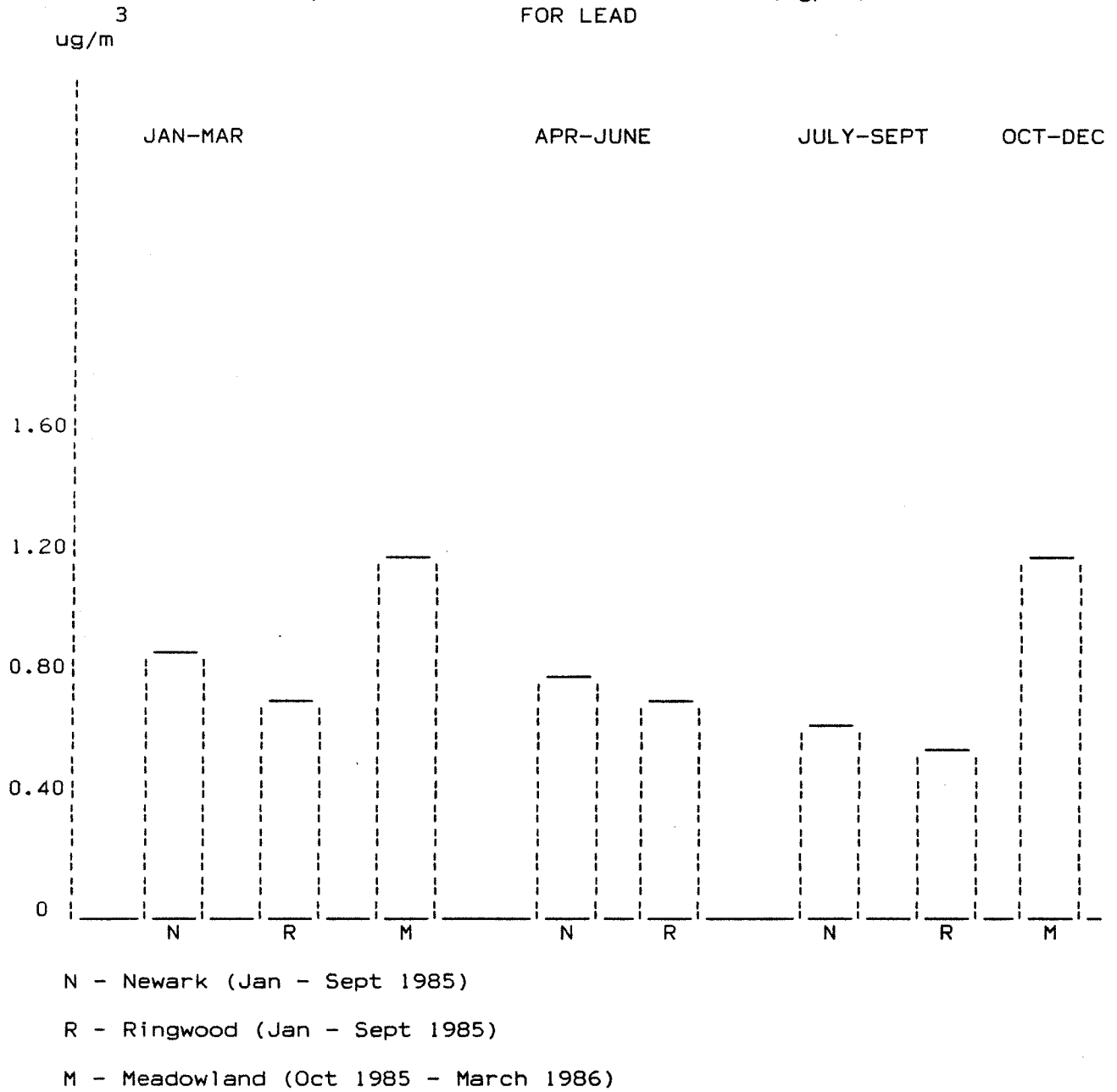
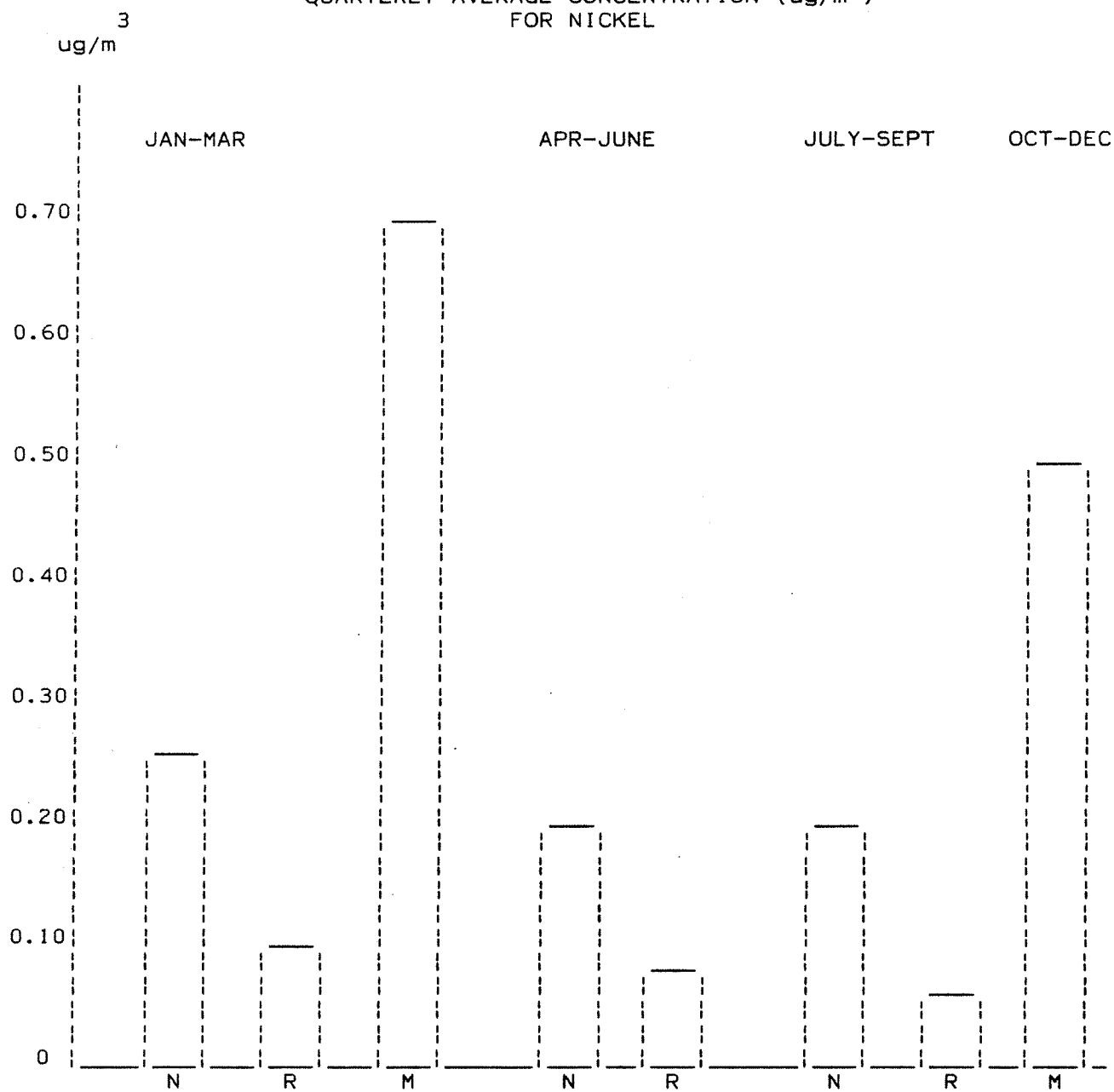


FIGURE 4.3 (Continue)

QUARTERLY AVERAGE CONCENTRATION ($\mu\text{g}/\text{m}^3$)
FOR NICKEL



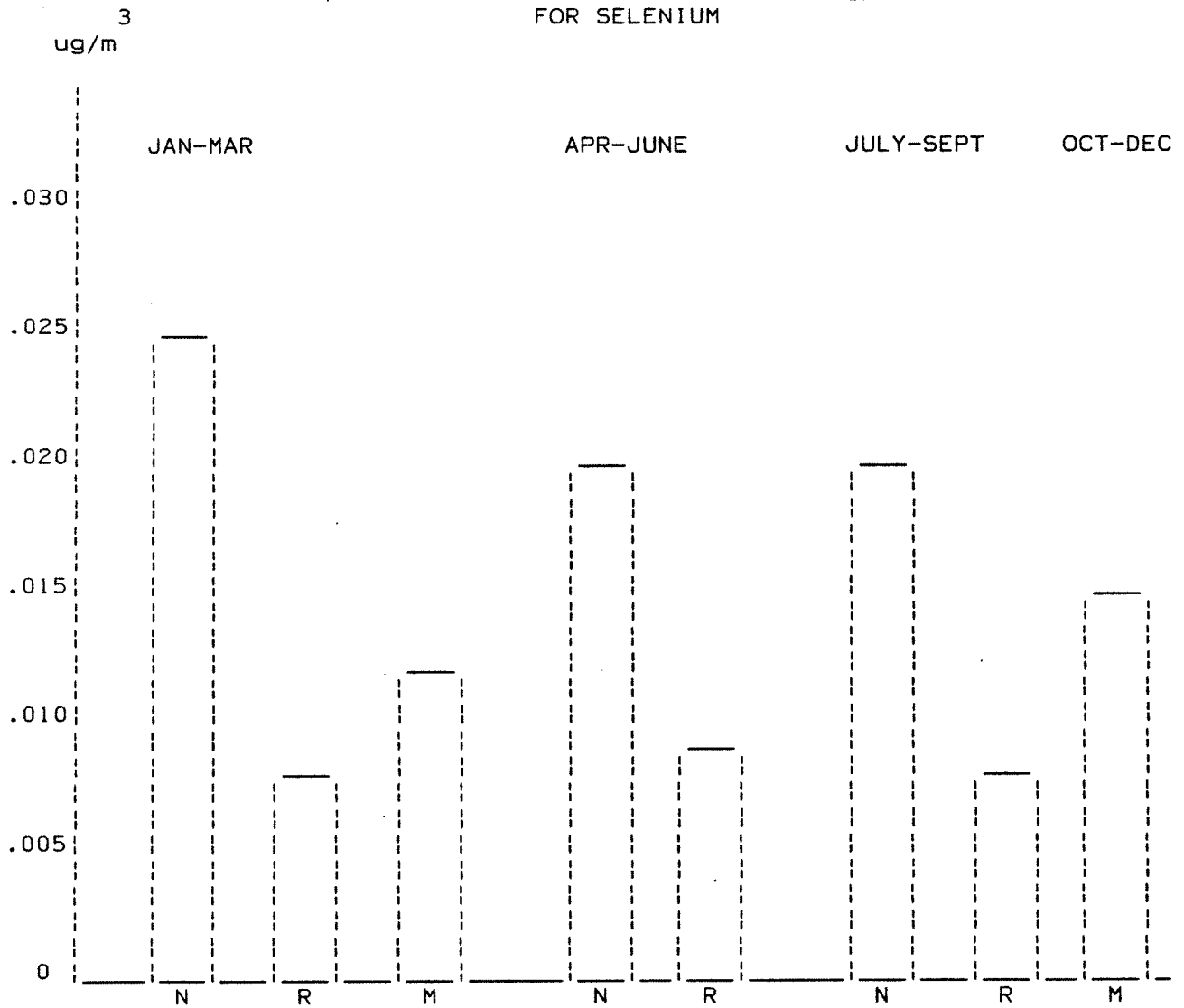
N - Newark (Jan - Sept 1985)

R - Ringwood (Jan - Sept 1985)

M - Meadowland (Oct 1985 - March 1986)

FIGURE 4.3 (Continue)

3
QUARTERLY AVERAGE CONCENTRATION (ug/m³)
FOR SELENIUM



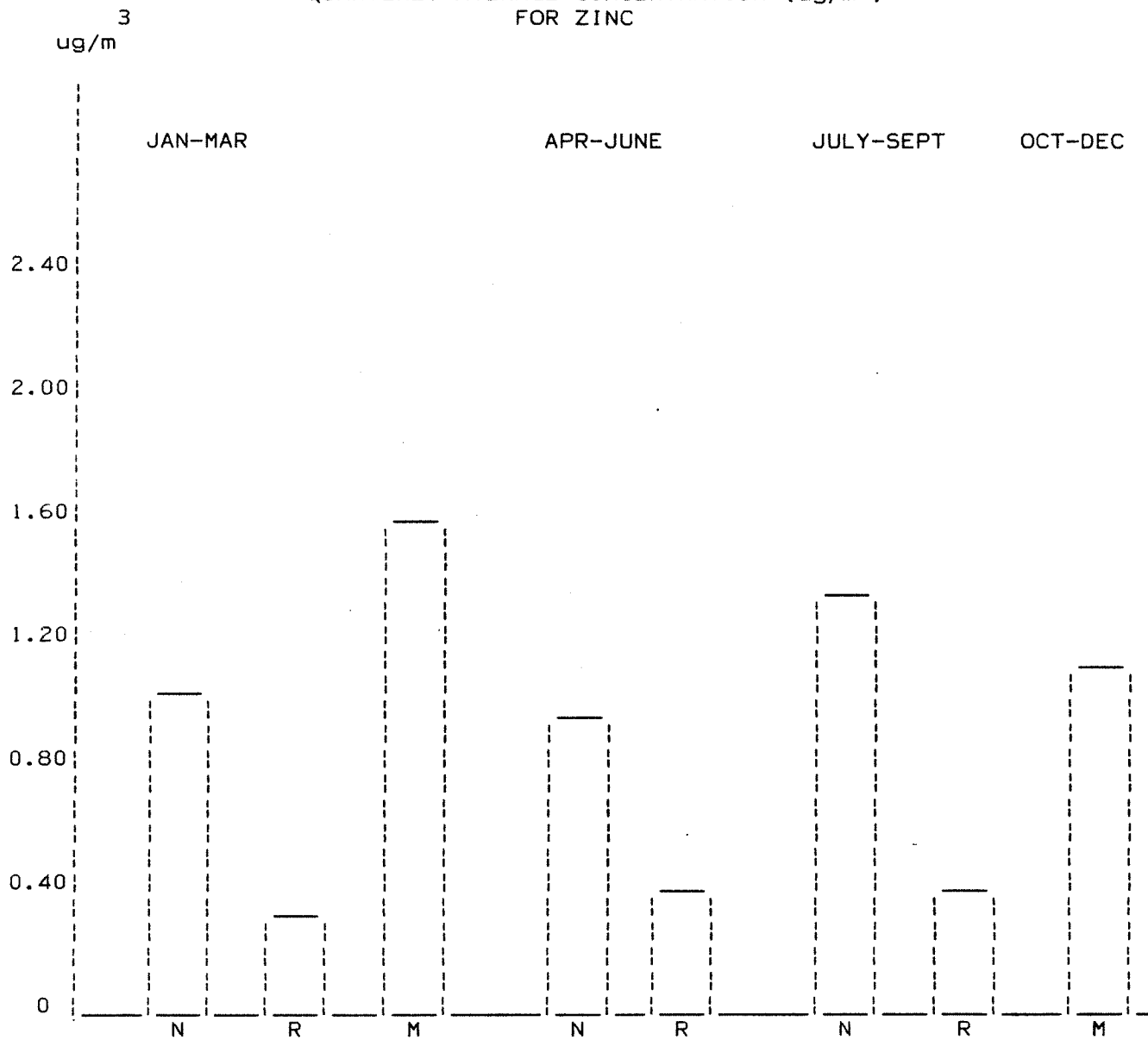
N - Newark (Jan - Sept 1985)

R - Ringwood (Jan - Sept 1985)

M - Meadowland (Oct 1985 - March 1986)

FIGURE 4.3 (Continue)

QUARTERLY AVERAGE CONCENTRATION ($\mu\text{g}/\text{m}^3$)
FOR ZINC



N - Newark (Jan - Sept 1985)

R - Ringwood (Jan - Sept 1985)

M - Meadowland (Oct 1985 - March 1986)

4.4 Averages by Day of the Week

Table 4.4 illustrates the average concentrations of the metals by day of the week at each site.

Newark Site: In the Newark site, 5 samples for each day of the week was included in the average concentrations, and it was observed that Lead concentration was relatively constant throughout the periods sampled. A low value was shown on Tuesday. Highest value of 0.90 ug/m^3 was exhibited on Mondays.

As value was relatively constant with slight increases on Thursday and Friday, and there was a decrease on Monday values.

Nickel has relatively constant concentration values throughout. Monday observed the highest value of 0.32 ug/m^3 , while Saturday had the lowest value of 0.19 ug/m^3 .

High concentrations of Se were observed on Wednesday and Saturday, while Monday and Tuesday showed lower values.

A relatively consistent high level of Zn with slight decrease on Thursday and Sunday was observed. Zinc exhibited the highest concentration of all the metals analysed in Newark.

Ringwood Site: The metal average concentrations calculated by day of the week in Ringwood showed that Lead value was observed to be relatively constant, with slight drop on Mondays. But, the most significant drop was on Sundays (0.59 ug/m^3) which might suggest low traffic on the road.

As has relatively constant level of concentration. A lowest value was observed on Thursdays with a value of 0.004³ ug/m³.

A relatively constant Ni concentration level was observed. Although there was a slight drop on Sundays and Mondays.

Slight variation was observed for Se. Tuesdays observed a slight increase, while Mondays exhibited a drop in the overall average concentrations.

The most notable trend observed in the Zn data is the peaking of the concentration on Friday and slight drops from averages on Mondays and Tuesdays.

The average concentrations of all the metals analysed in Ringwood was based on five samples for each day of the week. Since the site is a remote rural area, most of the sources of the pollutant are attributed to regional transportation.

Meadowland Site: Meadowland was sampled from October 1985 through March 1986 and has only three samples for each day of the week included in the averages.

The consistent high level of Pb probably indicated consistent emission of Lead from local sources and regional transportation. A slight drop on Tuesday is noted.

As concentration was relatively constant throughout with slight drops on Mondays and Thursdays. The most unique aspect of this metal was that, it was not observed on Sunday and Wednesday.

The Nickel was relatively constant throughout with slight decrease on Sundays and Thursdays. The peaks were observed on Saturdays.

Selenium was relatively constant with slight increase on Thursdays. Although no detectable value was observed on Friday which might probably be attribute to unexplainable external factor.

Zinc concentration was consistently high with exception of Saturdays where there was a decrease. It is possible that the landfill particulates had an effect on the concentration. The high concentrations of the metals can be attributed to landfill activities and regional transport, since there is no industrial emission in the area.

TABLE 4.4

NEWARK SITE Overall Average Concentrations of Five Samples by Day of
 3
 Week in (ug/m)

TOXIC METALS	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Arsenic	0.028	0.019	0.022	0.029	0.034	0.032	0.024
Lead	0.85	0.90	0.55	0.77	0.79	0.84	0.77
Nickel	0.31	0.32	0.23	0.27	0.27	0.26	0.19
Selenium	0.016	0.014	0.14	0.033	0.019	0.017	0.037
Zinc	0.81	1.51	1.45	1.57	0.63	1.46	1.00

RINGWOOD SITE Overall Average Concentrations of Five Samples by Day of
 3
 Week in (ug/m)

TOXIC METALS	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Arsenic	0.008	0.007	0.008	0.010	0.004	0.007	0.009
Lead	0.59	0.62	0.72	0.73	0.78	0.76	0.65
Nickel	0.041	0.037	0.057	0.052	0.052	0.016	0.055
Selenium	0.008	0.006	0.010	0.008	0.008	0.008	0.007
Zinc	0.43	0.30	0.37	0.19	0.40	0.61	0.40

MEADOWLAND SITE Overall Average Concentrations of Three Samples by Day
 3
 of Week in (ug/m)

TOXIC METALS	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Arsenic	----	0.014	0.032	----	0.022	0.030	0.032
Lead	1.18	1.22	0.97	1.18	1.35	1.23	1.59
Nickel	0.38	0.58	0.83	0.55	0.30	0.59	0.87
Selenium	0.013	0.012	0.012	0.014	0.024	----	0.015
Zinc	1.87	1.02	1.04	1.74	1.31	1.84	0.84

CHAPTER 5

CONCLUSION

The present study shows that the concentration of the trace elements measured at Ringwood and Meadowland can be related to estimated anthropogenic emission which were transported to the site by wind weather patterns. The major sources of these pollutants in the urban environment are known to be: combustion of fossil fuels for power generation, automotive power, incineration of refuse industrial processes, coal fired combustion and natural sources. Moreover, individual metal source strengths may vary according to season of the year and data on seasonal variations have been sought as a clue to the relative importance of the sources with which they were associated. Surprisingly, the three sites did exhibit a seasonal or particular trend. For example, in the case of Lead by the day of week, there was no indication that the concentrations at all the sites are systematically lower on weekends (when some reduction of source strength due to decreased traffic flow might be expected). It appears that meteorological variations from day to day were a more important determinant. Although, the atmospheric concentrations of all the metals were higher in Newark (urban area) and highest at Meadowland compared with the Ringwood (rural area), they exhibited limited trends in this relatively short time study.

5.1 Error Analysis

The standard solutions used for the calibration curve were of 1000 ppm and purchased from Fisher Scientific Inc. Springfield, NJ. The standards were rated $\pm 0.2\%$ accurate by US National Bureau of Standard. The standards were diluted using pipets, burets and volumetric flasks which have standard error limit of less than 1%. Reading small differences in buret contributed an error of about 3%. On this basis, the accuracy of the standard solution was placed within 2-3% of the nominal value. The standard solutions deteriorated due to adsorption effect, thereby introducing error. The effect was eliminated by preparing new solutions at least once every 4 weeks.

The accuracy of the atomic absorption analysis on the digested sample solutions was estimated to be about ± 10 absorbance units for the metals analysed. The determination of the limit was based on the atomic absorbance reading itself and the standard curve by which the absorbance reading was converted to the metal concentration. The readings of the absorbance was obtained directly from the Varian Model 12 spectrometer digital readout. The readings was stable to ± 2 absorbance units on a scale of 1 to 1000. The absorbance reading is directly proportional to the metal concentration in the sample. So high metal concentration exhibited low error while low concentration showed high error.

The process of sample digestion used was a standard

method approved and accepted by the U.S. Environment Protection Agency (25). An approximate error limit of 10% was assigned to this step by step assumption that it contributed half the total error of $\pm 20\%$ accepted by U.S. EPA.

The samples were collected with a glass fiber filters. These filters were rated to have collection efficiency of 99.9% for 0.3 micron particles and greater than 99.9% for larger particles as reported by the manufacturer, Gelman Inc. (Chicago, Ill) The summary of the errors is illustrated in Table 5.2.

TABLE 5.1
MINIMUM DETECTABLE QUANTITIES

Metals	Total Mass (Micrograms)	Concentrations (ug/m ³) Δ
As *	12.0	24.0
Pb	1.8	3.6
Ni	1.6	3.2
Se *	10.0	20.0
Zn	2.0	4.0

* Hydride generation method used.

Δ Assuming a 500 m³ sample volume was collected.

This total amount of each metal is required to give a signal of 4 times the noise level for 50 ml volume of analyze solution obtained via digestion procedures described. Occasionally, a value less than this minimum is reported. These low values, due to spectrophotometer readings of less than 4 x noise or due to subtraction of a large blank, have a larger margin of error than discussed in Section 5.1.

TABLE 5.2

SUMMARY OF ERROR ANALYSIS

TERMS	ACCURACY (%)	ERROR LEVEL (%)
Standards	97.00	± 3.00
AA Analysis	95.00	± 10.00
Digestion	90.00	± 10.00
Collection Efficiency	99.00	± 1.00

$$\text{Random Error\%} = \left(3^2 + 10^2 + 10^2 + 1^2 \right)^{1/2} = 14.46\%$$

APPENDIX DATA

NEWARK SITE

Toxic Metals In Airborne Particulates

Sampling Site: Newark

Concentrations in ug/M³

Date (1985)	1/7/85 Mon	1/13/85 Sun	1/19/85 Sat	1/25/85 Fri	1/31/85 Thurs	2/6/85 Wed	2/12/85 Tues	2/18/85 Mon	2/18/85 Sun	3/2/85 Sat
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	1.28	0.85	0.70	1.00	1.67	0.89	0.83	0.70	0.71	0.69
Zn	3.33	0.85	0.77	1.08	1.16	2.72	2.61	0.67	0.68	0.47
Ni	0.31	0.48	-	0.36	0.35	0.56	0.28	-	0.28	0.39
As	0.032	0.030	0.022	0.033	-	0.028	0.020	-	0.023	0.026
Se	-	-	0.047	0.080	0.067	0.053	-	-	-	0.081
Volume (M) ³	402	366.5	429.25	350.75	360.25	359.75	443.75	429.75	443.75	448.75

NA = Means not analysed for

- = Means not detected

Toxic Metals in Airborne Particulates

3

Sampling Site: Newark

Concentrations in ug/M

Date (1985)	3/8/85 Fri	3/14/85 Thurs	3/20/85 Wed	3/26/85 Tues	4/1/85 Mon	4/7/85 Sun	4/13/85 Sat	4/19/85 Fri	4/25/85 Thurs	5/1/85 Wed
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	0.86	0.67	0.75	1.02	0.93	0.97	0.86	0.88	0.98	0.92
Zn	0.83	0.53	0.92	0.76	0.87	0.82	0.80	1.30	1.16	2.06
Ni	0.30	-	0.61	-	0.15	0.14	0.15	0.18	-	-
As	0.037	0.035	0.030	-	-	0.037	0.029	0.033	0.031	0.040
Se	-	-	-	0.021	0.018	0.024	0.018	0.020	0.014	0.031
³ Volume (M)	411.50	416.50	398.75	373.25	413.50	416.50	423.75	428.50	414.75	415.25

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

Sampling Site: Newark

3
Concentrations in ug/M

Date (1985)	5/7/85 Tues	5/13/85 Mon	5/19/85 Sun	5/25/85 Sat	5/31/85 Fri	6/6/85 Thurs	6/12/85 Wed	6/18/85 Tues	6/24/85 Mon	6/30/85 Sun
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	0.86	0.91	1.01	0.92	0.75	0.69	0.69	0.78	0.85	N/A
Zn	1.13	1.51	0.91	0.71	1.73	0.55	0.68	0.60	0.77	N/A
Ni	0.17	0.16	0.19	-	0.48	0.58	0.43	-	0.33	N/A
As	0.029	0.037	-	0.033	-	0.053	0.032	0.022	0.042	N/A
Se	0.017	0.022	-	0.026	-	-	0.040	0.020	0.041	N/A
Volume (M) ³	429.75	416.50	405.25	423.75	413.50	397.50	461.75	736.50	449.50	

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

3

Sampling Site: Newark

Concentrations in ug/M

Date (1985)	7/6/85 Tues	7/12/85 Mon	7/18/85 Sun	7/24/85 Sat	7/30/85 Fri	8/5/85 Thurs	8/11/85 Wed	8/17/85 Tues	8/23/85 Mon	8/29/85 Sun
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	0.70	0.79	0.78	0.63	0.61	0.74	0.72	0.69	0.73	0.71
Zn	1.08	1.68	0.81	1.20	1.98	1.92	1.16	1.51	2.16	1.16
Ni	0.35	-	0.33	-	0.23	-	0.45	0.32	0.26	0.38
As	-	0.051	0.039	0.043	0.039	-	0.041	0.035	0.035	0.046
Se	0.036	-	0.031	0.031	-	-	0.034	0.032	-	-
³ Volume (M)	429.75	398.75	608.75	449.50	443.75	378.50	389	390.50	398.50	398.75

NA = Means not analysed for

- = Means not detected

Toxic Metals in Airborne Particulates

3

Sampling Site: Newark

Concentrations in ug/M

Date (1985)	9/4/85 Wed	9/10/85 Tues	9/16/85 Mon	9/22/85 Sun	9/28/85 Sat
Sampling Per	24 hrs	24 hrs		24 hrs	24 hrs
Pb	0.72	0.70	N/A	0.82	0.84
Zn	1.86	1.62	N/A	1.58	1.67
Ni	-	-	N/A	0.32	0.14
As	-	0.023	N/A	0.036	0.038
Se	0.041	0.023	N/A	0.024	0.022
Volume (M) ³	397.50	691.75		391.75	729.25

NA = Means not analysed for

- = Means not detected

RINGWOOD SITE

Toxic Metals In Airborne Particulates

Sampling Site: Ringwood

3
Concentrations in ug/M

Date (1985)	1/7/85 Mon	1/13/85 Sun	1/19/85 Sat	1/25/85 Fri	1/31/85 Thurs	2/6/85 Wed	2/12/85 Tues	2/18/85 Mon	2/18/85 Sun	3/2/85 Sat
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	0.48	0.63	0.69	0.71	0.86	0.78	0.79	0.82	0.76	0.82
Zn	0.78	0.63	-	0.56	0.36	-	0.52	-	-	0.64
Ni	0.010	0.011	0.009	0.008	0.010	-	0.010	0.010	0.011	-
As	0.010	0.010	0.012	0.013	-	0.011	0.009	0.009	0.009	0.010
Se	-	0.006	0.007	0.009	0.010	0.012	0.008	0.009	-	0.006
³ Volume (M)	366.50	370.50	369.25	372	318.50	324.50	382.25	380	403.50	443.75

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

Sampling Site: Ringwood

3
Concentrations in ug/M

Date (1985)	3/8/85 Fri	3/14/85 Thurs	3/20/85 Wed	3/26/85 Tues	4/1/85 Mon	4/7/85 Sun	4/13/85 Sat	4/19/85 Fri	4/25/85 Thurs	5/1/85 Wed
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs		24 hrs	24 hrs
Pb	0.87	0.72	0.82	0.86	0.69	0.68	0.71	N/A	0.74	0.68
Zn	0.69	0.49	-	-	0.53	0.45	0.53	N/A	0.49	0.47
Ni	0.010	0.009	0.012	0.009	-	0.029	0.028	N/A	0.16	0.16
As	-	0.009	0.009	0.007	0.006	0.010	0.009	N/A	-	0.012
Se	0.006	-	0.008	0.012	0.009	0.007	0.010	N/A	0.013	0.011
³ Volume (M)	393	387.25	387.25	381	389	387.75	393		381	404

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

3

Sampling Site: Ringwood

Concentrations in ug/M

Date (1985)	5/7/85 Tues	5/13/85 Mon	5/19/85 Sun	5/25/85 Sat	5/31/85 Fri	6/6/85 Thurs	6/12/85 Wed	6/18/85 Tues	6/24/85 Mon	6/30/85 Sun
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	0.69	0.69	0.76	0.68	0.70	0.78	0.70	0.78	0.80	0.67
Zn	0.49	-	0.49	0.38	0.55	0.31	0.46	0.45	-	0.36
Ni	0.18	-	0.18	0.20	-	0.037	0.039	0.026	-	0.025
As	0.009	0.007	-	0.007	0.006	-	0.008	0.008	0.009	0.007
Se	0.012	-	0.010	0.009	0.009	0.006	0.011	0.006	0.009	0.012
Volume (M)	397.50	404	397.50	406	406	391.75	393	398.75	389.25	403.50

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

Sampling Site: Ringwood

3
Concentrations in ug/M

Date (1985)	7/6/85 Sat	7/12/85 Fri	7/18/85 Thurs	7/24/85 Wed	7/30/85 Tues	8/5/85 Mon	8/11/85 Sun	8/17/85 Sat	8/23/85 Fri	8/29/85 Thurs
Sampling Per						24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	N/A	N/A	N/A	N/A	N/A	0.67	0.62	0.51	0.77	0.80
Zn	N/A	N/A	N/A	N/A	N/A	0.49	0.63	0.48	0.64	0.37
Ni	N/A	N/A	N/A	N/A	N/A	0.19	0.033	0.048	0.044	0.045
As	N/A	N/A	N/A	N/A	N/A	0.010	0.008	0.008	0.10	0.009
Se	N/A	N/A	N/A	N/A	N/A	0.013	0.012	-	0.008	0.009
³ Volume (M)						380	381	387.25	382.50	387.75

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

3

Sampling Site: Ringwood

Concentrations in ug/m

Date (1985)	9/4/85 Wed	9/10/85 Tues	9/16/85 Mon	9/22/85 Sun	9/28/85 Sat
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs
Pb	0.69	0.50	0.17	0.04	0.51
Zn	-	0.37	0.32	0.46	0.35
Ni	0.047	0.062	0.046	-	0.042
As	0.009	0.008	-	0.009	0.008
Se	-	0.012	-	0.012	0.008
Volume (M)	390.50	387.75	378.50	376.50	423.75

NA = Means not analysed for

- = Means not detected

HACKENSACK MEADOWLAND SITE

Toxic Metals in Airborne Particulates

3

Sampling Site: Environment Center Hackensack - Meadowland

Concentrations in ug/M

Date (1985)	10/5/85 Sat	10/11/85 Fri	10/17/85 Thurs	10/23/85 Wed	10/30/85 Tues	11/5/85 Mon	11/11/85 Sun	11/17/85 Sat	11/23/85 Fri	11/29/85 Thurs
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs		24 hrs
Pb	1.29	1.27	1.32	1.15	1.25	1.17	1.11	2.68	N/A	1.32
Zn	1.78	1.87	1.50	1.25	1.28	1.26	1.30	1.32	N/A	1.11
Ni	-	-	1.20	-	1.20	1.23	-	1.16	N/A	-
As	0.035	0.031	-	-	0.034	0.040	-	0.033	N/A	0.039
Se	0.028	0.030	0.032	-	-	0.026	-	-	N/A	0.034
³ Volume (M)	224.29	224.29	224.29	244.68	224.29	224.29	224.29	224.29		203.90

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

3

Sampling Site: Environment Center Hackensack - Meadowland

Concentrations in ug/M

Date(1985/86)	12/5/85 Wed	12/11/85 Tues	12/17/85 Mon	12/23/85 Sun	12/29/85 Sat	1/4/86 Fri	1/10/86 Thurs	1/16/86 Thurs	1/22/86 Wed	1/28/86 Tues
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs		24 hrs
Pb	1.17	1.39	1.28	N/A	N/A	N/A	N/A	1.43	1.26	1.30
Zn	2.63	1.37	0.96	N/A	N/A	N/A	N/A	2.62	1.61	1.52
Ni	-	-	1.07	N/A	N/A	N/A	N/A	-	1.02	1.11
As	-	0.039	-	N/A	N/A	N/A	N/A	0.029	-	0.021
Se	0.032	0.028	-	N/A	N/A	N/A	N/A	-	0.024	0.018
³ Volume (M)	224.29	203.90	224.29					244.68	244.68	244.68

NA = Means not analysed for

- = Means not detected

Toxic Metals In Airborne Particulates

3

Sampling Site: Environment Center Hackensack - Meadowland

Concentrations in ug/M

Date (1985/86)	2/3/86 Mon	2/9/85 Sun	2/15/86 Sat	2/21/86 Fri	2/27/86 Thurs	3/5/86 Wed	3/11/86 Tues	3/17/86 Mon	3/23/86 Sun	3/29/86 Sat
Sampling Per	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs		24 hrs
Pb	1.17	1.12	1.21	1.19	1.32	1.15	1.18	1.25	1.31	1.17
Zn	1.71	2.11	1.30	1.80	1.52	1.47	1.27	1.40	2.21	1.56
Ni	-	-	1.21	1.18	-	1.16	1.01	-	1.15	1.17
As	0.025	-	0.031	0.028	0.019	-	0.035	0.032	-	0.027
Se	-	0.020	0.030	-	0.028	-	-	0.021	0.019	-
Volume (M) ³	244.68	244.68	244.68	244.68	244.68	244.68	244.68	244.68	244.68	244.68

NA = Means not analysed for

- = Means not detected

FOOTNOTES

1
Cook J, "Environmental Pollution By Heavy Metals",
International Journal of Environmental Studies, Vol. 9, 1977,
p 253.

2
Steven, J. Elsenrelch, Nancy A. Metzger and Noel R.
Urban, "Response of Atmospheric Lead to Decreased Use of Lead
in Gasoline", Environmental Science Technology, Vol. 20 No. 2
1986, p. 171.

3
Elsenrelch, J.S., Metzger A. N and Urban R. N. p 171.

4
Elsenrelch, J.S., Metzger A. N and Urban R. N. p 171.

5
Ilhan Olmez and Gordon Glen, "Rare Earths: Atmospheric
Signatures for Oil Fired Power Plants and Refineries",
Science, Vol. 229, Sept 1985, p. 966.

6
Liaquat Husain and Parekh p.p, "Trace Element
Concentrations in Summer Aerosols at Rural Sites in New York
State and Their Possible Sources", Atmospheric Environment,
Vol 15, No.9 1981, p.1717.

7
Richard, L. Davison; David F. Natusch and Wallace, J.
"Trace Elements in Fly Ash", Environmental Science and
Technology, Vol. 8, No. 13, Dec 1974, p. 1107.

8
Rober H. Daines, Harry Motto and Daniel
Chilko, "Atmospheric Lead: Its Relationship to Traffic Volume
and Proximity to Highways", Environmental Science and
Technology. Vol 8, 1970, p.318.

9
Alzona J, Cohen B.L, Rudolph. H, Jow H. and Frohliger
J.O, "Indoor-Outdoor Relationships for Airborne Particulate
Matter of Outdoor Origin", Atmospheric Environment Vol. 13,
1979, p.55

10
Alzona J, Cohen B.L., Rudolph H., Jow H.N. and Froliger
J.O. p.55

11
Alzona J, Cohen B.L., Rudolph H., Jow H.N. and Froliger
J.O. p.55

- 12
Annapurna V, Mahajan B.A and Murti M.V.R. "Studies of Blood Lead Levels in Bombay's Citizens", International Journal Environmental Studies, Vol. 24 1985 p. 239.
- 13
Stephen Hall, "Pollution and Poisoning", Environmental Science and Technology, Vol 6, No. 1, Jan 1972, p.32.
- 14
Roy M. Harrison and Clive R. Williams, "Airborne Cadmium, Lead and Zinc at Rural and Urban Sites in North-West England,"Atmospheric Environment", Vol 16, No 11 1982, p. 2669.
- 15
Khandekar R.N, Kelkar D.N. and Vohr K.G, "Lead, Cadmium, Zinc, Copper, and Iron in the Atmosphere of Greater Bombay", Atmospheric Environment, Vol 14 1980, p. 457.
- 16
George T. Wolff and Patricia E. Korsog, "Estimates of the Contributions of Sources to Inhalable Particulate Concentrations in Detroit", Atmospheric Environment, Vol 19 No. 9 1985, p. 1399.
- 17
Wolff G. and Korsog P, p. 1399.
- 18
Roy M. Harrison and Clive R. Williams, " Airborne Cadmium, Lead and Zinc at Rural and Urban Sites in North-West England", Atmospheric Environment, Vol. 16, No.11 1982 p. 2669.
- 19
Harrison R and Williams C, p. 2669
- 20
Harrison R and Williams C, p. 2671
- 21
Harrison R and Williams C, p. 32
- 22
General Metal Works Inc., 8369 Bridgetown Road, Village of Cleves, Ohio 45002.
- 23
The Staplex Co., 777 Fifth Ave, Brooklyn, New York, 11232.
- 24
Wolff G. and Korsog P., p. 1407.

25

Joseph W. Bozzelli, B.B. Kebbekus and A. Greenberg,
"Analysis of Selected Toxic and Carcinogenic Substances in
Ambient Air in New Jersey", New Jersey Institute of
Technology Air Pollution Research Lab, May 1980. p 57.

26

Fukuzaki Norio, Takaak Yanaka and Urushiyania Yoshio.
Effects of Studded Tires on Roadside Airborne Dust Pollution
in Niigata, Japan. Atmospheric Environment, Vol 20., No. 2
1986, p. 377.

BIBLIOGRAPHY

- Annapurna, V; Mahajan B.A.; and Murti M.V.R. "Studies of Blood Lead levels in Bombay's Citizens", International Journal of Environmental Studies, Vol 24, 1985, pp. 239-243.
- Bogden D. John, Singh P. Narayani and Morris, M. "Cadmium, Lead and Zinc Concentrations in Whole Blood Samples of Children", Environmental Science and Technology, Vol 8, No.8, August 1974, pp 740-744.
- Bullock, J and Lewis M.W., "Influence of Traffic on Atmospheric Pollution", Atmospheric Environment, Vol 2, 1968, pp. 517-534.
- Colombo A. "The Underfined Nature of the Blood-Lead -Air Lead Relationship from biological and Statistical Grounds", Atmospheric Environment, Vol. 19, No 9. 1985, pp. 1484-1493.
- Cook, J "Environmental Pollution by Heavy Metals", International Journal of Environmental Studies, Vol 9, 1977, pp. 253-266.
- Cohen L Arnold, "Dependence of Hi-Vol Measurement on Airflow Rate." Environmental Science and Technology, Vol 7., No.1, January 1973, pp 60-61.
- Davison R.L.; Natusch D.F.S. and Wallace J.R, "Trace Elements in Fly Ash: Dependence of Concentrations on Particle Size." Environmental Science and Technology, Vol 8, No. 13, Dec 1974, pp 1107-1113.
- Daines, R.H; Motto H and Chilko D,M "Atmospheric Lead : It Relationship to Traffic Volume and Proximity to Highways". Environmental Science and Technology, 1970, p.318.
- Dorn, C.R; Pierce, J.O; Phillips P.E. and Chase G.R., "Airborne Pb,Cd,Zn and Cu Concentration by Particle Size Near a Pb Smelter". Atmospheric Environment, Vol 10, 1076, pp 443-446.
- Eisenreich J. Steven, Metzger, Nancy and Urban Noel, "Response of Atmospheric Lead to Decreased use of Lead in Gasoline". Environmental Science and Technology, Vol. 20, No. 2 1986, pp 171-173.
- Fukuzaki Norio; Yanaka Takaaki and Urushiyama Yoshio, "Effects of Studded Tires on Roadside Airborne Dust Pollution in Niigata, Japan" . Atmospheric Environment, Vol. 20, No. 2 1986, pp. 377-386.

- Gillmore T. Jerry and Raymond H. Lea, "Effect of Decreased use of Lead in Gasoline on the Soil of a Highway". Journal of Environmental Science Technology, Vol. 17, No 2, 1983, pp 121-123.
- Hall K. Stephen, "Pollution and Poisoning". Environmental Science and Technology, Vol. 6, No1, January, 1972, pp 31-35.
- Habibi, K. "Characterization of Particulate Matter in Vehicle Exhaust". Environmental Science Technology, Vol 7, 1973, pp. 223-234.
- Harrison M. Roy; Laxen P.H. Duncan and Wilson J.S. Chemical Association of Lead, Cadmium, Copper and Zinc in Street Dust and Roadside Soils". Environmental Science and Technology, Vol. 15, No. 11, Nov. 1981, pp 1378-1382.
- Harrison M.R. and Williams R. "Airborne Cadmium, Lead and Zinc at Rural and Urban Sites in Northwest England". Atmospheric Environment, Vol 16, No.11 1982, pp 2669-2681.
- Illhan Olmez; Glen E.G; "Rare Earths: Atmospheric Signatures for Oil Fired Power Plants and Refineries". Science, Vol 229, No. 6, Sept 1985, pp. 966-968.
- Jozef M.P. and Brynjulf Ottar; Urszula, T and Willy M. "Long Range Transport of Trace Elements to N.Y. Alesund, Spitsbergen". Atmospheric Environment, Vol 19, No.6. pp 857-865.
- Kebbekus B.B. and Bozzelli J.W. "Lead and Toxic Metals In Airborne Particulate". Program on Environmental Cancer and Toxic Substances NJDEP, Oct 1979, pp 1-42.
- Khandekar R.N; Kelkar D.N and Vohra K.G. "Lead, Cadmium, Zinc, Copper and Iron in the Atmosphere of Greater Bombay". Atmospheric Environment, Vol. 14 1980, pp 457-461.
- Kleinman M.T; Kneip T.J; Eisenbud M; "Seasonal Pattern of Airborne Particulate Concentrations in New York City". Atmospheric Environment, Vol 10 1976, p. 9.
- Leaderer B.P. "Summer of New York Summer Aerosol Study". Journal of Air Pollution Control Association, Vol 28, 1978, p. 321.
- Lloy Paul and Dousey Joan "Airborne Toxic Elements and Organic Substances". Environment Science and Technology, Vol. 20, No. 1 1986, p. 196.

Lloy Paul, Wolff T. George and Knerp J.T. "Toxic Airborne Elements in New York Metropolitan Area". Journal of Air Pollution Control Association, Vol 28, No. 5, May 1978, pp. 510-512.

Parekh P.P; and Husain Liaquat; "Trace Element Concentrations in Summer Aerosols at Rural Sites in New York State and Their Possible Sources". Atmospheric Environment, Vol. 15, No. 9 1981, pp 1717-1725.

Wolff T.G. and Korsog P.E. "Estimates of the Contributions of Sources to Inhalable Particulate Concentrations in Detroit". Atmospheric Environment, Vol 19, No. 9. 1985, pp. 1399-1409.