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Volume V

Risk Assessment and Statistical Analyses

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This report is a collaborative effort of the staffs of the Region II Office of the U.S. Environmental Protection Agency (EPA), the New Jersey Department of Environmental Protection and Energy, the New York State Department of Environmental Conservation, the New York State Department of Health, the University of Medicine and Dentistry of New Jersey and the College of Staten Island. The project was undertaken at the request of elected officials and other representatives of Staten Island concerned that emissions from neighboring industrial sources might be responsible for suspected excess cancer incidences in the area.

Other EPA offices that provided assistance included the Office of Air Quality Planning and Standards, which provided contract support and advice; and particularly the Atmospheric Research and Exposure Assessment Laboratory, which provided contract support, quality assurance materials, and sampling and analysis guidance, and participated in the quality assurance testing that provided a common basis of comparison for the volatile organic compound analyses. The Region II Office of Policy and Management and its counterparts in the States of New York and New Jersey processed the many grants and procurements, and assisted in routing funding to the project where it was needed.

The project was conceived and directed by Conrad Simon, Director of the Air and Waste Management Division, who organized and obtained the necessary federal funding.

Oversight of the overall project was provided by a Management Steering Committee and oversight of specific activities, by a Project Work Group. The members of these groups are listed in Volume II of the report. The Project Coordinators for EPA, Robert Kelly, Rudolph K. Kapichak, and Carol Bellizzi, were responsible for the final preparation of this document and for editing the materials provided by the project subcommittee chairs. William Baker facilitated the coordinators' work.

Drs. Edward Ferrand and, later, Dr. Theo. J. Kneip, working under contract for EPA, wrote several sections, coordinated others, and provided a technical review of the work.

The project was made possible by the strong commitment it received from its inception by Christopher Daggett as Regional Administrator (RA) for EPA Region II, and by the continuing support it received from William Muszynski as Acting RA and as Deputy RA, and from Constantine Sidamon-Eristoff, the current RA. The project has received considerable support from the other

project organizations via the Management Steering Committee, whose members are listed in Volume II.

PREFACE - DESCRIPTION OF THE STATEN ISLAND/NEW JERSEY URBAN AIR TOXICS ASSESSMENT PROJECT REPORT

This report describes a project undertaken by the States of New York and New Jersey and the United States Environmental Protection Agency with the assistance of the College of Staten Island, the University of Medicine and Dentistry of New Jersey and, as a contractor, the New Jersey Institute of Technology.

Volume I contains the historical basis for the project and a summary of Volumes II, III, IV, and V of the project report.

Volume II of the report lists the objectives necessary for achieving the overall purpose of the project, the organizational structure of the project, and the tasks and responsibilities assigned to the participants.

Volume III of the report presents the results and discussion of each portion of the project for ambient air. It includes monitoring data, the emission inventory, the results of the source identification analyses, and comparisons of the monitoring results with the results of other studies. Volume III is divided into Part A for volatile organic compounds, and Part B for metals, benzo[α]pyrene (BaP), and formaldehyde. Part B includes the quality assurance (QA) reports for the metals, BaP, and formaldehyde.

Volume IV presents the results and discussion for the indoor air study performed in this project. It contains the QA reports for the indoor air study, and a paper on the method for sampling formaldehyde.

Volume V presents the results of the detailed statistical analysis of the VOCs data, and the exposure and health risk analyses for the project.

Volume VI, in two parts, consists of information on air quality in the project area prior to the SI/NJ UATAP; quality assurance (QA) reports that supplement the QA information in Volume III, Parts A and B; the detailed workplans and QA plans of each of the technical subcommittees; the QA reports prepared by the organizations that analyzed the VOC samples; descriptions of the sampling sites; assessment of the meteorological sites; and a paper on emissions inventory development for publicly-owned treatment works.

The AIRS database is the resource for recovery of the daily data for the project. The quarterly summary reports from the sampling organizations are available on a computer diskette from the National Technical Information Service.

STATEN ISLAND/NEW JERSEY
URBAN AIR TOXICS ASSESSMENT PROJECT

VOLUME V. RISK ASSESSMENT AND STATISTICAL ANALYSES

EPA/902/R-93-001f

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1. EXPOSURE AND HEALTH RISK ASSESSMENT

1.1 INTRODUCTION

A primary objective of the Staten Island/New Jersey Urban Air Toxics Assessment Project (SI/NJ UATAP) was to assess exposure and health risk arising from inhalation of airborne toxic pollutants in the area.[1] The outdoor air sampling sites and sampling frequencies were chosen so that spatial and temporal concentration differences of air toxics within the Staten Island/New Jersey region could be determined, and exposures and associated health risks in the communities surrounding each site could be estimated.

Volume II of the project report provides a detailed description of the SI/NJ UATAP. For the reader's orientation, Tables V-1-1a through 2b listing the sampling sites and the chemicals for which the samples were analyzed, and Map V-1-1 shows the locations of the monitoring sites. Staten Island is bordered on the west by a complex of major industries including pharmaceutical plants, oil refineries, and chemical storage facilities. Other industrial sources of pollution include sewage treatment plants and the 1400-acre Fresh Kills Landfill.

This volume provides the exposure and risk assessments for the study chemicals for which toxicological information (e.g., inhalation reference concentrations and carcinogen unit risk factors) and air concentration data from the study are available. These conditions limited the scope of the quantitative risk assessment to 22 of the 40[2] study chemicals--11 volatile organic compounds (VOCs), 9 metals, benzo[α]pyrene (BaP), and formaldehyde.[3]

Exposure to air pollutants in the project study area was characterized qualitatively by comparing the measured pollutant levels with levels of those pollutants in other urban areas of the United States.

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[1] SI/NJ UATAP report, Volume II, Section 1.3.

[2] In this tally, m- and p-xylene are counted as one chemical.

[3] Note that formaldehyde is a VOC, that its segregation from other VOCs in this report is a consequence of its collection by a different method from that used for the other VOCs.

The health risks associated with the exposure were characterized by conducting a quantitative health risk assessment. In a quantitative health risk assessment, data on pollutant effects determined from experimental exposure of laboratory animals or, for some pollutants, from human exposure, are used to estimate the risk (likelihood or probability) of such health effects at the pollutant concentrations measured in the project area.

These risks are expressed either by comparing the measured concentrations with levels that are considered to be substantially without appreciable risk (for noncancer effects) or by estimating the increased risk of cancer from exposure to the measured pollutant levels. Both types of risk estimates are termed "increased" risk to indicate that they do not express the total risk of these effects. Many other environmental, socio-demographic, and genetic factors contribute to an individual's total risk of cancer and other health conditions.

Two approaches to quantitative risk assessment for the project data are presented. The Level 1 risk assessments assume that an individual is exposed for an entire lifetime to the annual average air pollutant concentration recorded at one of the project monitors for the period from October 1, 1988, through September 30, 1989. The Level 2 risk assessments include both indoor and outdoor monitoring data, and assume that body weight and inhalation rate vary over the lifetime of the individual. VOCs were addressed separately from metals, BaP, and formaldehyde in the Level 1 risk assessments, so that there are two Level 1 risk assessments in this report. The Level 2 risk assessment addressed only the 13 VOCs quantitated in indoor air during the period from July 10, 1990, through March 19, 1991.

The risk assessments presented in this report employed methodologies outlined in EPA guidelines. (U.S. EPA, 1986a, 1986b, 1986c, 1992).

Note that these risk assessments for the SI/NJ UATAP are not complete assessments of air pollution risk for Staten Island and nearby New Jersey, since (1) the study compounds do not represent all the pollutants in ambient air, and (2) exposure via routes other than direct inhalation (i.e., ingestion and dermal) from ambient air are not addressed.

1.2 AIR POLLUTANT CONCENTRATIONS IN THE SI/NJ UATAP STUDY AREA

Tables V-1-3 and V-1-4 summarize the annual average concentrations of the air pollutants monitored in the SI/NJ UATAP. In general, these air monitoring results show that air

pollutant levels in the region are in the ranges for those pollutants in other urban areas in the United States. This is illustrated by the data from other urban areas summarized in Figures V-1-1 through 10 (VOCs), and Figures V-1-11 through 24 (metals, BaP, and formaldehyde).

Data from the EPA 1988 and 1989 Urban Air Toxics Monitoring Program (UATMP) studies (U.S. EPA, 1989b; and U.S. EPA, 1989c) were selected for this comparison since they provided concentration data for virtually all of the SI/NJ UATAP study chemicals for a large number of urban locations nationwide. Some of the 1988 UATMP sites are in highly industrialized locations, while others are in residential sections of urban areas. The SI/NJ UATAP sites are in residential neighborhoods: on rooftops of fire stations, schools, a police department, a post office, and a pumping station; and at ground level at a hospital, a park, and a private home. However these sites are generally very close to highly industrialized areas, as evidenced by the microinventory of emissions sources within on kilometer of each monitor.[4] A description of the 1988 UATMP sites and a brief comparison of the SI/NJ UATAP and the UATMP studies are in the appendix of this volume. The site reports prepared for the SI/NJ UATAP are in Volume VI of the six-volume SI/NJ UATAP report.

When comparing data from different studies, differences in reported concentrations should not be construed as significant without knowledge of limitations in data quality. Even within the SI/NJ UATAP set of data, apparent differences in concentration should not be assumed to be statistically significant. In the cases of the SI/NJ UATAP concentration data for a limited set of chemicals, the statistical analysis section of this volume presents intersite concentration differences that were found to be statistically significant.

1.2.1 VOCs

For ten VOCs, Figures V-1-1 through 10 compare the minimum, median, and maximum of the SI/NJ UATAP site annual averages for the period from October 1988 through September 1989 (excluding Piscataway, the background site for the VOCs) and the annual averages for Piscataway for the same period, to the UATMP VOC annual average concentrations for 1988 (October 1987 through September 1988) and 1989 (January 1989 through December 1990). The VOC comparison data for 1988 are from air monitoring sites in 19 cities. The 1989 data were collected in 12 cities. Six cities provided data in both years. The 1989 data include two

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[4] This microinventory is found in Volume III, Part A, of the SI/NJ UATAP report.

monitoring stations each for two of the cities (Washington, D.C., and Wichita, Kansas). The UATMP sites are listed below.

1988 UATMP sites

Atlanta, GA	Baton Rouge, LA	Birmingham, AL
Burlington, VT	Cleveland, OH	Chicago, IL (Carver H.S. and Washington, H.S.)
Dallas, TX	Dearborn, MI	Detroit, MI
Hammond, IN	Houston, TX	Jacksonville, FL
Lansing, KY	Louisville, KY	Miami, FL
Midland, MI	Port Huron, MI	Portland, OR
Sauget, IL		

1989 UATMP sites

Baton Rouge, LA	Camden, NJ	Chicago, IL (Carver H.S. and Washington, H.S.)
Dallas, TX	Ft. Lauderdale, FL	Houston, TX
Miami, FL	Pensacola, FL	Sauget, IL
St. Louis, MO	Washington, DC #1	Washington, DC #2
Wichita, KS #1	Wichita, KS #2	

Figures V-1-1 through 10 are described below. Note that these descriptions do not ascribe significance to the magnitudes of the differences observed.

The annual average concentrations of some of the VOCs differed widely between the two monitoring stations in Washington and Wichita. Large differences were observed in the annual average concentrations of some chemicals in the same cities in different years, e.g., in the cases of benzene and trichloromethane in Dallas. Some all-city median chemical concentrations also varied widely between the two groups (1988 and 1989 groups) of cities. This demonstrates the variability that may be found within an urban area in the same year, and between sets of data for different years.

Annual average chemical concentrations at the other SI/NJ UATAP monitoring sites were generally within the range of the annual average concentrations for the same chemicals at the UATMP sites. For the xylenes and trichloromethane, the SI/NJ UATAP data are at the low end of the range of UATMP concentrations. The dichloromethane levels at the SI/NJ UATAP sites were higher than levels in many of the other cities. The tetrachloromethane and benzene levels at the SI/NJ sites were higher than those at the 1988 UATMP cities; but at the low end of the range of concentrations of the 1989 UATMP cities.

In general, then, for the periods compared, exposure to these ten VOC compounds in the SI/NJ UATAP study area are in the range of exposures in other urban areas. Dichloromethane levels were at the high end of the range of levels from the other cities.

1.2.2 Metals, Benzo[α]pyrene, and Formaldehyde

For the metals, BaP, and formaldehyde, Figures V-1-11 through 24 compare the medians of the annual average concentrations for the SI/NJ UATAP sites with the annual average concentrations for the 1988 UATMP sites.

Concentrations of molybdenum, nickel, and vanadium at the SI/NJ UATAP sites were higher than those reported for the UATMP sites; and the concentration of chromium was higher than at most of the UATMP sites. The risks associated with these concentrations are discussed in section 1.4.5. The median annual average concentration of nickel at the SI/NJ UATAP sites is two to ten times higher than concentrations at the UATMP sites, with the exception of Louisville, KY, where the annual average concentration of nickel was about 1.5 times higher than the SI/NJ UATAP median.

1.3 QUANTITATIVE RISK ASSESSMENT - HAZARD IDENTIFICATION, REFERENCE CONCENTRATIONS, AND INHALATION UNIT RISK FACTORS

As defined by the National Academy of Sciences in 1983 (National Research Council, 1983), risk assessment involves one or more of the following steps:

- hazard identification,
- dose-response assessment,
- exposure assessment, and
- risk characterization.

Risk assessment has been used extensively by regulatory agencies to compare potential risks from different chemicals, from exposure through different media (air, water, soil), and from exposure in different geographic areas. It is important to note that the risks presented are probabilities involving assumptions that may lead to over- and underestimates of risk.

1.3.1 Hazard Identification

The 40 chemicals studied are known to cause, or are suspected of causing adverse health effects. The health hazards that may arise from exposure to the chemicals studied in the

SI/NJ UATAP include non-cancer toxicity (e.g., effects on the liver or central nervous system)[5] and cancer.

1.3.2 Reference Concentrations and Inhalation Unit Risk Factors

Inhalation reference concentrations (RfCs)[6] and/or inhalation unit risk factors (IURFs) to assess noncancer toxicity and for cancer, respectively, have been identified for 16[7] of the study chemicals for which concentration data are available. Tables V-1-6 and 7 list the available RfCs and IURFs.

1.3.2.1 Reference concentrations for noncancer toxicity

Where available, RfCs were used in the risk assessment for noncancer health effects. Currently, only a small number of inhalation RfCs is available on the Integrated Risk Information System (IRIS) (U. S. EPA, 1990a), which contains the EPA's consensus toxicological information on approximately 500 chemicals.[8] Table V-1-6 identifies those study chemicals for

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[5] The potential target organs for the non-cancer health effects of the study chemicals are listed in Table V-1-17 in conjunction with the discussion of additive risk.

[6] In this report, "reference concentration" and "RfC" are used as generic terms, not specific to the reference concentrations provided by EPA's Reference Concentration/Reference Dose Workgroup. See discussion in Section 1.3.2.1.

[7] The xylenes (for which RfCs were recently withdrawn from IRIS), and lead and zinc (for which National Ambient Air Quality Standards, and not RfCs are used) are excluded from this count.

[8] The system is updated on a monthly basis to reflect currently available toxicological and regulatory information. IRIS is available to the public through the National Library of Medicine's TOXNET System.

which RfCs were available on IRIS or in the HEAST[9] (U.S. EPA, 1992b), or were provided by the New York State Department of Health (NYSDOH).

Inhalation RfCs appearing on IRIS represent EPA consensus; they were developed by EPA's Reference Dose/Reference Concentration Workgroup. This workgroup is comprised of senior scientists from the different Program Offices and Regions within EPA who have expertise in inhalation and oral toxicology, and risk assessment.

An IRIS inhalation RfC considers toxic effects for both the respiratory system (portal-of-entry) and for effects peripheral to the respiratory system. The RfC is expressed in units of milligrams/cubic meter (mg/m^3). In general, the inhalation RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfCs were derived according to the "Interim Methods for Development of Inhalation Reference Doses" (U. S. EPA, 1990b) developed by EPA scientists and peer-reviewed. The RfC methodology has been reviewed by the Science Advisory Board, a panel that reviews scientific documents for EPA. Note that RfCs can be derived for noncarcinogenic health effects of carcinogenic compounds.

The development of the RfC involves an analysis of the available toxicological data to identify the No Observed Adverse Effect Level (NOAEL). The NOAEL is defined as an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and appropriate controls. While effects may be produced at this level, they are not considered adverse per se, or precursors to specific adverse effects. When research results yield several NOAELs for different adverse effects from a chemical, the regulatory focus is primarily on the lowest one.

To protect sensitive subpopulations (children, the elderly, etc.) exposure should be limited to a fraction of the NOAEL by introducing suitable factors from 10 to 100,000. The RfC is calculated using the following equation:

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[9] The Health Effects Assessment Tables (HEAST) document is developed by the Office of Solid Waste and Emergency Response and the Office of Research and Development. The health effects information in these tables is regarded as provisional risk assessment information in that, except where the information is referenced to IRIS, it does not represent an EPA-wide consensus, although its inclusion does indicate concurrence by individual EPA program offices.

$$RfC = \frac{NOAEL}{(\text{Modifying Factor}) \times (\text{Uncertainty Factor})}.$$

Uncertainty factors (factors of 10) are intended to account for

(1) the variation in sensitivity among the members of the human population;

(2) the uncertainty in extrapolating from animal data to human exposures;

(3) the uncertainty in extrapolating from data obtained in a study that is less than lifetime exposure; and

(4) the uncertainty in using the Lowest Observed Adverse Effects Level (LOAEL) when a NOAEL has not been or cannot be determined.

Based on the Workgroup's assessment of the overall data base for a chemical, a factor of 10 is assigned for each applicable source of uncertainty, and the factors are multiplied to yield an uncertainty factor. The maximum uncertainty factor is 3000; this takes into account the compounding of error likely when uncertainty from all four sources affects the derived RfC.

The modifying factor ranges from 1 to 10, depending on the overall database (i.e., the number and quality of studies available, quality of data, etc.) for the chemical; the default value is 1.

Summaries of the bases for the RfCs developed by EPA and NYSDOH are provided in Volume VI, Appendices. Also in Volume VI are memoranda concerning the differences in development of the former HEAST RfC for chromium and the current NYSDOH RfC for chromium (Dollarhide, 1992), and the status of the RfC for xylene (Poirier, 1992).

1.3.2.2 Unit risk factors for carcinogenicity

Table V-1-7 summarizes the unit risk factors available for the study chemicals, their Chemical Abstract Service Numbers, and the Carcinogenic Weight of Evidence classifications. The Weight of Evidence classification was developed by EPA's Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup, composed of senior scientists from EPA program offices selected for their expertise in assessing carcinogens. CRAVE's review process involves an extensive analysis of the available toxicological, scientific and cancer

information on the chemicals. Based on this review, CRAVE then assigns a Weight of Evidence Classification to the chemicals as outlined in EPA's Risk Assessment Guidelines for Carcinogens (U.S. EPA, 1986a). The EPA classification is as follows:

Group A - Human carcinogen (based on human epidemiological evidence)

Group B - Probable human carcinogen

B1 - indicates limited evidence from human studies

B2 - indicates sufficient evidence from animal studies, but inadequate evidence from human studies

Group C - Possible human carcinogen (based on animal evidence)

Group D - Not classifiable as to human carcinogenicity (based on lack of evidence)

Group E - Evidence of non-carcinogenicity for humans

Chemicals ranked as Group D carcinogens lack adequate data for the development of cancer dose-response information; they are treated as non-carcinogens until additional research information becomes available and the chemical can be reclassified. The CRAVE Workgroup reviews data on an on-going basis; updates are provided on IRIS.

Three of the metals and one of the VOCs in the SI/NJ UATAP have been classified as, or associated with compounds classified as, Group A carcinogens. One metal and formaldehyde are Group B1. Five VOCs, one metal, and BaP are Group B2. Three VOCs and two metals are Group D. Of the remaining chemicals analyzed during the project, but excluded from quantitative risk assessments for carcinogenicity, two are Group D (1,1,1- and 1,1,2-trichloroethane); unit risk factors are available for two, but no valid ambient air concentration data were reported (chloromethane and beryllium); and 16 are unclassified.

When assessing cancer risks, EPA assumes that the carcinogenic substances cause some level of risk at any exposure level; that is, a zero-threshold for adverse effects is assumed. In developing unit risk factors, EPA typically uses a non-threshold, linearized, multistage model to extrapolate from high-dose data of animal tests to the low doses typically resulting from human exposure to low concentrations in ambient air. Using this model, a cancer slope factor (CSF)--proportion affected per unit of dose--is developed by CRAVE for each chemical. The CSF, expressed as (milligrams of substance per kilogram [kg] body weight per day [d])$^{-1}$, and weight of evidence can be used to

For this risk analysis, the Inhalation Unit Risk Factor (IURF) was used. The IURF is a quantitative estimate of the increased probability of developing cancer from a 70-year lifetime continuous exposure to a concentration of one microgram of a given pollutant per cubic meter air. The IURF's assume that the individual weighs 70 kg (154 lbs.), and that the rate of inhalation is 20 cubic meters/day over a 70-year period.

The CSFs and IURFs in Table V-1-7 that were found in IRIS reflect the EPA consensus for these chemicals as of January 28, 1992. As new toxicological information becomes available, the CRAVE Workgroup reviews it and, if warranted, changes the CSF and IURF to reflect the new data.

The chromium IURF is based on chromium VI (valence +6), for which carcinogenic data were available. The amounts of chromium VI in the ambient air samples were not determined. In this risk assessment, chromium VI is treated as the only carcinogenic component of the total (reported) chromium concentration[10], and the total chromium is assumed to contain 1 or 10% chromium VI. This range was chosen because of the absence of site-specific data on sources of chromium VI versus chromium III.[11] This may lead to over- or underestimates of excess risk.

1.4 LEVEL 1 RISK ASSESSMENTS

Table V-1-8 summarizes the availability of RfCs, IURFs, and ambient air concentration data for quantitative risk assessment.

1.4.1 Exposure Assumptions

The basic exposure variable used in the Level 1 risk assessment is the annual average ambient air concentration for the second year of the study (October 1988 through September 1989). The second-year data from each sampling organization were selected for risk calculation since these data are regarded as

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[10] Chromium has also been found in the +3 valence state; chromium III has not been determined to be carcinogenic.

[11] Discussions with OAQPS and review of EPA's sludge regulations indicated that chromium VI is not as stable as chromium III; therefore, it is expected that the latter oxidation state would be more prevalent in the ambient air.

more self-consistent than the first-year data[12], and since one year is commonly used for assessing chronic risks. Annual averages were calculated as follows:

$$\text{Annual average} = (\Sigma n_i x_i)/(\Sigma n_i),$$

where n_i = number of samples in the i^{th} quarter, and
x_i = average concentration in the i^{th} quarter.

For the three sites Bayley-Seton, Eltingville, and Dongan Hills, these annual averages are biased towards the first and second quarters of the year because of the greater sampling frequency during those quarters.[13]

The Level 1 risk assessment assumes that an individual would be exposed for 70 years to the concentrations identified in Tables V-1-3 and V-1-4. In addition, the individual is assumed to weigh 70 kgs, and inhale 23 cubic meters[14] of ambient air during 24-hour exposures every day of those 70 years.

These assumptions are used commonly for screening risk assessments such as those presented here (e.g., U.S. EPA, 1989d; U.S. EPA, 1990c).

Anecdotal information and the 1990 census data suggest that many residents in the study area spend a good part of their time either living in the community or working there. However, it was not possible to determine the percentage of the community that would match the 70-year assumption used in this risk assessment. (A summary of the population analysis is included in the appendix of this volume.) For an unknown percentage of the community,

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[12] The Quality Assurance Section supports this conclusion. During the beginning of the first year of monitoring, organizations were de-bugging their operations; sampling and analysis by each organization was more constant through the course of the second year. See Volume III, Part A, Section 2, of the SI/NJ UATAP report.

[13] The effect of the differences in sampling frequency is most pronounced in the annual averages listed for Dongan Hills for hexane, benzene, toluene, and m- and p-xylenes. If the average of all of the sample concentrations is compared to annual averages computed by averaging the quarterly averages, the differences are that the latter set of averages is lower than the former by 0.14 ppb (16%), 0.53 ppb (27%), 0.57 ppb (14%), and 0.36 ppb (14%), respectively.

[14] This value is based on 16 hours of light activity and 8 hours of resting, assumptions that are part of the Reference Man scenario (ICRP, 1981).

these calculations might lead to errors in risk estimates for the following reasons:

- Residents might not live in the community for an entire lifetime (70 years). Current data in the Exposure Factors Handbook (U. S. EPA, 1989a) indicate that the average person (50th percentile) moves every 9 years with an upper bound estimate (90th percentile) of 30 years. If an individual moves to an area with no exposure to these chemicals after 30 years or 9 years, the individual's exposure would be reduced. Conversely, if relocation resulted in exposure to higher concentrations than those in the study area, the lifetime risks presented here would be underestimates.

- Residents might spend a portion of the day away from the area.

- Residents might also spend part of the year on vacations or outside of the area.

The Level 1 approach to the exposure assessment, with its use of outdoor air concentrations and default (standard) assumptions, does not address the health impact of episodic high exposures and other short-term (acute and less than 1 year) exposure variations relative to the annual average concentrations, or of activity patterns and indoor exposures. The Level 2 risk assessment includes both indoor and outdoor VOC exposure data.

One of the exposure (dose) assumptions in the Level 1 analyses is 23 m^3/day as an inhalation rate. This inhalation rate assumption (constant) is not the standard assumption used by EPA. This modified inhalation rate has been incorporated into the inhalation RfCs and IURFs, yielding the modified (adjusted) RfCs and IURFs listed in Tables V-1-6 and 7.[15]

1.4.2 Results for the VOCs

For noncancer health impacts, the Table V-1-3 ambient air concentrations were compared to the Table V-1-6 reference

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[15] The standard RfCs and IURFs are based on a standard inhalation rate = 20 m^3/day at a temperature of 25 °C, lifetime = 70 years. The Level 1 risk assessment deviates from this standard scenario both in inhalation rate and temperature assumed (20 °C).

concentrations. The formalization used for this comparison was the Hazard Quotient (HQ), where HQ = ambient concentration/ reference concentration.[16,17]

Table V-1-9 presents the HQs calculated for 9 VOCs. The HQs are less than 0.1 for all compounds except benzene, tetrachloromethane, and, for two sites, tetrachloroethene; only benzene has an HQ greater than 1. According to the current perspective of exceedance of an RfC, an HQ greater than 1 suggests a need for further analysis of the bases (e.g., RfC, concentration data) of the calculated HQ. From an additive risk perspective, a mixture of chemicals (here, ambient air) with HQs less than one and a common target organ may result in a risk of concern for that target organ (i.e., a hazard index greater than 1 for the target organ). See Section 1.6 for further detail.

For potential individual cancer risk estimates, multiplication of the modified unit risk factors (modified to reflect an inhalation rate of 23 m^3/day rather than 20 m^3/day) by the Table V-1-3 concentrations of the pollutants generated the Table V-1-10 estimates of potential excess lifetime cancer risk per million for 6 VOCs. Since the estimates apply to a 70-year period, the annual risks would be lower.

The resulting estimates of potential excess cancer risk range from 0.4 to 61 per million over a lifetime (e.g. 70 years). For benzene, tetrachloromethane, and trichloromethane-- compounds detected at all SI/NJ UATAP monitoring sites--estimated excess lifetime cancer risks are higher than 10/million (10^{-5}) at some of the sites. For benzene and tetrachloromethane, the estimated excess cancer risks were found to be consistent across all

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[16] This deviates from the definition of hazard quotient in that the definition specifies that the subject exposure be of duration similar to that in the study from which the reference concentration was derived. The HQs in this risk assessment were calculated without regard for likely differences between the subject chronic exposures and the durations of the exposures leading to the reference concentrations. However, most of the reference doses are derived from chronic exposure studies.

[17] The HQ does not define a dose-response relationship; therefore, its numerical value should not be construed to be a direct estimate of risk. (Adapted from the discussion of Hazard Index in "Guideline for the Health Risk Assessment of Chemical Mixtures," [U. S. EPA, 1986b]).

sites.[18] While the estimated potential excess cancer risks calculated for trichloromethane at the Staten Island sites of Susan Wagner, PS-26, Port Richmond, Pump Station, Great Kills, and Tottenville were 1.7 to 8 times higher than at the New Jersey and remaining Staten Island sites, this result must be viewed with caution since the analytical methodologies were not equivalent at all sites.[19] (See Section 2 of Volume III, Part A, for further detail.) Trichloromethane is very volatile; breakthrough may have occurred for this compound at the New Jersey sites and at the Bayley-Seton, Eltingville, and Dongan Hills sites in New York, but, due to differences in effectiveness of the sorbents used in sample collection, not at the other six Staten Island sites. For further discussion of apparent site-to-site differences, see the statistical analysis of the VOCs data in Section 2 of this volume.

1.4.3 Results for the Metals, Benzo[α]pyrene, and Formaldehyde

Table V-1-3 summarizes the ambient air concentrations for the metals, BaP, and formaldehyde. Tables V-1-11 and 12 present the Level 1 risk calculations for the non-cancer and cancer effects of the study chemicals for which reference concentrations (RfCs) and/or unit risk factors (URFs) were available. In the case of lead, concentrations were compared to the National Ambient Air Quality Standard (NAAQS) for lead.[20] For zinc, concentrations were compared to the NAAQS for PM-10[21].

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[18] While the statistical analysis (Section 2 of this volume) found statistically significant intersite differences in the concentrations of benzene and tetrachloromethane, the risk assessment was not sensitive to these differences.

[19] The sites listed were run by NYSDEC; the remaining sites were run by NJDEP/NJIT and CSI.

[20] The current NAAQS for lead is under review; it might be revised downward to reflect current toxicological and epidemiological evidence of the neurotoxic effects of lead. Thus, this risk assessment for lead is not regarded as conservative.

[21] PM-10 is particulate matter with an aerodynamic diameter less than or equal to 10 microns, the size range considered respirable.

The hazard quotients for the non-cancer effects were less than 1 for cadmium, manganese, mercury, zinc, and formaldehyde[22]; the concentrations reported for lead were 3 to 7% of the NAAQS for lead. The HQ values calculated for nickel were close to 1, suggesting a need for further information on the nickel species present in the atmosphere, and further refinement of the RfC for nickel. The hazard quotient for total chromium was calculated using two different RfCs--one formerly from EPA[23], the other from NYSDOH. The former EPA RfC is regarded as more appropriate for chromium VI than for total chromium since it is based on an occupational study of workers exposed primarily to chromic acid containing Cr VI. The justification for using 10% and 1% of the total chromium concentration as the chromium VI concentration follows under the discussion of cancer risk. The NYSDOH value yielded HQs from 0.1 to 0.3; while the former EPA value yielded HQs from 0.07 to 1.5, depending upon the site and the percent chromium VI assumed. These results suggest the need for further data on the chemical composition of the chromium in ambient air, and for EPA's forwarding an RfC for chromium.[24]

As shown in Table V-1-12, the estimated increases in probability of developing cancer were in the range from 0.24 to 37 in a million. Cancer risks were less than 1 in a million (10^{-6}) for BaP and formaldehyde; as mentioned in Section 1.1, this risk for formaldehyde is likely to be an underestimate due to ozone interference with the sampling method. For arsenic, cadmium, chromium, and nickel, they were greater than 1 in a million.

Since chromium in its hexavalent oxidation state is the only chromium species believed to be carcinogenic, cancer risk for chromium was calculated using the assumptions that 10% or 1% of the total chromium concentrations was chromium VI. Chromium VI

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[22] The value used as an RfC for formaldehyde was developed as a guideline concentration for short-term (1- to 4-hour) exposures. In addition, ozone interference with the formaldehyde sampling method tends to lead to formaldehyde readings that are less than actual. If a chronic RfC were lower than the short-term RfC and if ozone interference did occur, then the HQ derived from the ratio of the low annual average to the high reference concentration might tend to underestimate the noncancer risk from formaldehyde.

[23] The EPA RfC for chromium was withdrawn from the HEAST as of the 1992 update. The RfC for chromium is under review at EPA.

[24] An ongoing EPA cancer and noncancer effort for chromium is expected to provide an RfC for chromium in 1993.

is found at percentages substantially higher than 10% only in locations adjacent to major emission sources (e.g., chromium electroplaters, cooling towers using chromate as a bactericide) or in areas immediately adjacent to hazardous waste sites containing chromium-laden slag (Lioy et al., 1992a). In an effort to be conservative[25], the 10% value was included in the calculation. This assumes that a source with emissions similar in composition to incinerator emissions was located just beyond one kilometer from each site; no such source was within one kilometer of any of the three New Jersey monitors for which valid data are available.[26]

The carcinogenicity of nickel, like that of chromium, varies with the compound in which the metal is presented. However, the specific compounds in the ambient air samples were not determined. Cancer potency factors have been derived for nickel subsulfide and for nickel refinery dust. Nickel subsulfide is associated primarily with a special process sometimes used in the refining of nickel. Thus, use of the nickel subsulfide cancer potency factor or RfC in a quantitative risk assessment for nickel in ambient air was regarded as inappropriate. The cancer potency factor and RfC for general refinery dusts, composed mostly of nickel oxide and elemental nickel, were considered more appropriate; they were used to calculate risks where nickel subsulfide is not known to be present.

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[25] This use of the term "conservative" indicates an intent to err in the direction of protecting human health by overestimating risk, avoid underestimating.

[26] In this part of New Jersey, stacks from chromium-emitting sources are less than 1000 feet high, low enough that the greatest impact from the source emissions would be within 1 km of the stack, and decrease rapidly beyond 1 km. Thus, sources farther than 1 km from the monitor were regarded as without significant impact on the monitor. Assuming that all other sources contributing Cr VI to the total chromium contain less than 10% Cr VI, 10% would be the highest proportion of Cr VI in the sample. Based on this assessment of dispersion characteristics of incinerator emissions, an assumption of 10% chromium VI was considered conservative from a risk assessment perspective. (Lioy, 1992b.)

If the general scenario above is inappropriate for specific sources and monitor sites in this study, this estimate of 10% as the hexavalent proportion of the total reported chromium concentrations may not be conservative. In the absence of better site-specific information, however, there is precedent within EPA for use of the 10% assumption.

1.4.4 Uncertainties and Limitations

A list of the uncertainties and limitations in approach affecting the Level 1 risk assessments follows.

1. The non-cancer and cancer risk characterizations presented are based on the assumption that the annual average concentration derived from one year of monitoring data reflects an individual's exposure to a given pollutant at a site for a 70-year period. Since emissions and, hence, air quality vary from year to year with such emission source variables as automotive usage and fuel composition, and industrial plant operations and production, and since the amount and direction of variation is unknown, it is unclear how much this assumption affects the calculated risks.

   For example, auto usage or fuels may change, and few plants in the area will operate or emit air pollutants at the same levels for 70 years, though the area in which they are located may remain industrial. Thus, future exposures could be lower or higher than the SI/NJ UATAP monitoring data indicate. The controls mandated by the Clean Air Act Amendments of 1990 should continue to lower the concentrations of many of the pollutants measured in this study. Future pollutant exposures and risks will be lower than risks based on 1988-1989 concentration data if the control steps actually do lower the airborne concentrations, and if these reductions are not offset by future growth.

   In addition, these risk assessments do not address the consequences of short-term peak exposures (e.g., as a result of periodic releases from point sources) to concentrations higher than the annual average concentrations. However the risk assessment for such exposures would require the use of health effect dose-response estimates tailored to the particular exposure assessment, and concentration data focusing on peak concentrations.

2. The calculated excess risks assume continuous outdoor exposure, without addressing the potential exposures from indoor environments in which many people in this country spend much of their time. Indoor concentrations of certain pollutants (e.g., formaldehyde and several VOCs) are commonly several times higher than outdoor concentrations. Thus, risk estimates based on outdoor air concentrations alone may underestimate the contribution of such pollutants to total risk. In contrast, for a pollutant with incomplete penetration into the indoor environment from outdoor sources and no indoor sources, risk estimates based on outdoor air concentrations alone may lead to a higher estimate of the contribution of such pollutants to total risk.

3. The analyses assume that people are continuously exposed to air toxics at the average levels measured at the monitoring station. This assumption does not consider such exposure variables as a person's moving throughout the urban area, spending time outside of the area (e.g., during vacations, work), changing homes several times during a lifetime, or living closer to a source than the location of any of the monitors; or differences in lifestyle. (Section 1.4.1 contains further detail.) An overestimate of risk from exposure to air in the study area may result; and an over- or underestimate of risk from exposure to air in all locations, depending on whether air pollutant concentrations in the other locations are higher or lower than in the study area.

4. The RfCs for the individual chemicals were derived using different methods (available NOAEL, extrapolation from oral RfD to inhalation RfC, etc.) that include different uncertainty adjustments and modifying factors

5. In developing linearized unit risk factors, EPA uses a non-threshold linearized multistage model, which is linear at low doses, to extrapolate from high-dose experimental data to the low doses typically caused by exposure to ambient air pollutants. In other words, carcinogenic substances are assumed to cause some risk at any exposure level. If the true dose-response relationship at low doses is less than linear (e.g., has a threshold), then the unit risk estimates based on EPA IURFs would tend to be high, and therefore overestimate the risk.

   The unit risk factor is based on the upper bound of a 95% confidence interval; if the true unit risk values are less than that upper bound, then the calculated risks might be overestimates.

6. The cancer Weight of Evidence, Inhalation Unit Risk Factors, and reference concentrations reflect the current state of toxicological knowledge for the specific chemicals. As more scientific information is acquired, these values could change significantly, as they have in the past, and thus the magnitudes and relative contribution of particular pollutants to estimated risk can change. The result is a degree of uncertainty that cannot be assessed.

7. The risk estimates presented do not address the potential for the ambient air mixture of pollutants to exhibit biological activity that is synergistic, additive, or antagonistic relative to their individual effects. An additive risk assessment is presented in Section 1.6.

8. The pollutants monitored do not include all pollutants present in ambient air.

9. Uncertainty resulting from issues related to chromium and nickel are discussed in Section 1.4.3.

10. Particles collected were ≤50 microns in aerodynamic diameter, a size range that includes particles larger than the 10-micron aerodynamic diameter considered the upper end of the respirable-size range. Thus, risk estimates driven by the concentration of respirable-size particles may be overestimated.

11. Errors or limitations in the reported concentrations affect the reliability of the risk estimates. The direction of the impact on the risk estimate varies with the chemical. Discussions of data quality are found in Volume III, Parts A and B. Note the following:

    Chemical analytical standards for accuracy were not run for mercury at Carteret, Elizabeth, and Highland Park; and for arsenic at Susan Wagner High School (SW) and PS-26.

    The analytical recovery of BaP was poor for samples at SW and PS-26 to the extent that the reported BaP concentrations at these sites should be regarded as minimum values. The recovery of nickel from samples at these same sites was 75%.

    An ozone interference with the formaldehyde collection method used in the ambient air portion of this project resulted in the reporting of formaldehyde concentrations as less than actual; no correction based on ozone concentration is available.

    The availability of concentration data for a chemical at some sites but not others indicates that the omitted data did not meet sampling and/or analysis data quality objectives for the project, or that quantitation of that chemical was not performed by the analytical lab(s) connected with the site(s).

1.4.5 Discussion

This Level 1 risk assessment focused on the chemicals for which health information (IURFS and RFCs) or a NAAQS, and quality-assured/quality-controlled data were available.

Of the VOCs, only benzene was present at concentrations exceeding its RfC. Benzene, tetrachloromethane, and trichloromethane concentrations yielded estimated excess lifetime cancer risks that exceeded ten per million. The risk estimates for these chemicals were similar to those estimated for the UATMP sites. See Tables V-1-13 and 14.

The risk estimates for chromium and nickel in the study area were higher than the estimates for the 1988 UATMP sites. These results suggest the need for further analysis of the chemical composition of the chromium (i.e., valence state) and nickel (dust, subsulfide, etc.) in ambient air, and of the information supporting the RfCs for chromium. Again, apparent site-to-site differences in estimated risks may not be statistically significant. No effort has been made to characterize the accuracy or precision of the UATMP annual averages and no statistical tests were performed on the differences in concentrations between the SI/NJ UATAP data and the UATMP data.

1.5 LEVEL 2 RISK ASSESSMENT (FOR VOCS ONLY)

1.5.1 Introduction

People are exposed to air contaminants outdoors; at work or school; in cars, buses, and trains; and in their homes. The air inside buildings and vehicles comes from outside and so generally contains the same contaminants as the outdoor air. However, there are many indoor sources that can increase the level of air contaminants inside houses, offices, schools, and other buildings. Smoking and other activities also increase contaminant levels inside vehicles.

The Level 1 risk assessment bases the estimates of lifetime average air contaminant exposure on outdoor contaminant levels measured during this project. The Level 2 assessment supplements the Level 1 risk characterization by indicating how exposure and risk levels differ when considering both indoor and outdoor contaminant levels for four residences in the study area.

Studies by the National Academy of Sciences (NAS, 1981) and the National Institute of Occupational Safety and Health (NIOSH, 1989) have shown that as buildings become more air-tight (in response to demands for energy conservation), and the exchange of air between inside and outside decreases, there is a potential to increase the concentrations of pollutants within the building. Contaminants that have been found frequently indoors include formaldehyde, combustion products (i.e., from stoves, heaters,

and smoking), bacteriological contaminants, and some outdoor air pollutants that penetrate indoors.

To assess the potential risks from indoor air pollutants, NYSDOH carried out sampling for VOCs in four homes and two nearby outdoor sites in the study area for a period of eight months. These four homes are not to be regarded as representative of indoor air in the study area.

The Level 2 risk assessment is provided for VOCs only. Particulates data were not collected indoors, and results from the indoor air formaldehyde samples were invalid due to sampler malfunctions. Data from other studies show that indoor formaldehyde concentrations are generally greater than outdoor concentrations. For example, data on the National Ambient Volatile Organic Compounds (VOC) Data Base (Shah and Heyerdahl, 1988) indicate a median ambient concentration of 4.1 ppb, and a median indoor concentration of 42 ppb. This national median indoor concentration, twice the RfC, corresponds to an estimated increased lifetime cancer risk of over 100 per million.

Concentrations of the naturally-occurring radioactive gas radon were also measured as part of the indoor air study. The indoor levels ranged from 0.19 picoCuries per liter (pCi/1) to 1.86 pCi/1; the outdoor levels ranged from 0.30 to 1.37 pCi/1. While radon exposure via indoor air is a significant contributor to estimated excess cancer risk, it is not addressed in detail in this report because of the non-anthropogenic nature of this air pollutant. The results, including estimated potential excess cancer risk, are discussed more thoroughly in Volume IV.

1.5.2 Concentration Data Used in the Level 2 Exposure Assessment

1.5.2.1 Residential site indoor and outdoor data

The Level 2 risk assessment is based on VOC concentration data from four homes and two nearby outdoor sites that were monitored as part of the indoor air portion of the SI/NJ UATAP. Two homes were located in Staten Island, and two were located in Carteret, New Jersey. While Volume IV of the project report presents those data, certain information is repeated here to establish the context of the indoor and outdoor data. The indoor/outdoor VOC concentration ratios for the indoor air portion of the project are summarized in Tables V-1-15 and 16. Statistical tests, the results of which appear in Tables V-1-15 and 16, were performed to determine whether there were significant differences between the mean indoor and outdoor VOC concentrations for each house. See Volume IV, Indoor Air, for a detailed discussion of these results.

1.5.2.2 Comparison of the outdoor air data from the indoor air and the ambient air portions of the SI/NJ UATAP

Tables V-1-17 and 18 compare ambient data collected at PS-26 in Staten Island and Carteret High School in New Jersey by the New York State Department of Health (NYSDOH) from July 1990 through March 1991, to data collected at PS-26 and another location in Carteret from October 1988 through September 1989. The data collected during the quarter beginning April 1989 are not included so that data collected during the same seasons (although different years) can be compared. In the discussion that follows, the data from the ambient air (two-year) portion of the SI/NJ UATAP are referred to as the UATAP data, and the indoor air data are referred to as the NYSDOH data. Trichloromethane (chloroform), tetrachloromethane (carbon tetrachloride), trichloroethene (trichloroethylene), and tetrachloroethene (tetrachloroethylene) were not detected in enough NYSDOH samples to make valid comparisons. At PS-26, for six chemicals, the mean concentrations reported by NYSDOH were higher than the mean values reported by the UATAP; ratios of NYSDOH means to UATAP means at PS-26 ranged from 1.3 to 3.5. For Carteret, this ratio ranged from 0.8 to 4.4. Mean NYSDOH values for hexane and benzene at Carteret High School were lower than those reported for the UATAP Carteret site. Mean NYSDOH values for all other chemicals at Carteret High School were higher than the mean values reported for the UATAP Carteret site.

The results of this limited study conducted by NYSDOH are generally in good agreement with the indoor sampling results of the TEAM study (U.S. EPA, 1987b) and the VOCs data base, and the two-year ambient air sampling portion of the SI/NJ UATAP.

In summary, the outdoor air data from the two portions of the project are consistent considering that they were collected in different years. Some differences between the two sets of data were expected due to such factors as different meteorological conditions, variations in source emissions, interlaboratory differences in accuracy, and, in the case of Carteret, different monitoring sites. In all cases, however, the NYSDOH concentrations remained in the <10-ppb range, and the outdoor levels for the residential indoor study did not differ substantially from those reported for the ambient air portion of the SI/NJ UATAP. The maximum differences for compounds available from both data sets was 2.2 ppb (for toluene in Travis, Staten Island), with the NYSDOH value being higher. Such differences are regarded as without significant impact on the risk assessment, such that the shorter-term, eight-month data set for two outdoor sites is regarded as appropriate for use in the Level 2 risk assessment, where indoor and outdoor concentrations measured simultaneously are preferable.

1.5.3 Exposure Assessment

Increased health risks associated with exposure to the VOC compounds which were measured in the ambient air and inside homes are estimated under the assumption that an individual is exposed to the average measured levels for his or her entire lifetime. For this purpose, the lifetime is divided into three segments: from birth to two years of age, from three to eighteen years of age and from nineteen to seventy years of age. Average body weights and inhalation rates are assigned to each of these age intervals in calculating the individual's dose from inhalation of pollutants in the air. The individual is assumed to spend a portion of every day indoors and the remainder outdoors. This division of time is assumed to vary with age according to a specific scenario. The inhalation rate is also assumed to vary between indoor activities and outdoor activities.

The general equation and the data used in making the Level 2 exposure estimates are presented Table V-1-19, along with a sample calculation of lifetime average daily dose for a given residence. The inhalation rates and body weights were derived from data in the "Exposure Factors Handbook" (U.S. EPA, 1989a), Tables 3-1 and 3A-2. From Table 3-1, resting, light exercise, and moderate exercise exercise inhalation rates (cubic meter per hour, m^3/h) for a 10-year-old child were used for the age interval three to 18; and the rates for an average adult were used for the age interval 19 to 70. Data for the inhalation rate of the infant (birth to two years old) were derived from Table 3A-2 in the handbook, which lists resting minute ventilation rates (liters per minute, l/m) for the infant. The range is from 0.25 to 2.09 l/m, with a mean value of 0.84 l/m. No data are given for periods when the infant is exercising (for example, crying, or, at a later age, crawling or walking). To account for such periods of increased minute ventilation in the present analysis, the upper end of the range of minute ventilation rates for the resting infant was used to characterize the infant's inhalation rate for the entire day. This ventilation rate of 2.09 l/m corresponds to an inhalation rate of 0.125 m^3/h. Table V-1-19a summarizes the inhalation rates assumed in this exposure assessment.

Table V-1-19b indicates the number of hours each day that the individual is assumed to be indoors and outdoors during each age interval. The further assumptions are made that half of the time indoors is spent resting, and the other half is spent performing light exercise; and that the time outdoors is spent at the moderate exercise level of activity. The Table V-1-19a inhalation rates, the Table V-1-19b scenarios for the numbers of hours per day spent indoors and outdoors, and the aforementioned activity assumptions were used to calculate the Table V-1-19c

volumes of air inhaled indoors and outdoors, and the total volume of air inhaled each day. To account for the possibility of very different lifestyles leading to a wide variation in the amount of air inhaled outdoors, an alternative scenario is presented for the adult. This scenario, which appears in Tables V-1-19b and 19c as scenario 2, assumes that the adult spends seven hours a day outdoors, in contrast to one and one-half hours per day spent outdoors in the other scenario for the adult age interval.

Lifetime average exposure and risk are estimated by combining the assumed inhalation volumes and body weights with indoor and outdoor pollutant concentration data and toxicological data for each air pollutant.

The individual's daily exposure to a pollutant for each age interval is calculated by multiplying the volume of inhaled indoor air by the concentration of the pollutant in indoor air, doing the same with the outdoor air volume and concentrations, and adding the two products to arrive at the total quantity of pollutant inhaled daily in units of micrograms per day (μg/d). This quantity is divided by the body weight corresponding to the subject age interval to calculate an average daily pollutant dose for that age interval in micrograms per kilogram of body weight per day (μg/kg/d). The general equation for calculating the average daily dose of an inhaled pollutant for a given age interval is as follows:

$$\text{Dose} = [(\text{Inhaled Indoor Air} \times C_{in}) + (\text{Inhaled Outdoor Air} \times C_{out})]/\text{Body Weight}$$

The units of dose are in μg/kg-day.

Doses are calculated for an infant, a child, and an adult, using the indoor and outdoor concentrations of pollutants in Tables V-1-20 through 23. Lifetime average daily exposure doses are then calculated as the age-weighted average of doses during infancy, childhood, and adult life, as follows:

$$\text{Lifetime average daily exposure} = [(2/70) \times \text{Infant Dose}] + [(16/70 \times \text{Child Dose}] + [(52/70) \times \text{Adult Dose}].$$

A sample calculation is provided in Table V-1-19.
The calculated results for each pollutant (expressed in μg/kg-day) are listed in Tables V-1-20 through 23.

1.5.4 Risk Assessment Results and Discussion

Tables V-1-20 through 23 present the estimated increased lifetime cancer risks and the HQs calculated using the lifetime average daily dose estimates. Calculation of cancer risks employed the cancer potency factor. Calculation of the HQs entailed conversion of exposure from units of $\mu g/kg\text{-}d$ to the units of concentration used for the RfCs, $\mu g/m^3$. The device for this conversion was calculation of a composite air concentration that would deliver the lifetime average daily exposure assuming an inhalation rate of 20 m^3/d for a 70-kg individual, where 100% of the inhaled pollutant is transported across interfaces to reach the organ where it causes/results in adverse effects.[27] (See example in Table V-1-20.) The use of 100% as the portion crossing interfaces to the target organ is a default assumption; informtion on absorption, partition coefficients, or pharmacokinetic factors was not pursued.

Comparing the calculated exposures for the two activity scenarios for individual chemicals points out the relative importance of indoor and outdoor contamination levels for the individual's total exposure. Under scenario 2, the individual inhales a greater total volume of air each day. When indoor concentrations are considerably higher than outdoor concentrations, as is the case of chloromethane in Tables V-1-22 and 23, scenario 2 yields a slightly higher lifetime average dose than is estimated under scenario 1 because of the greater total inhaled air volume. When the average outdoor concentration of a pollutant is greater than the average indoor concentration, as is the case of dichloromethane in Table V-1-20, the difference between the two scenarios is even greater, reflecting the combined effect of the greater amount of time the individual spends outdoors under scenario 2 and the higher outdoor concentration.

The risk results for the Level 2 risk assessment were consistent with those for the Level 1 risk assessment for the VOCs. The estimated lifetime risks of cancer were in the range of one to 90 per million, with benzene, tetrachloromethane, and trichloromethane each yielding risks of about 50 per million.

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[27] An alternate approach to the HQ is a time-weighted average of the indoor and outdoor air concentrations, where the time spent indoors and outdoors is an average across age intervals. In such an approach, the RfC is regarded as protective of the most sensitive population, so that attention to age intervals and activity scenarios is unnecessary. This approach may be legitimate for the RfCs from IRIS, but perhaps not for those from other sources.

For noncancer toxicity risks, benzene was the only measured pollutant with an HQ greater than 1.

1.5.5 Uncertainties and Limitations

In addition to items 1, 4, 5, 6, and 7 in Section 1.4.4, the uncertainties and limitations section of the Level 1 risk assessment, there are a number of uncertainties and limitations associated with the indoor air risk assessments. They include the following:

1. The analysis assumes that current equipment (i.e., stoves, cleaning products, insulation, etc.) will remain constant over the next 70 years. However, with increased knowledge of potential indoor air pollutants, it is anticipated that these products might change and the level of indoor air pollution levels might be reduced.

2. The pollutants monitored do not include all pollutants present in ambient air or in indoor air.

3. The analyses assume that people are exposed to either the average concentration at the indoor monitor or the average concentration at the outdoor monitor for a lifetime. Movement within the house or beyond the neighborhood of the house is not considered. An over- or underestimate of risk may result from this assumption.

4. The analysis assumes that the concentrations found in the homes are representative of all indoor contaminants. However, the level of contaminants in other indoor areas (i.e., schools, malls, automobiles, or work environment) might vary. The potential impacts on the risks are either over- or underestimates which cannot be determined.

1.6 ADDITIVE RISK ASSESSMENT

1.6.1 Introduction

Risk estimates based on consideration of exposure to one chemical at a time might significantly underestimate the risks associated with simultaneous exposure to several substances. The additive risk assessment considers simultaneous exposure to chemicals in the ambient air. The methodology used in this analysis was based on the EPA guidelines for risk assessment of

chemical mixtures (U.S. EPA, 1986b); it assumes that dose-specific information on the toxicity of the chemical mixtures (i.e., ambient air and indoor air) was not available.

The additive risk assessment relies on the median risks calculated for each chemical for all the sites in the Level 1 (ambient air) risk assessment, which used concentration data for the year October 1988 through September 1989. This covers the potential noncancer toxicity risks from 18 of the study chemicals; and the cancer risks from 12 chemicals. The Level 1 risk estimates are presented in Tables V-1-9 through 12.

No similar assessment of additive risk has been done using the indoor air (Level 2) results. Indoor air monitoring was conducted at four homes to supplement the ambient air results by providing examples of the difference between indoor and outdoor air contaminant levels. Whereas the ambient monitoring stations were selected to characterize air quality throughout the entire study area, the indoor air sampling was much too limited to draw general conclusions about indoor exposure throughout the study area. Thus, it would be inappropriate to use these indoor air data to characterize additive risk for the study area.

As shown in Table V-1-24, the number of sites for which data were available varied greatly for the metals and to a lesser extent for the VOCs. Considering the uneven availability of data for the sites, use of the medians of the concentrations for all sites was regarded as an equitable approach to characterizing risk for the study area as a whole. The use of median concentrations is based on the premise that no statistically-significant intersite differences in risk were found in a monitoring network considered representative of the study area. The known errors in this premise are as follows:

Statistically significant intersite differences in tetrachloroethene concentrations resulted in a difference in HQs that may be significant in an additive risk assessment.[28] The largest intersite difference was between the high at the Dongan Hills monitor and the low at the Susan Wagner High School monitor; on the basis of the unadjusted, reported concentrations, the HQs were 0.2 and 0.05, respectively.

The particulates/formaldehyde network of monitors was much less extensive than the VOCs network; it is less likely to represent the study area as a whole. Thus the use of the median for all sites is less justifiable for the particulates/formaldehyde risks than for the VOCs risks.

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[28] Refer to the statistical analysis of the VOCs data presented in Section 2 of this volume.

Chromium concentrations are known to be high in soils in Hudson County, New Jersey, due to past disposal/dissemination practices. If the soils are resuspended and transported so that they reach project monitors in New Jersey but not in Staten Island, then the ambient air concentrations in New Jersey might be higher than would be found in Staten Island.

As is the case for the Level 1 risk assessment from which the medians are derived, the risks in Table V-1-24 are based on the assumptions that a 70-kg individual inhales 23 m^3 of ambient air daily and continuously for 70 years, and that the pollutant concentrations in the air are constant at the median annual average concentrations reported for the monitors. These estimates might potentially overestimate risks in the event that the individual moves from the study area to an area with lower concentrations of these contaminants.

1.6.2 Noncancer Analysis

Analysis of noncancer health effects was carried out using the Hazard Index (HI) approach outlined in EPA's chemical mixtures guidelines (U. S. EPA, 1986b). This approach assumes that simultaneous exposures to several chemicals at concentrations less than their respective reference concentrations could result in an adverse health effect. It also assumes that the risk of an adverse effect is proportional to the sum of the ratios of the exposure concentrations to their respective RfCs, i.e., to the sum of the Hazard Quotients. A screening HI for chronic health effects was calculated as follows: for each chemical, the median HQ was selected for the sites in Tables V-1-9 and 11; then the sum of these median HQs was calculated. This is considered a screening HI since it is developed without regard for target organ of toxicity[29]; if this total were less ≤ 1, then separation of the HQs by target organ would not be pursued. Table V-1-25 lists the median HQs and the screening HI. Since the screening HI was 4 or 5, depending on which RfC was used for chromium, the chemicals were grouped by target organ (system) of toxicity, and their HQs totaled for those organs (systems).

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[29] The so-called target organ of toxicity is the organ or system upon which the RfC is based; other organs or systems might be adversely affected by exposure to the pollutant, but these effects occur at exposures higher than those at which the target organ is adversely affected.

The resulting groups were for respiratory tract irritation, liver effects, hematopoietic effects[30], kidney effects, and central nervous system effects. As summarized in Table V-1-25, this second analysis indicated that the HI for respiratory tract irritation was 1 or 2, depending on which RfC was used for chromium; and the HI for hematopoietic effects was 2.

Review of the data indicates that three chemicals are primarily responsible for the HI's exceedence of unity. Nickel and chromium each contributed as much as 1, depending on which RfC was used for chromium, to the respiratory tract irritation HI; while benzene alone accounted for the hematopoietic HI.

1.6.3 Analysis for the Carcinogens

The additivity model was also used to estimate the combined cancer risk from exposure to VOCs, metals, and BaP. The combined cancer risk was estimated by simply adding the estimated risks for each of the pollutants according to the following equation:

$$\text{Total Cancer Risk} = \Sigma \text{ Risk}_i, \text{ where i is the } i^{th} \text{ substance.}$$

This approach to estimating the potential incremental individual lifetime cancer risk for simultaneous exposure to several carcinogens is based on EPA's guidelines for carcinogens (U. S. EPA, 1986a). It is an approximation of an equation for combining risks accounting for the joint probabilities of the same individual's developing cancer as a consequence of exposure to two or more carcinogens. This approach assumes independence of action by the chemicals involved; or more specifically, it assumes that no synergistic or antagonistic chemical interactions occur, and that the carcinogens will produce cancer. If these assumptions are incorrect, either an over- or underestimate of risk could result.

Table V-1-24 provides a summary of the cancer analysis using the median cancer risks for each chemical at the sites appearing in Tables V-1-10 and 12. The additive cancer risk is calculated using the alternative assumptions that 10% or 1% of the total reported chromium concentration is chromium VI. When the median estimated cancer risks for individual chemicals are added, the total excess cancer risk per million is 123 or 96, depending on whether 10% or 1% chromium VI, respectively, is assumed. Benzene (40), chromium at 10% (30), arsenic (20), and tetrachloromethane

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[30] This refers to effects on the blood and blood-producing organs and cells.

(12) each contributed more than 10 per million to the increased probability of developing cancer; and trichloromethane, nickel, chromium at 1%, and cadmium each contributed about 5 per million to the increased risk of cancer.

1.6.4 Uncertainties in the Additive Risk Assessment

Sources of uncertainty in the additive risk assessment are those provided for the Level 1 risk assessment, in addition to those listed below.

1. As noted in Section 1.6.1, the median concentrations used for the particulates and formaldehyde in general, and especially for chromium, may not equitably represent concentrations in the entire study area due to the limited monitoring network for those chemicals, and uneven availability of data at the various sites.

   For certain of the VOCs, statistically significant intersite differences in concentration were found; however, with the possible exception of tetrachloroethene, these VOCs provided only small contributions to the additive risk assessment.

2. In evaluating the non-carcinogen HI, it is important to note that the level of concern does not increase linearly as the RfC is approached or exceeded because the RfCs are not of equal accuracy or precision, and are not based on the same severity of effect.

3. The RfCs for the individual chemicals were derived using different methods (available NOAEL, extrapolation from oral RfD to inhalation RfC, etc.) that include different uncertainty adjustments and modifying factors, adding an additional level of uncertainty associated with the HI. However, two chemicals contributed most to the HI for respiratory tract irritation; and only one contributed to the HI for hematopoietic effects.

4. The IURF is based on a carcinogen potency factor that is an upper 95th percentile estimate of potency, and, because upper 95th percentiles of probability distributions are not strictly additive, the total additive cancer risk estimate might become artificially more conservative as risks from a number of different carcinogens are summed. However, it should be noted that seven pollutants contributed most to the total cancer total risk for the sites.

5. While the carcinogens that were analyzed had different Weights of Evidence for human carcinogenicity, the cancer

risk equation summed all carcinogens equally, giving as much weight to Group B or C as to Group A carcinogens.

6. The actions of two different carcinogens might not be independent; they might exhibit synergistic or antagonistic effects. This toxicological effect could not be accommodated in this analysis.

1.7 GENERAL CONCLUSIONS

Quantitative estimates of cancer and noncancer toxicity risks were made for 21 of the 40 study chemicals--22 volatile organic compounds (VOCs), 16 metals, benzo[α]pyrene, and formaldehyde--for which adequate toxicological data and concentration data were available. Only chronic risks based on average exposures were considered. Estimated increased lifetime cancer risks for individual pollutants were in the range of 0.4 to 61 per 1,000,000 for the Level 1 analysis (ambient air), and 1 to 80 per million for the Level 2 analysis (ambient and indoor air, VOCs only). The Hazard Quotients for non-carcinogenic effects were below one for all pollutants except benzene, chromium, and nickel. The estimated risks for chromium and nickel are believed to be conservative, i.e., err in the direction of overestimating risk. However, since the specific chemical species of chromium and nickel in the ambient air samples were not measured, assumptions were made in selecting and applying toxicological criteria.

The additive risk assessment for noncancer toxicity by target organ, and for cancer for all pollutants combined, yielded a maximum Hazard Index of 2 (hematopoietic effects and respiratory tract irritation), and a cumulative cancer risk of 96 or 123 per million, depending on the reference concentrations and chromium VI assumptions used in the estimates.

The estimated cancer and noncancer toxicity risks associated with benzene were consistently higher than those estimated for the other pollutants addressed in the Level 1 and Level 2 analyses. The next highest estimated risks in the Level 1 analysis were associated with nickel, chromium, and formaldehyde; while the next highest estimated risks in the Level 2 analysis (VOCs only) were from trichloromethane and tetrachloroethene.

Using the 1988 and 1989 Urban Air Toxics Monitoring Program (UATMP) studies as the basis for comparison, the risk estimates for nickel and chromium were higher for the study area than for other urban areas nationwide. An assessment of the significance of the magnitudes of the differences is not offered; some of the differences might be attributable to differences in sampling and

chemical analysis for the studies. This demonstrates the importance of considering differences in data quality, especially when comparing the results from different organizations.

The risk assessments provided here based on the SI/NJ UATAP data do not cover the risk for all pollutants in the ambient air and indoor air to which residents of the study area are exposed. Additional uncertainties associated with the Level 1, Level 2, and additive risk assessments have been listed with the assessments. Beyond the uncertainties associated with the most common risk assessment assumptions are those specific to (1) the reference concentration for chromium, (2) the concentration data for chromium and nickel, (3) recognition of a hazard quotient as being of sufficient magnitude to warrant further refinement of a risk assessment for noncancer toxicity (i.e., assessing a Hazard Quotient or Hazard Index as significant from a risk assessment perspective), and (4) the diversity of scientific interpretation that underlies toxicological dose-response information from various governmental agencies. Since the concentration data for chromium and for nickel, and the reference concentration for chromium have been critical to the magnitude of the cancer and noncancer toxicity risk estimates for this study, further refinement of these inputs to the risk assessment are recommended.

1.8 ACKNOWLEDGEMENT

This section was prepared by Ms. Marian Olsen and Ms. Carol Bellizzi of the Region II office of U.S. Environmental Protection Agency; Dr. Paul Lioy of the University of Medicine and Dentistry of New Jersey (UMDNJ), Robert Wood Johnson School of Medicine; Dr. John Hawley of the New York State Department of Health; Ms. Joann Held and Ms. Olga Boyko of the New Jersey Department of Environmental Protection and Energy; and Mr. Robert Majewski and Mr. Tom Gentile of the New York State Department of Environmental Conservation. The final draft was reviewed within EPA and modified to meet requirements for a risk assessment issued as an EPA report.

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Table V-1-1a: Sampling Sites - Staten Island

Site Code	Community Site Name	Sampling Type	Frequency	Operating dates
1	Westerleigh	NYSDEC Sorbent	every sixth day	10/87- 9/89
	Susan Wagner H.S.	Tenax	"	10/87-12/87
		Canister	"	4/88- 9/89
		Hi Volume Filter	"	10/87- 9/89
		Formaldehyde	"	7/88- 9/89
		Meteorology	continuous	4/88- 9/89
2	Travis	NYSDEC Sorbent	every sixth day	10/87- 9/89
	P.S. 26	Tenax	"	5/88-10/88[a]
		Canister	"	8/88- 9/89
		Hi Volume Filter	"	10/87- 9/89
3	Annadale, Eltingville	Tenax	every day[1]	10/87- 9/89
	Fire Station 167	Canister	every eighteenth day[2]	12/87- 9/89
4	Great Kills	NYSDEC Sorbent	every sixth day	9/88- 9/89
	Fire Station 162	Canister	every eighteenth day	9/88- 9/89
5	Port Richmond	NYSDEC Sorbent	every sixth day	10/87- 9/89
	Post Office	Tenax	"	6/88- 1/89[b]
		Canister	"	6/88- 9/89
		Formaldehyde	"	7/88- 9/89
6	Dongan Hills	Tenax	every day[1]	10/87- 9/89
	Fire Station 159	Canister	every eighteenth day[2]	1/88- 9/89
7	Pumping Station	NYSDEC Sorbent	every sixth day	10/88- 9/89
	Near Landfill, near	Canister	every eighteenth day	10/88- 9/89
	Staten Island Mall	Meteorology	continuous	10/88- 9/89
8	Clifton	Tenax	every day[1]	10/87- 9/89
	Bayley Seton Hospital	Canister	every eighteenth day[2]	2/88- 9/89
9	Tottenville	NYSDEC Sorbent	every sixth day	10/87- 9/89
	Fire Station 151	Tenax	"	6/88- 1/89[b]
		Canister	every eighteenth day	7/88- 9/89
		Meteorology	continuous	4/88- 9/89
10	Arthur Kill, Rossville	Hi Volume Filter	every sixth day	3/88-9/89[c]
	New York Telephone			

[1] Through 3/89. Every sixth day to 9/89.
[2] Rotated among sites 3, 6, and 8 on a monthly basis.
[a] Data did not meet QA requirements.
[b] Some data did not meet QA requirements.
[c] Samples taken only occasionally, not enough data to report.

Table V-1-1b: Sampling Sites - New Jersey

Site Code	Community Site Name	Sampling Type	Frequency	Operating dates
A	Elizabeth Mattano Park	Tenax	every sixth day	5/88- 9/89
		Canister	"	5/88- 9/89
		High Volume Filter	"	5/88- 9/89
		Formaldehyde	"	5/88- 9/89
B	Carteret Police Station	Tenax	every sixth day	10/87- 9/89
		Canister	"	10/87- 9/89
		High Volume Filter	"	10/87- 9/89
		Formaldehyde	"	11/87- 9/89
C	Sewaren Glen Cove School	Tenax	every sixth day	11/88- 9/89
		Canister	every eighteenth day[1]	12/87- 9/89
D	Piscataway Pvt. Residence	Tenax	every sixth day	11/88- 9/89
		Canister	every eighteenth day[1]	11/87- 9/89
		Formaldehyde	every sixth day	11/88- 4/89[2]
				5/89- 9/89[3]
E	Highland Park Fire Station	High Volume Filter	every sixth day	11/88- 9/89
--Newark Airport		Meteorological Data	hourly	routine NWS[b] data
--Elizabeth NJDEP Trailer		Meteorological Data	continuous	

[1] Rotated between sites C and D on a monthly basis.
[2] Analysis by EPA contractor lab.
[3] Analysis by NJIT.
[a] National Weather Service
[b] Data were not used due to equipment problems.

Table V-1-1c: Abbreviations used for site names

SW	Susan Wagner High School
PS-26	PS-26 is a public school in Travis
ELTVL	Eltingville, Annadale
GT KLLS	Great Kills
PRT RCH	Port Richmond
DONGAN	Dongan Hills
PUMP	Pumping Station near Staten Island Mall, near Freshkills Landfill
B-STN	Bayley Seton Hospital in Clifton
TOTT	Tottenville
ELIZ	Elizabeth
CART	Cartaret
SEW	Sewaren
PSCAT	Piscataway
HIPRK	Highland Park

Table V-1-2a: VOCs Analyzed During Project

Chloromethane[1]
Dichloromethane (Methylene Chloride)
Trichloromethane (Chloroform)
Trichloroethane, 1,1,1-
Trichloroethane, 1,1,2-
Tetrachloromethane (Carbon Tetrachloride)
Trichloroethylene
Tetrachloroethylene (Tetracholoroethene, perchloroethylene)
Dichloroethane, 1,1-
Dichloroethane, 1,2- (Ethylene Dichloride)
Tribromomethane (Bromoform)
Benzene
Toluene
Hexane
Xylene, o-
Xylene, m- and p- [2]
Ethlybenzene
Chlorobenzene
Styrene
Dichlorobenzene, o- (1,2 - dichlorobenzene)
Dichlorobenzene, m- (1,3 - dichlorobenzene)
Dichlorobenzene, p- (1,4 - dichlorobenzene)

[1] No valid data obtained from ambient air monitoring.
[2] Not separated by analytical method.

Table V-1-2b: Particulate Species Analyzed During Project

Arsenic
Barium
Benzo[α]pyrene
Beryllium[1]
Cadmium
Chromium
Cobalt
Copper
Iron
Lead
Manganese
Mercury
Molybdenum
Nickel
Selenium[2]
Vanadium
Zinc

[1] Never detected.
[2] No valid data were obtained.

Map V-1-1

(Figure II-1)
SI/NJ UATAP
Monitoring Locations

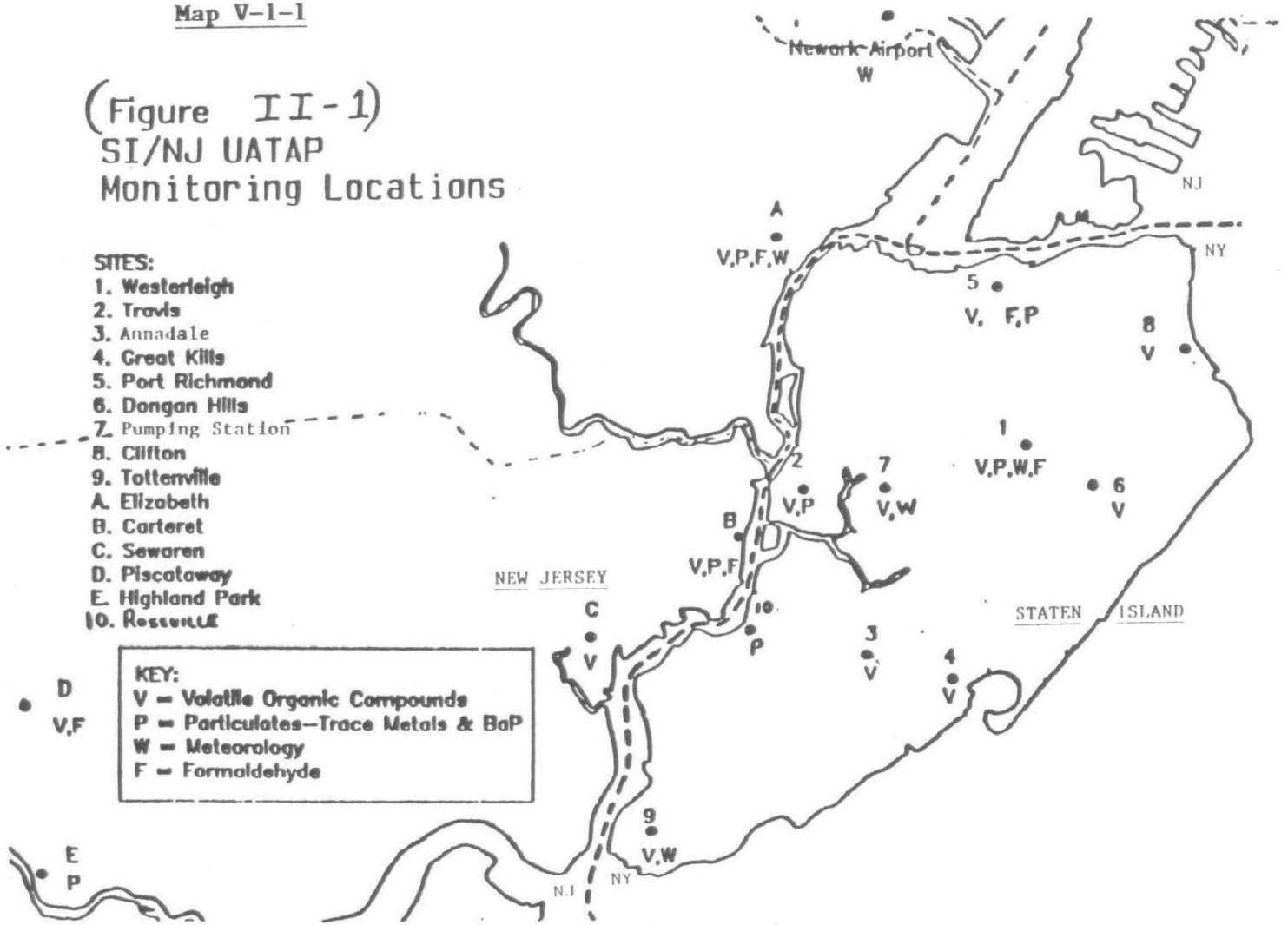


TABLE V-1-3: AMBIENT AIR CONCENTRATIONS FOR THE VOLATILE ORGANIC COMPOUNDS- ANNUAL AVERAGES FOR OCTOBER 1988 THROUGH SEPTEMBER 1989*

	Concentrations, ppb													
	NEW JERSEY					NEW YORK SITES								
	CART	ELIZ	SEW	PSCAT	NIPRK	SW	PS-26	PRT RCH	PUMP	GT KLLS	TOTT	B-STN	ELTVL	DONGAN
CHEMICAL														
DICHLOROMETHANE	--	--	--	--	-	0.47	0.93	0.85	0.76	0.50	0.60	--	--	--
TRICHLOROMETHANE	0.02	0.02	0.02	0.02	-	0.07	0.10	0.08	0.15	0.06	0.07	0.03	0.04	0.03
TETRACHLOROMETHANE	0.12	0.13	0.15	0.11	-	0.09	0.10	0.09	0.10	0.10	0.16	0.11	0.14	0.12
TRICHLOROETHENE	0.05	0.04	0.04	0.05	-	0.10	0.12	0.13	0.27	0.07	0.08	0.08	0.06	0.07
TETRACHLOROETHENE	0.17	0.21	0.21	0.13	-	0.18	0.19	0.24	1.09	0.20	0.20	0.27	0.21	0.68
HEXANE, n-	1.08	0.91	0.84	0.50	-	-	-	-	-	-	-	0.77	0.89	0.86
BENZENE	1.48	1.45	1.16	0.97	-	0.77	1.27	1.34	1.16	0.92	0.86	1.40	1.50	1.96
TOLUENE	3.80	3.62	2.88	2.11	-	2.42	3.88	4.25	3.87	2.89	2.81	3.19	3.45	4.10
XYLENE, o-	0.40	0.40	0.31	0.24	-	0.30	0.44	0.55	0.46	0.37	0.32	0.37	0.38	0.42
XYLENES, p- and m-	1.16	1.06	0.85	0.52	-	0.92	1.42	1.76	1.50	1.19	1.04	1.83	1.89	2.48
ETHYLBENZENE	-	-	-	-	-	-	-	-	-	-	-	0.50	0.53	0.66

* Annual avg. = $\frac{\Sigma n_i x_i}{\Sigma n_i}$, where n_i = number of samples in the ith quarter, x_i = avg. conc. in the ith quarter. Includes annual averages based on $\geq$ 38 samples.

- Samples not collected at this site.

-- Submitted data not good; inappropriate collection method.

Note: In the absence of acccuracy and precision characterization of the reported annual averages, differences should not be assumed to be statistically significant.

TABLE V-1-4: AMBIENT AIR CONCENTRATIONS[1] FOR METALS, BENZO[a]PYRENE, AND FORMALDEHYDE-ANNUAL AVERAGES FOR OCTOBER 1988 THROUGH SEPTEMBER 1989

Chemical	Concentrations, ng/m³					
	CART	ELIZ	HIPRK	SW	PS-26	PRT RICH
ARSENIC	----	----	----	3.7	4.3	-----
CADMIUM	4.2	1.6	2.1	2.4	2.5	-----
CHROMIUM, total	27	16	12	----	----	-----
LEAD[2]	43.1	38.6	91.1	39.5	45.7	-----
MANGANESE	21.6	14.8	13.3	15.2	18.8	-----
MERCURY	0.5	0.5	0.5	----	----	-----
NICKEL	28.2	23.6	22.4	19.1	20.2	-----
VANDIUM	----	----	----	15.2	16.9	-----
ZINC	116.1	113.9	97.8	113.2	96.3	-----
BaP	0.20	0.19	0.14	0.15	0.21	-----
FORMALDEHYDE[3]	----	----	----	2524 (2.02 ppb)	----	2137 (1.71 ppb)

--- Indicates that no data are available.

[1] Annual avg. = $\frac{\Sigma n_i x_i}{\Sigma n_i}$, where n_i = number of samples in the ith quarter, x_i = avg. conc. in the ith quarter. Includes annual averages based on ≥ 38 samples.

[2] Highest quarter concentrations, not annual average concentrations.

[3] Formaldehyde concentrations were converted from ppb to ng/m³ with the following formula (MW, molecular weight, of formaldehyde is 30.03): ng/m³ = (ppb)(MW)(1000)/24.04 l, where 24.04 l is volume of ideal gas at 20°C.

Note: Apparent site-to-site differences in concentration may not be statistically significant.

Table V-1-5: Key to Figures V-1-1 through 10, bar charts comparing annual average concentrations for the SI/NJ UATAP sites to those for the UATMP sites

Min. Ann. Avg., Med. Ann. Avg., Max. Ann. Avg. are, respectively, the minimum, median, and maximum annual averages for the specified group of site(s)s--**SI** being the SI/NJ UATAP sites, and **U** being the UATMP sites. **Ann. Avg.** is the annual average concentration for the specified site.

1988

SI SI/NJ UATAP sites (Oct. 1987 - Sept. 1988)
PI Piscataway (from SI/NJ UATAP)
U 1988 UATMP sites (Oct. 1987 - Sept. 1988)
A Atlanta, GA
B Baton Rouge, LA
C Birmingham, AL
D Burlington, VT
E Chicago, IL (Carver H.S. and Washington, H.S.)
F Cleveland, OH
G Dallas, TX
H Dearborn, MI
I Detroit, MI
J Hammond, IN
K Houston, TX
L Jacksonville, FL
M Lansing, KY
N Louisville, KY
O Miami, FL
P Midland, MI
Q Port Huron, MI
R Portland, OR
S Sauget, IL

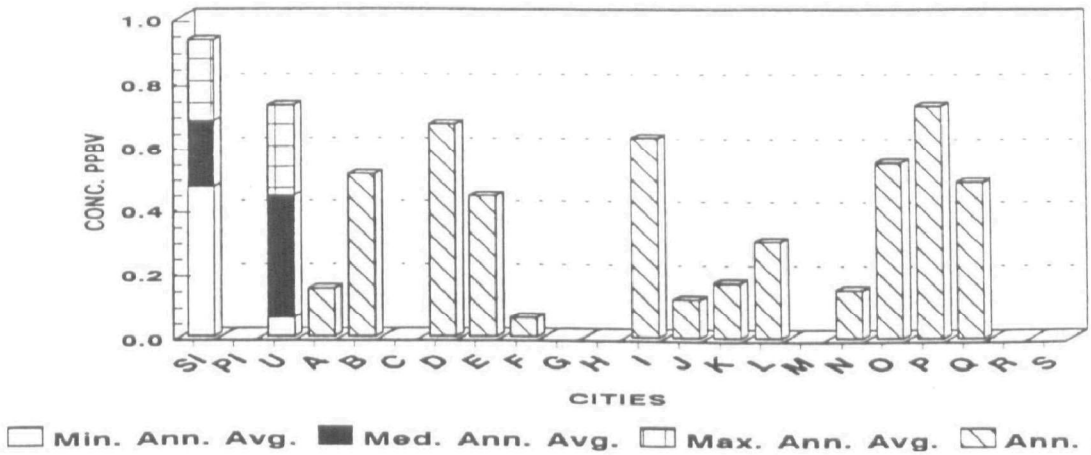
1989

SI SI/NJ UATAP sites
PI Piscataway (from SI/NJ UATAP)
U 1989 UATMP sites (Jan. 1989 - Jan. 1990)
a Baton Rouge, LA
b Camden, NJ
c Chicago, IL (Carver H.S. and Washington, H.S.)
d Dallas, TX
e Ft. Lauderdale, FL
f Houston, TX
g Miami, FL
h Pensacola, FL
i Sauget, IL
j St. Louis, MO
k Washington, DC #1
l Washington, DC #2
m Wichita, KS #1
n Wichita, KS #2

FIGURE V-1-1

Dichloromethane - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

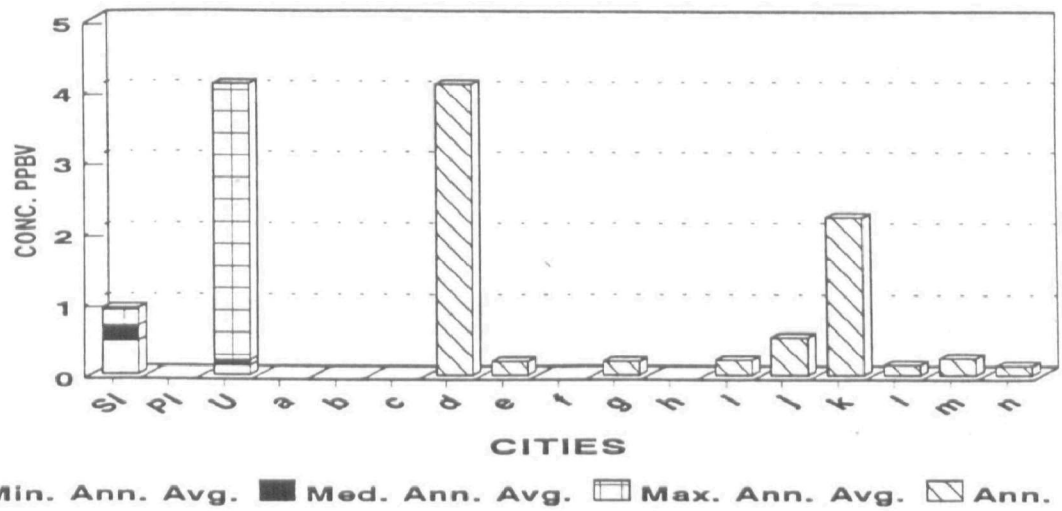
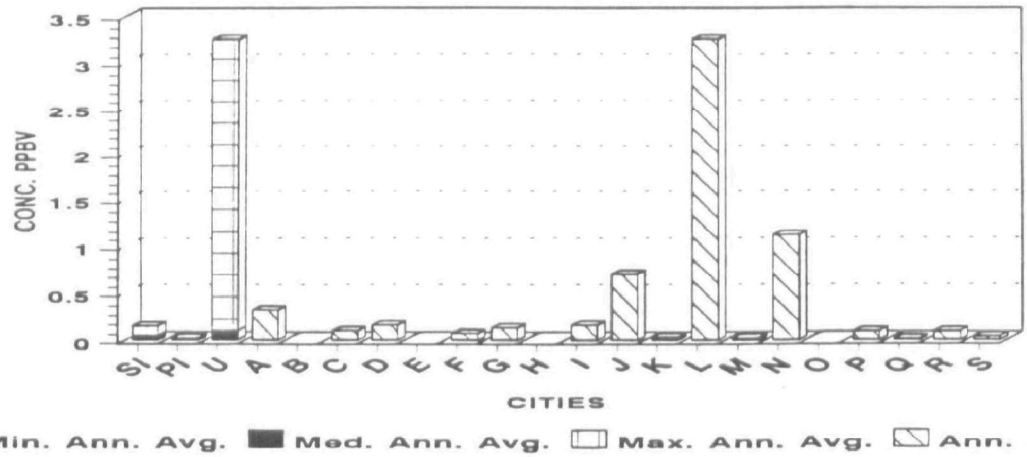


FIGURE V-1-2

Trichloromethane - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

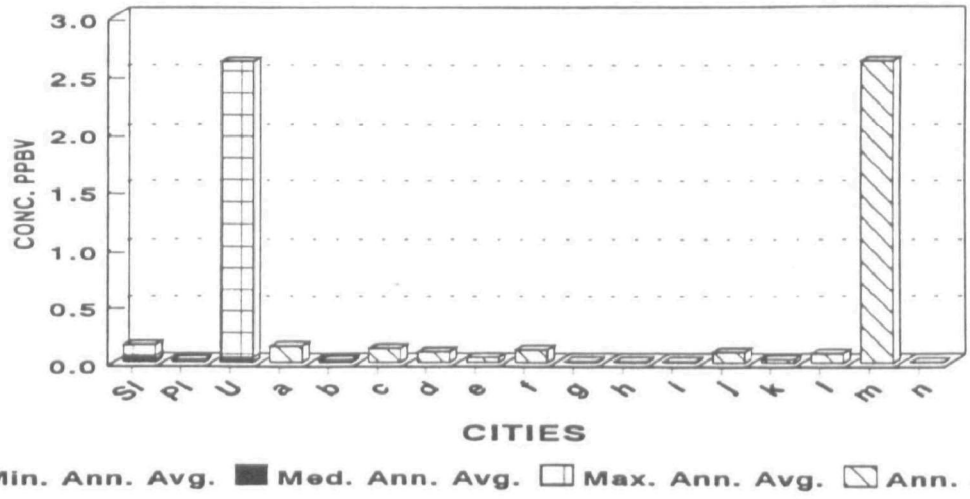
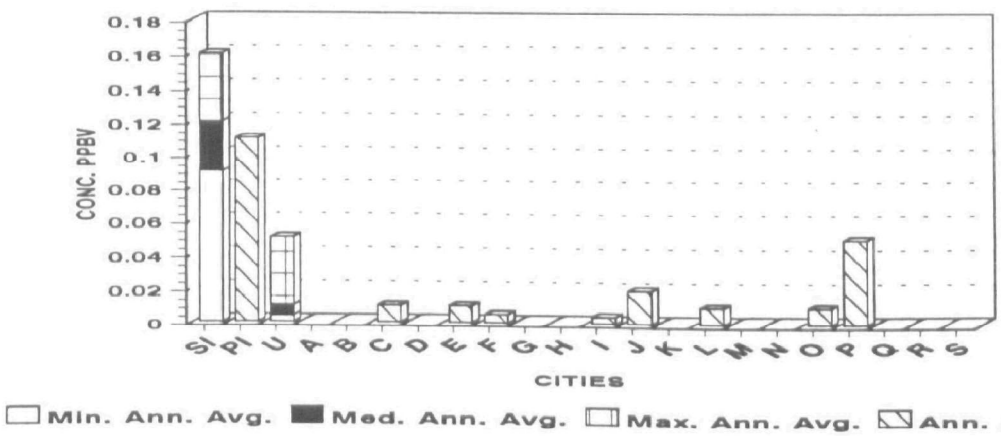


FIGURE V-1-3

Tetrachloromethane - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

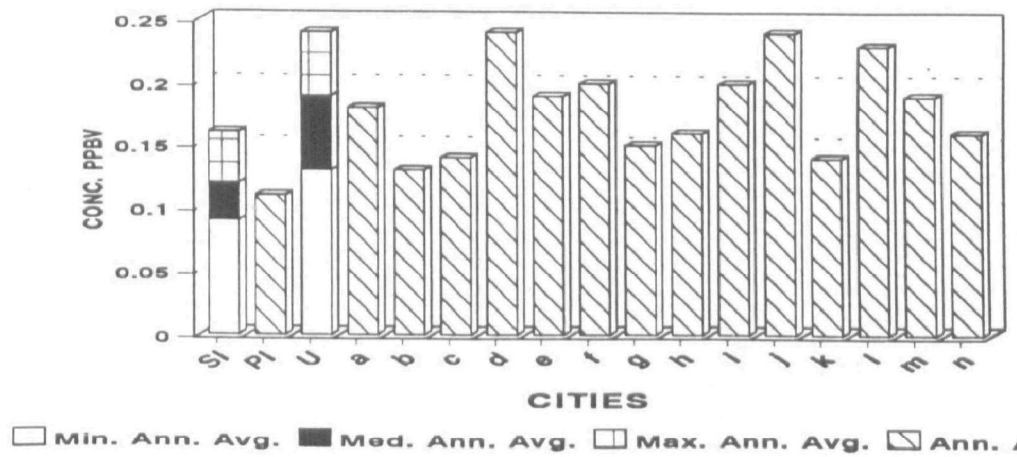
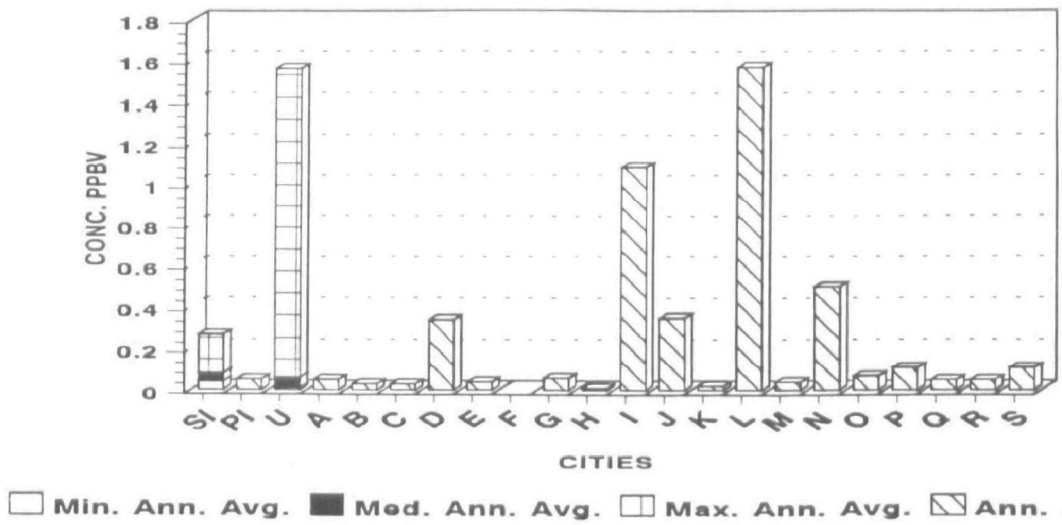


FIGURE V-1-4

Trichloroethylene - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

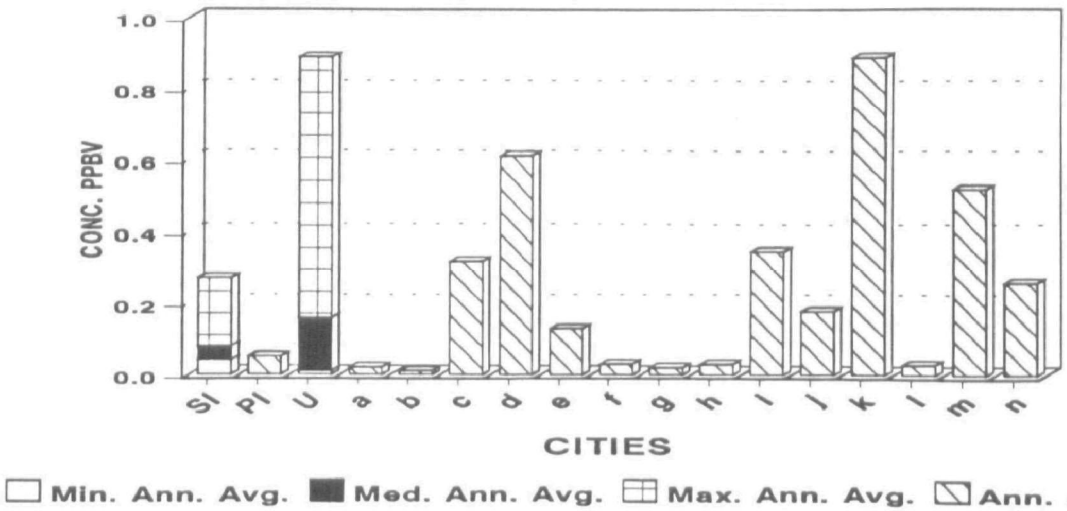
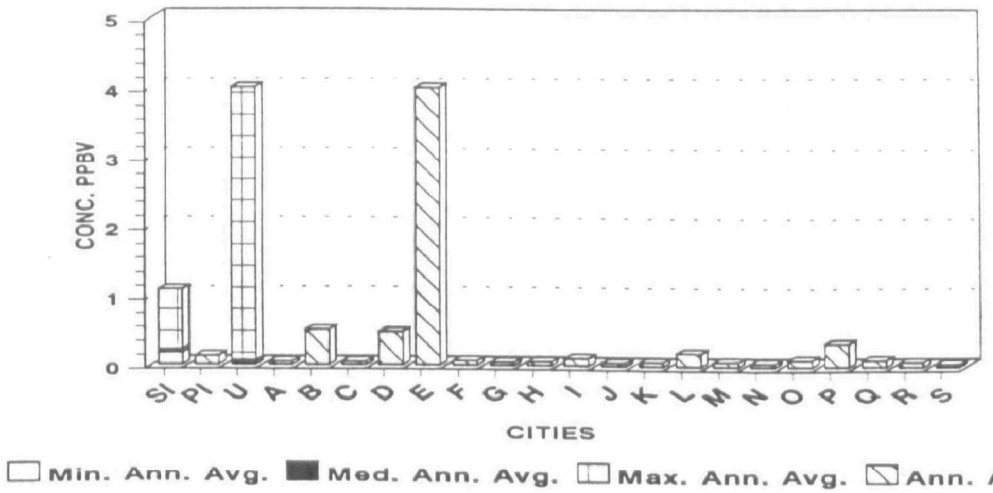


FIGURE V-1-5

Tetrachloroethylene - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

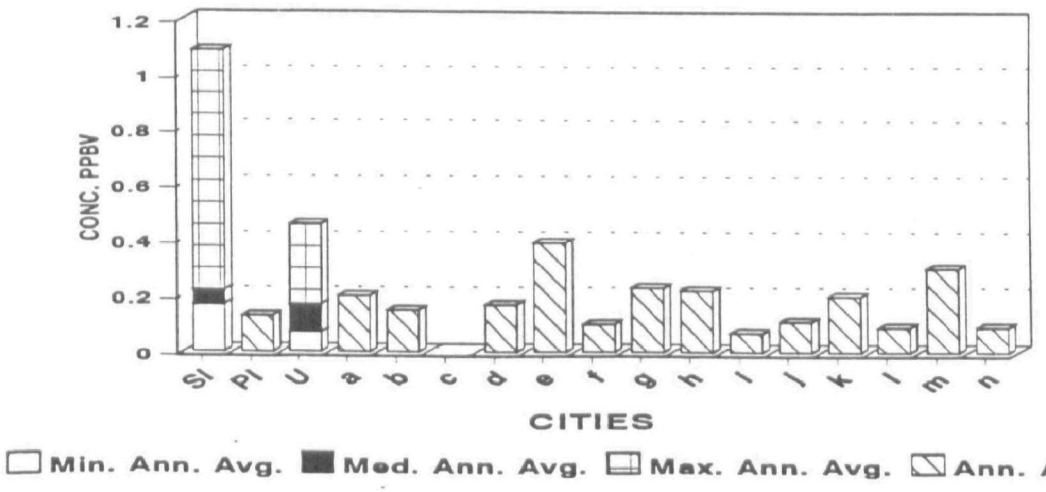
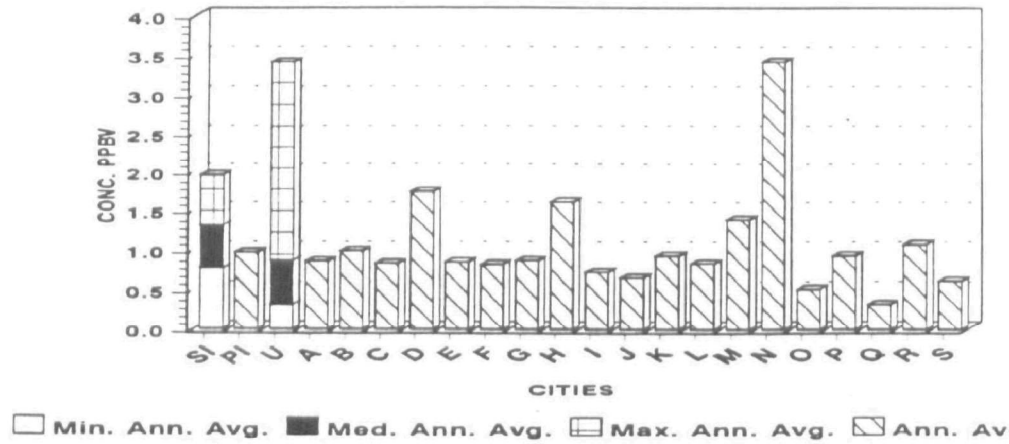


FIGURE V-1-6

Benzene - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

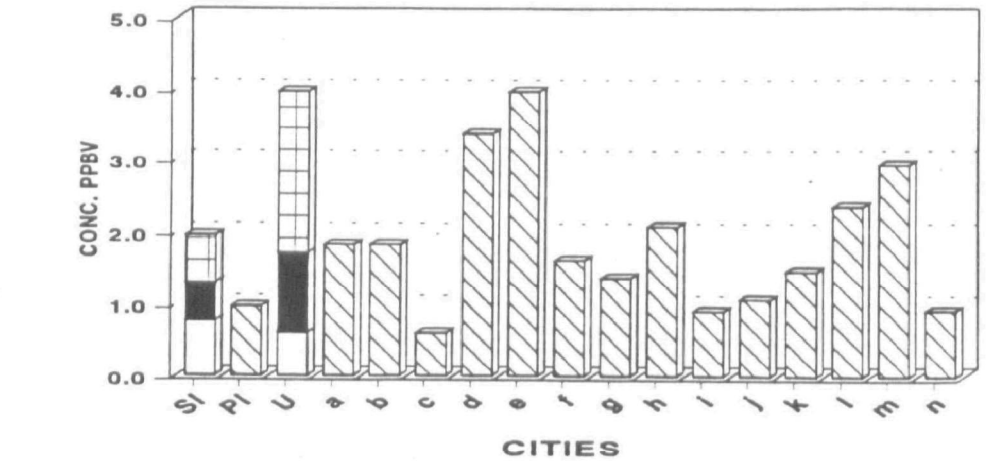
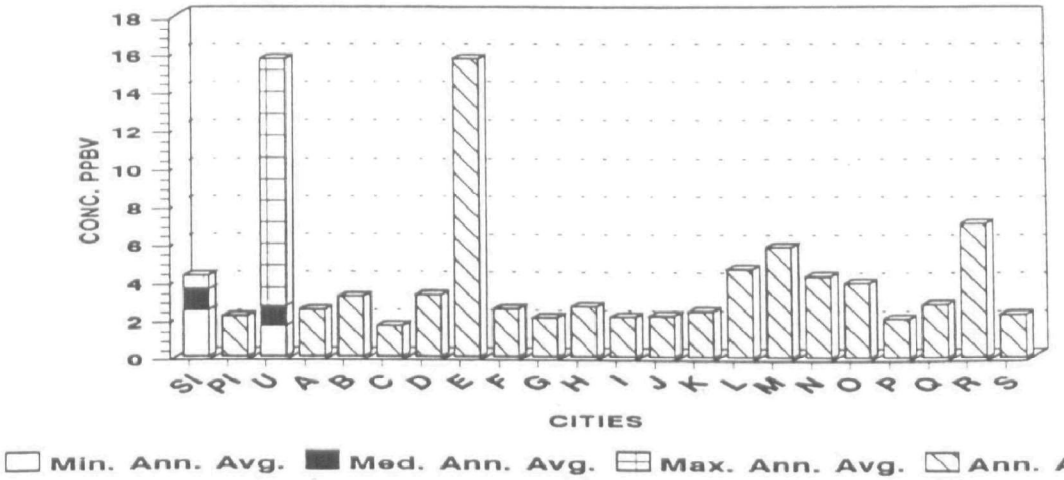


FIGURE V-1-7

Toluene - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

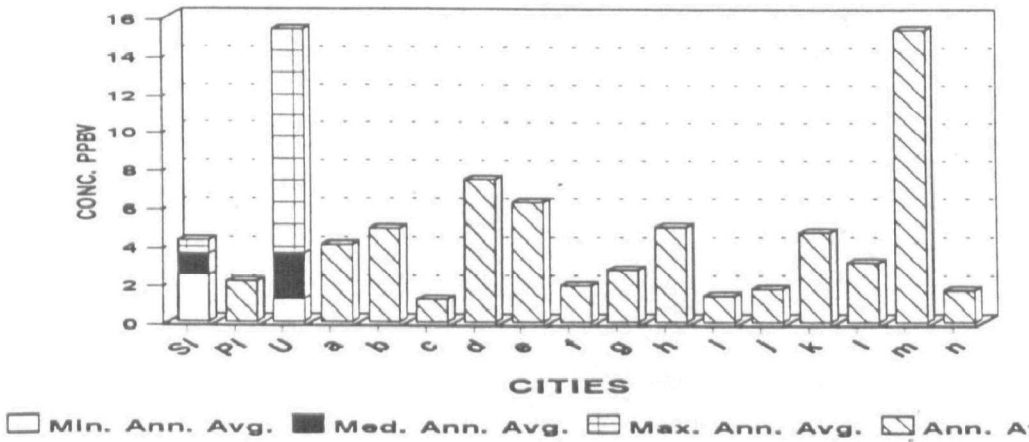
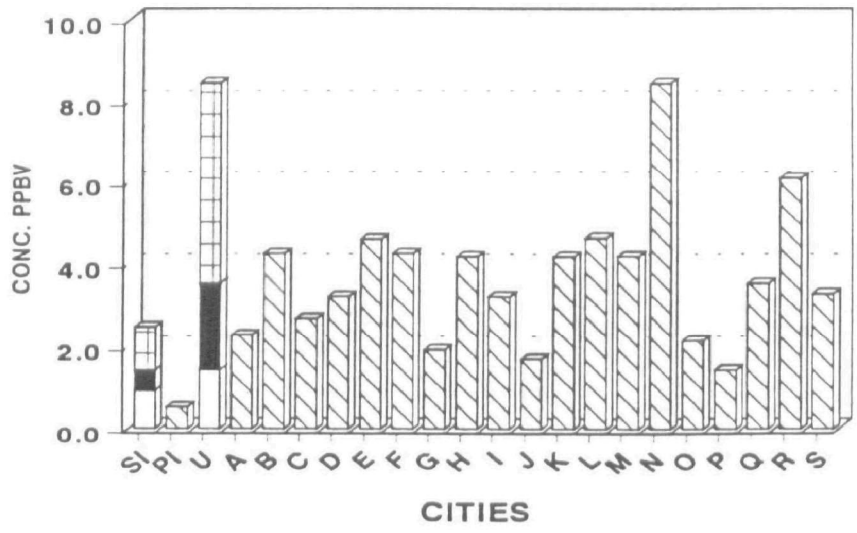


FIGURE V-1-8

Xylene (m- and p-) - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

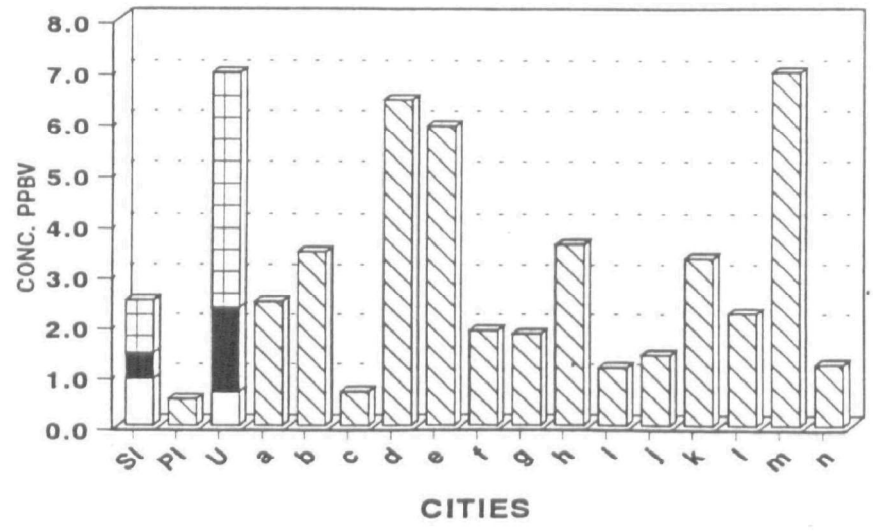
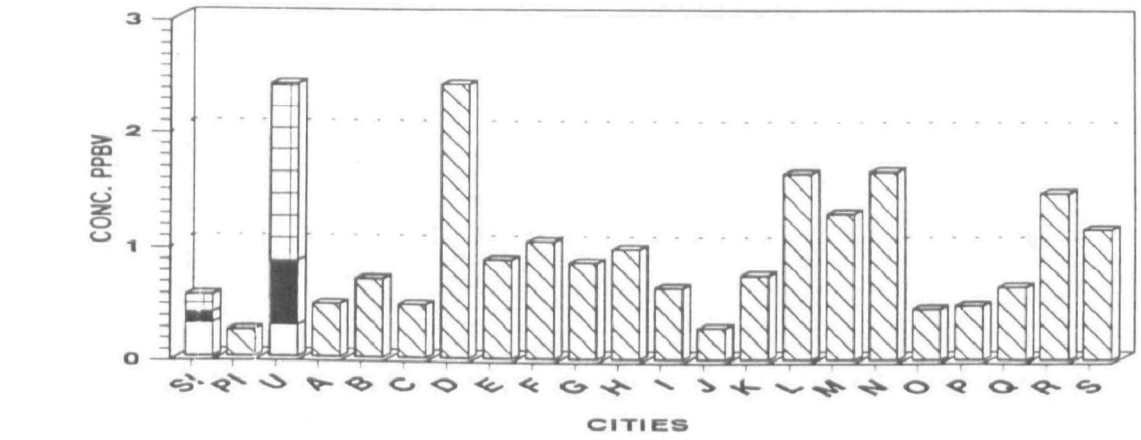


FIGURE V-1-9

Xylene (o-) - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

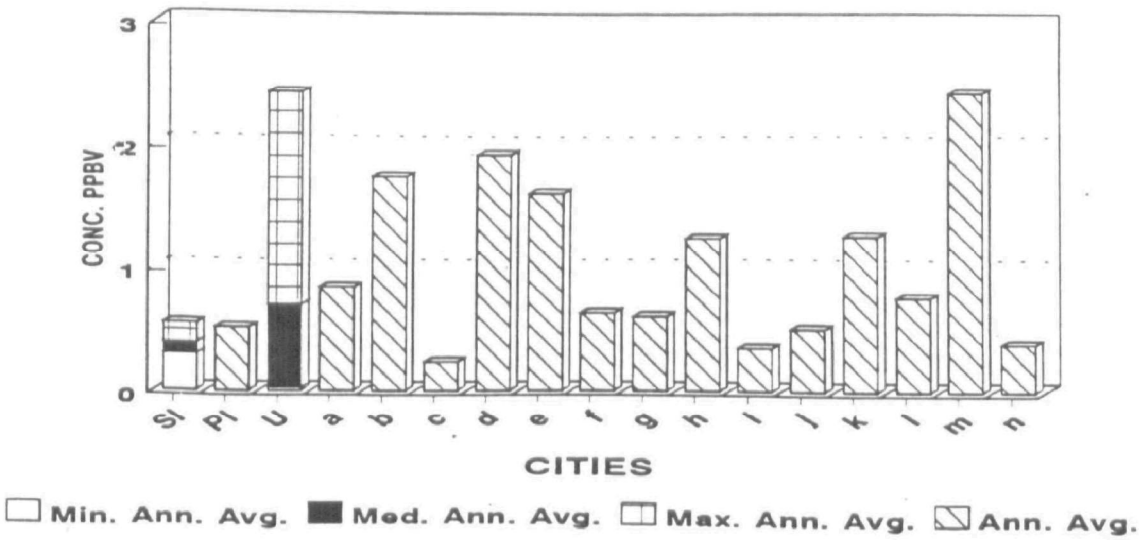
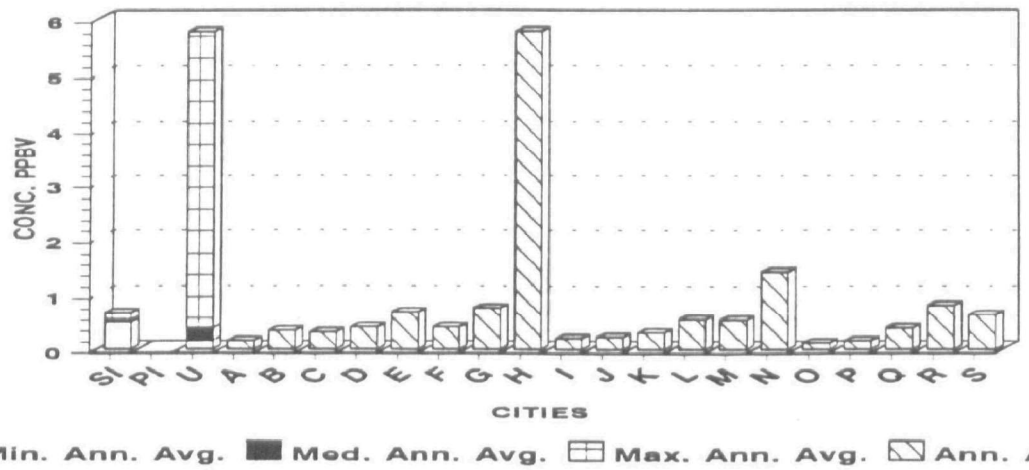


FIGURE V-1-10

Ethylbenzene - SI/NJ UATAP Compared to UATMP

a. 1988



b. 1989

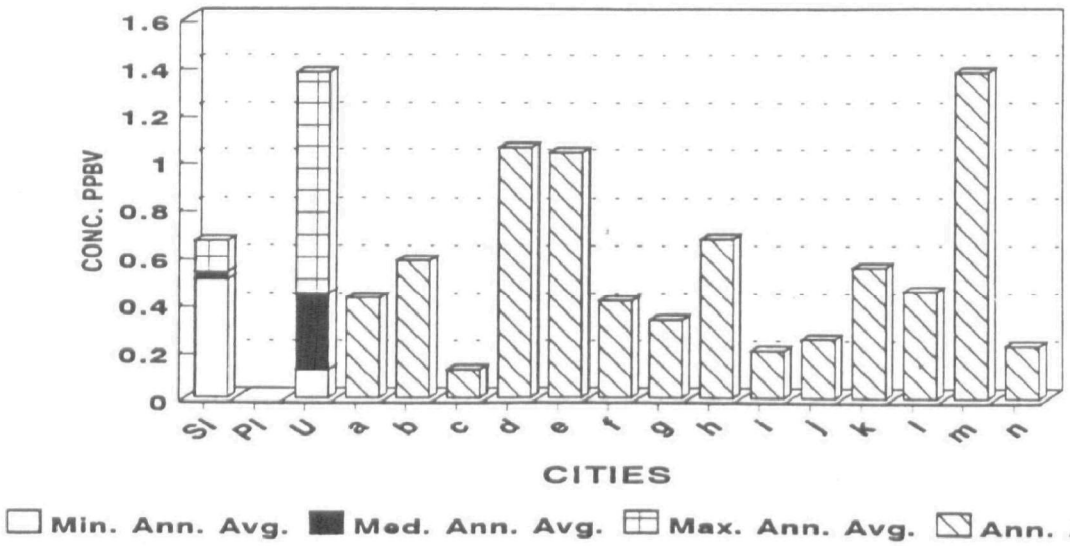
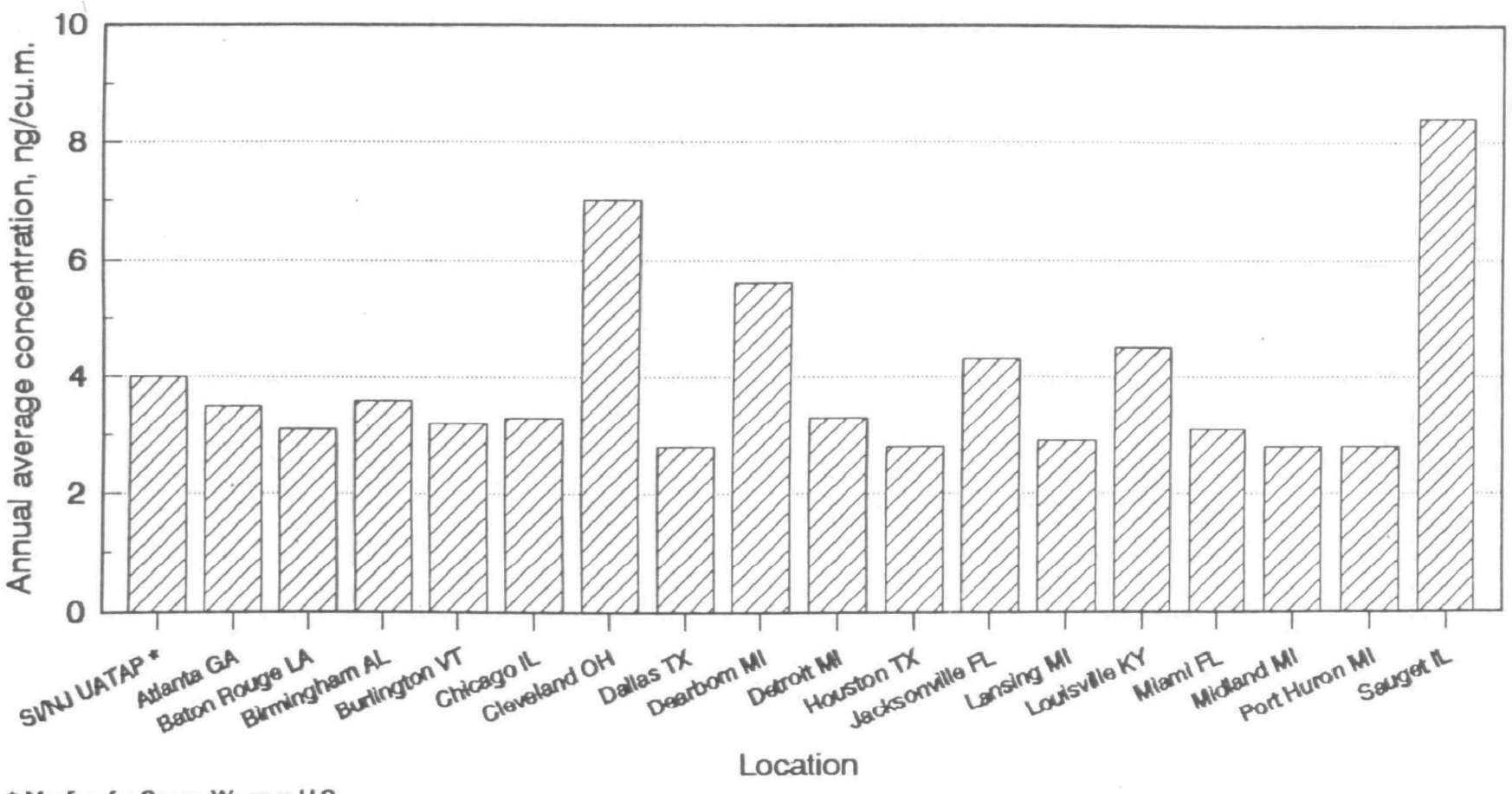


FIGURE V-1-11

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

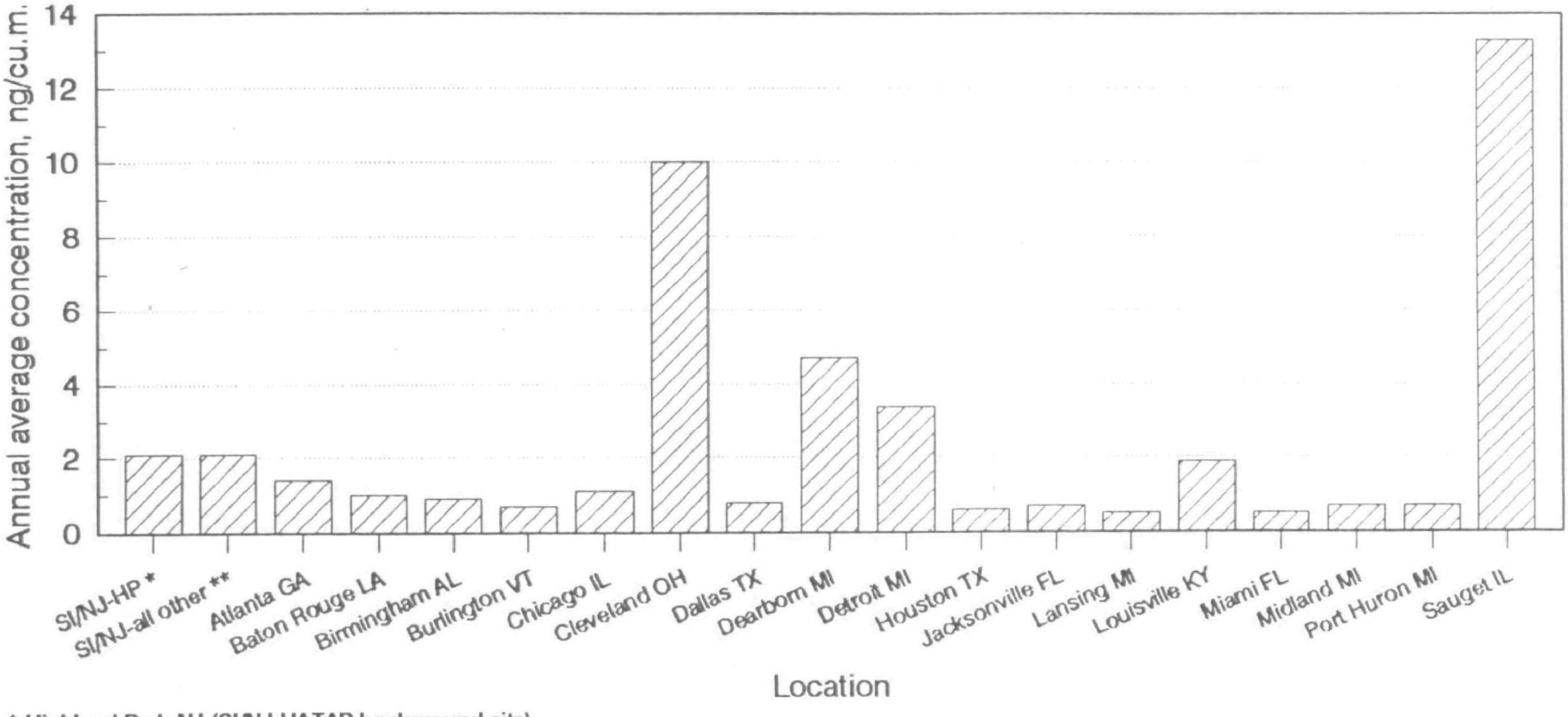


* Median for Susan Wagner H.S. and PS-26

FIGURE V-1-12

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

CADMIUM



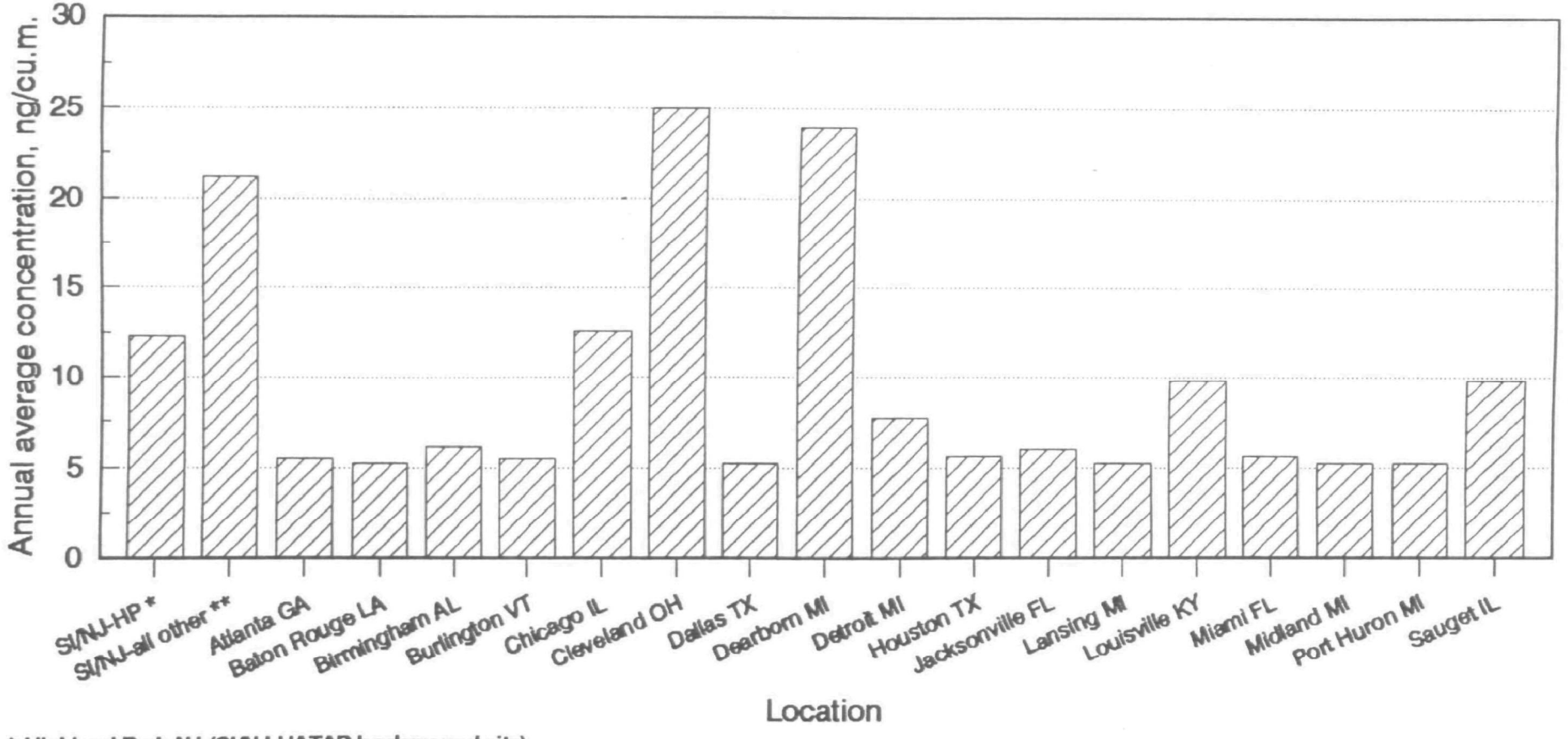
* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26 sites, and Susan Wagner H.S.

FIGURE V-1-13

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

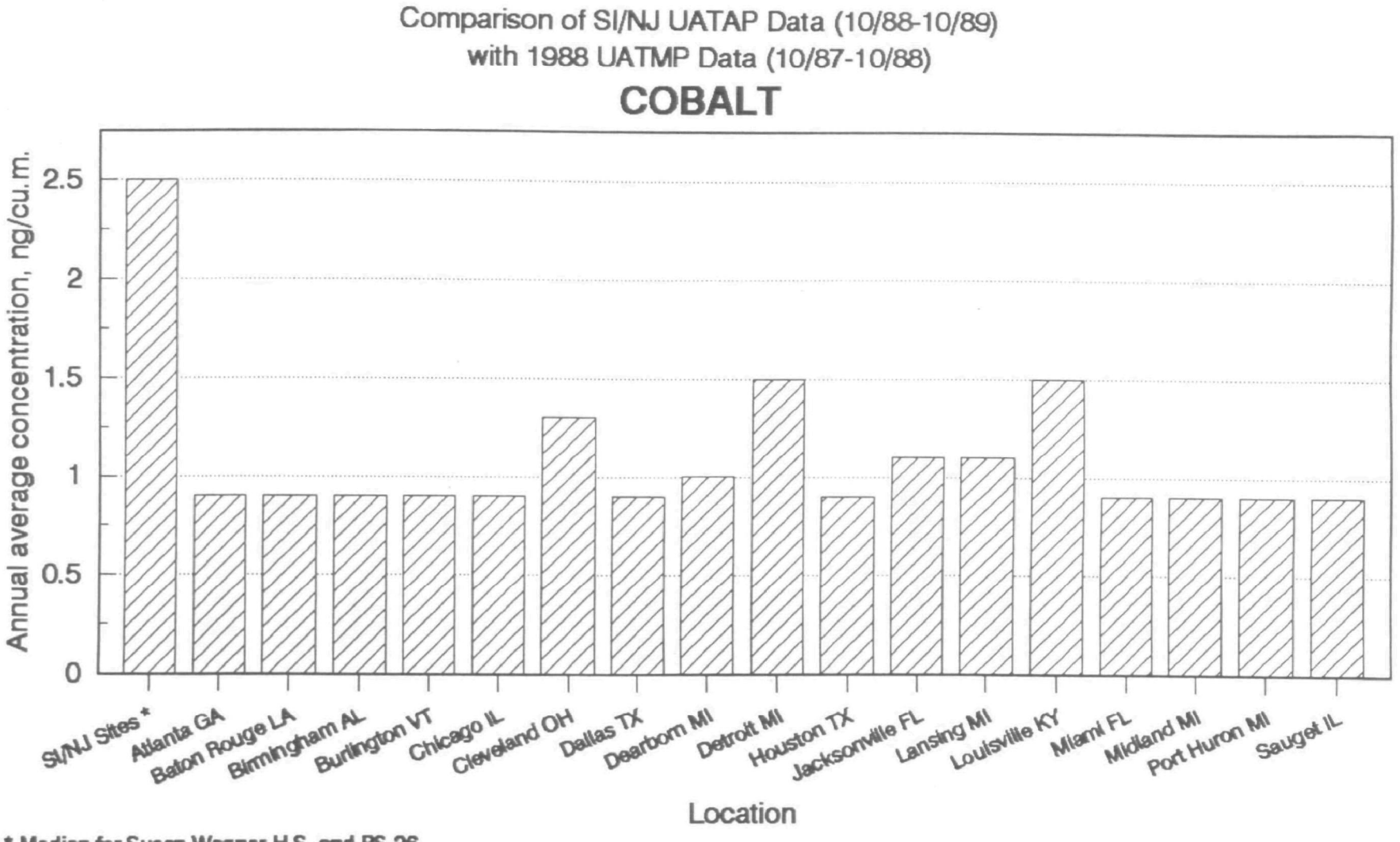
CHROMIUM



* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret and Elizabeth

FIGURE V-1-14

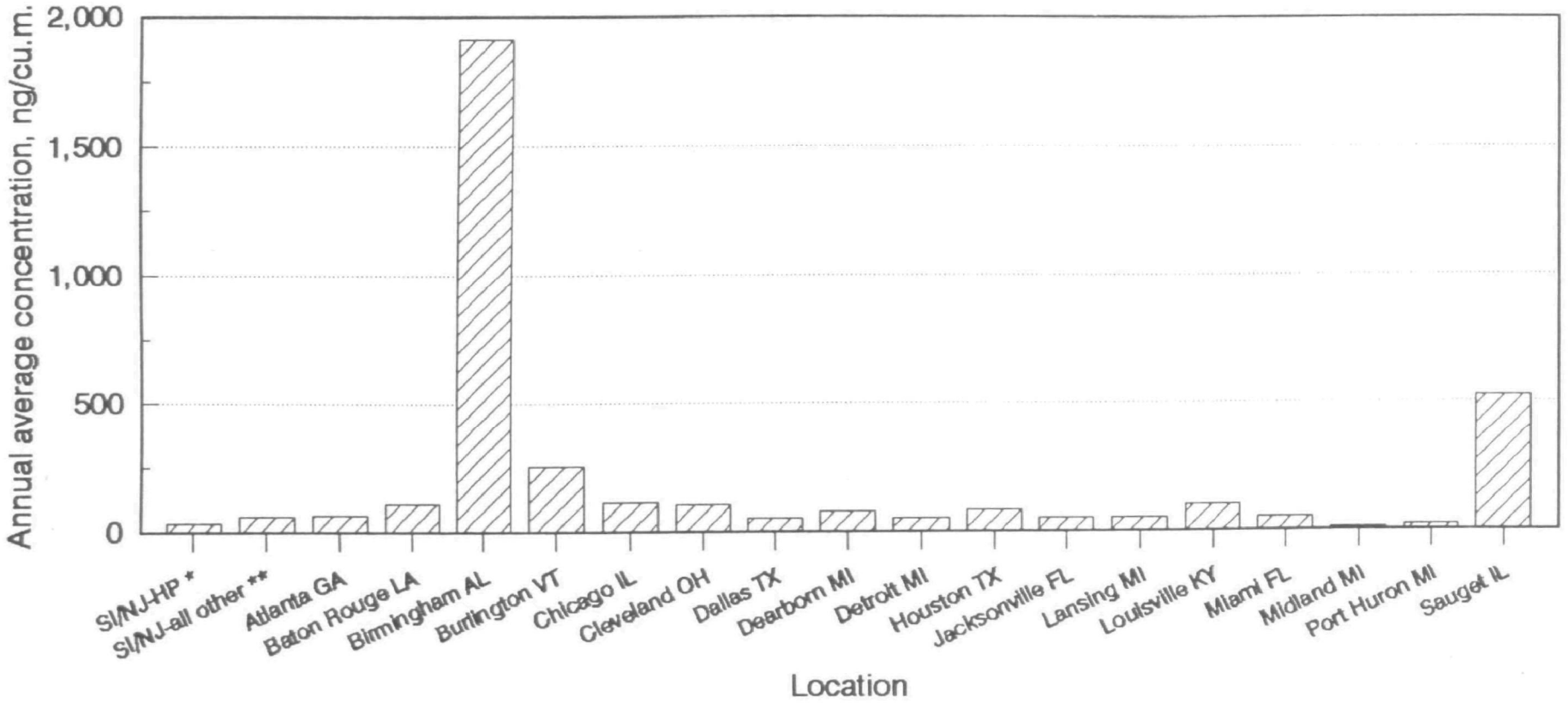


* Median for Susan Wagner H.S. and PS-26

FIGURE V-1-15

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

COPPER

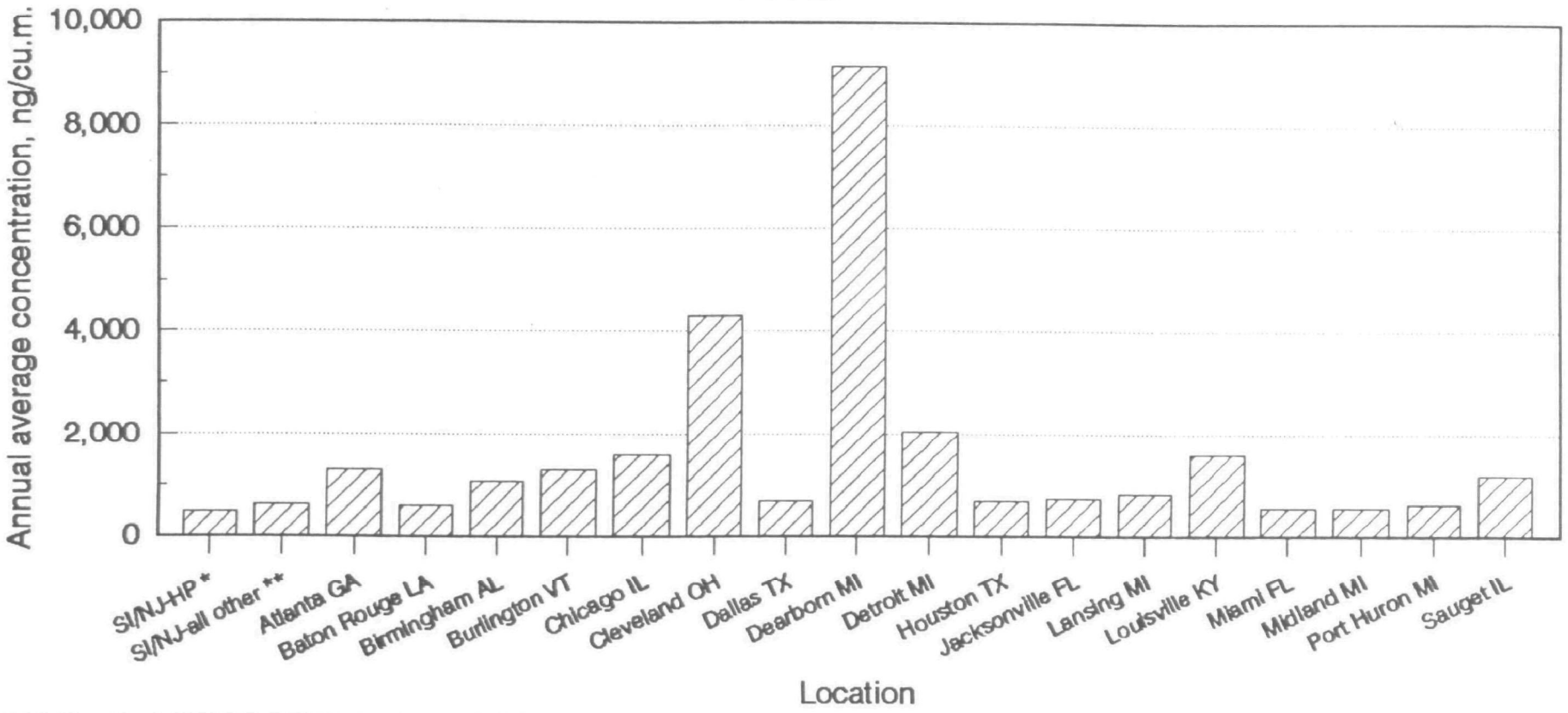


* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26, and Susan Wagner H.S.

FIGURE V-1-16

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

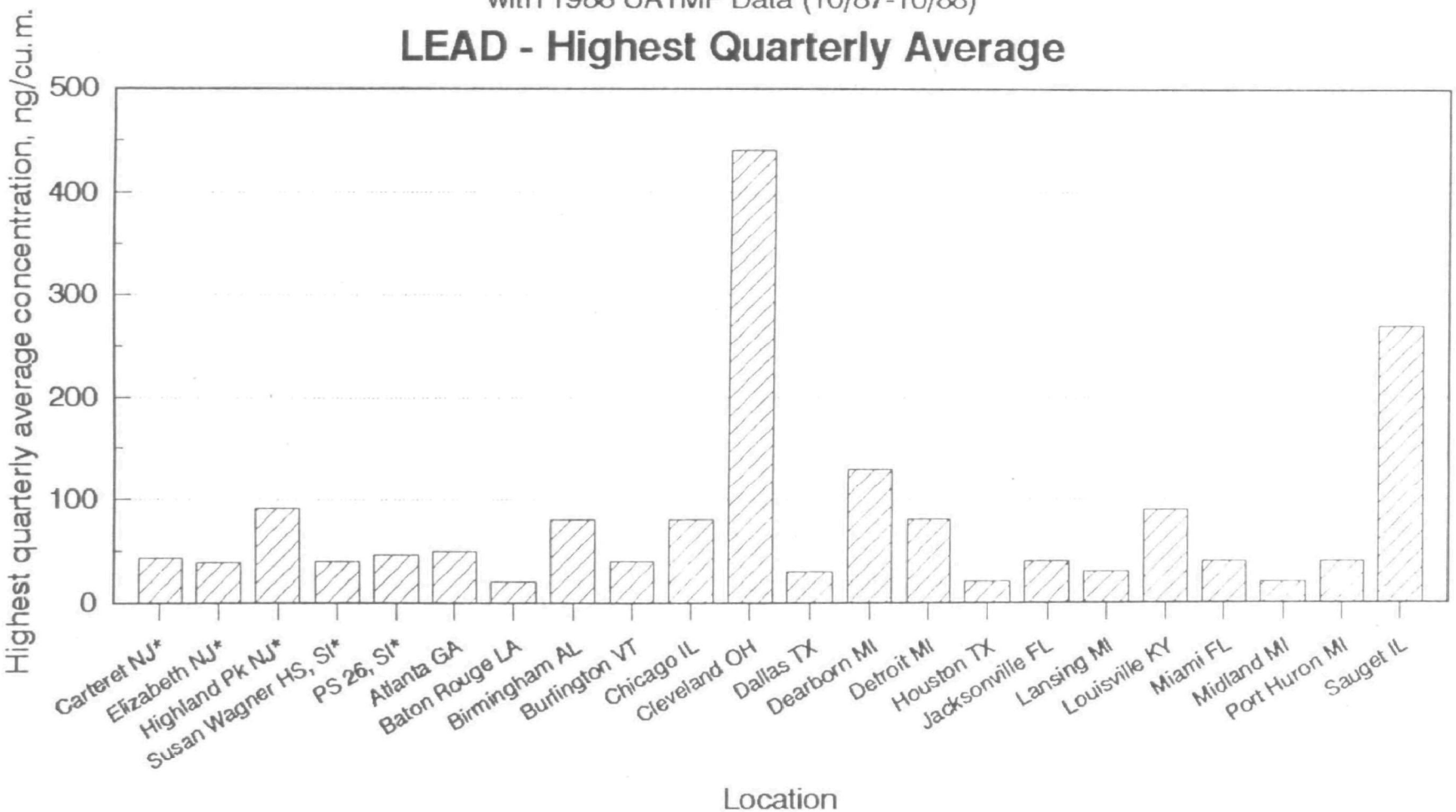


* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26, and Susan Wagner H.S.

FIGURE V-1-17

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

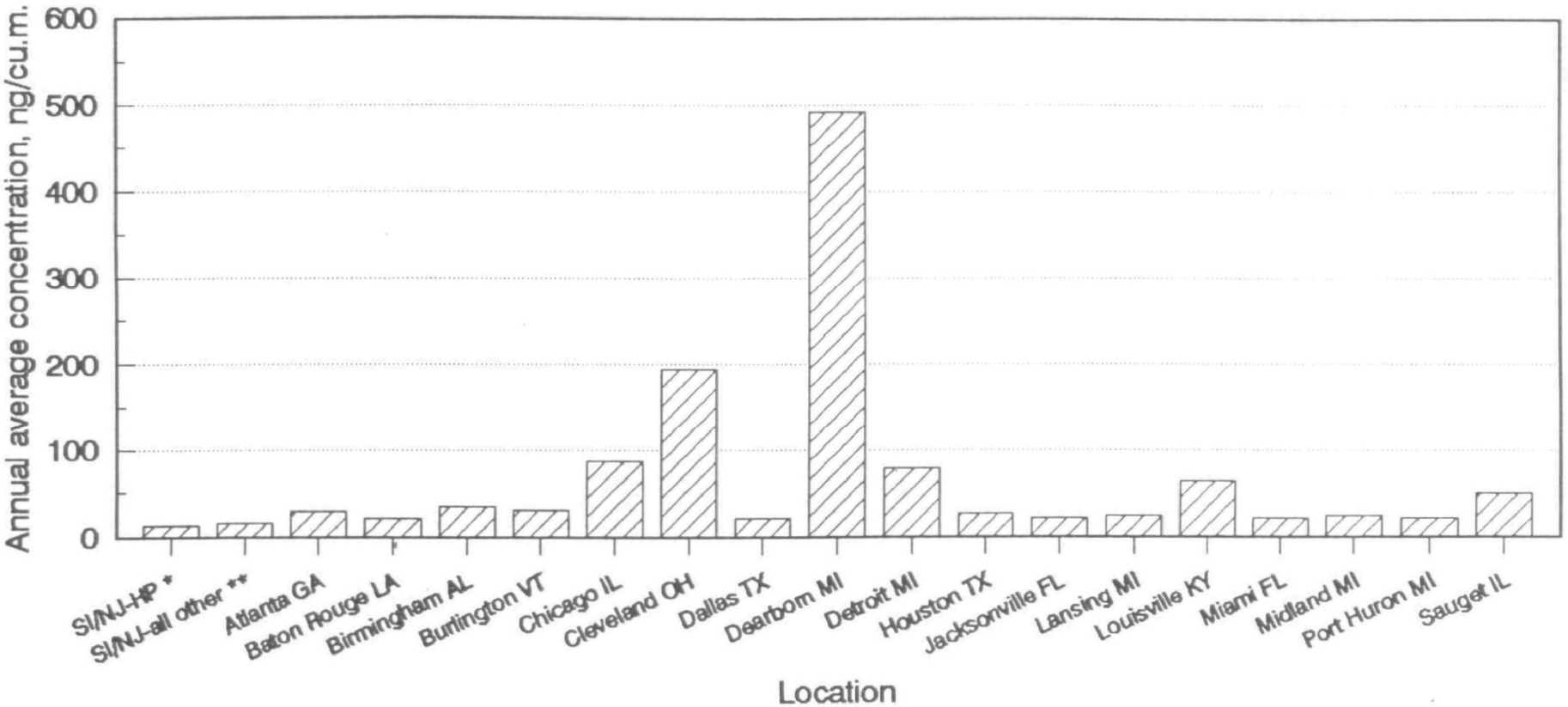


* SI/NJ UATAP site

FIGURE V-1-18

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

MANGANESE



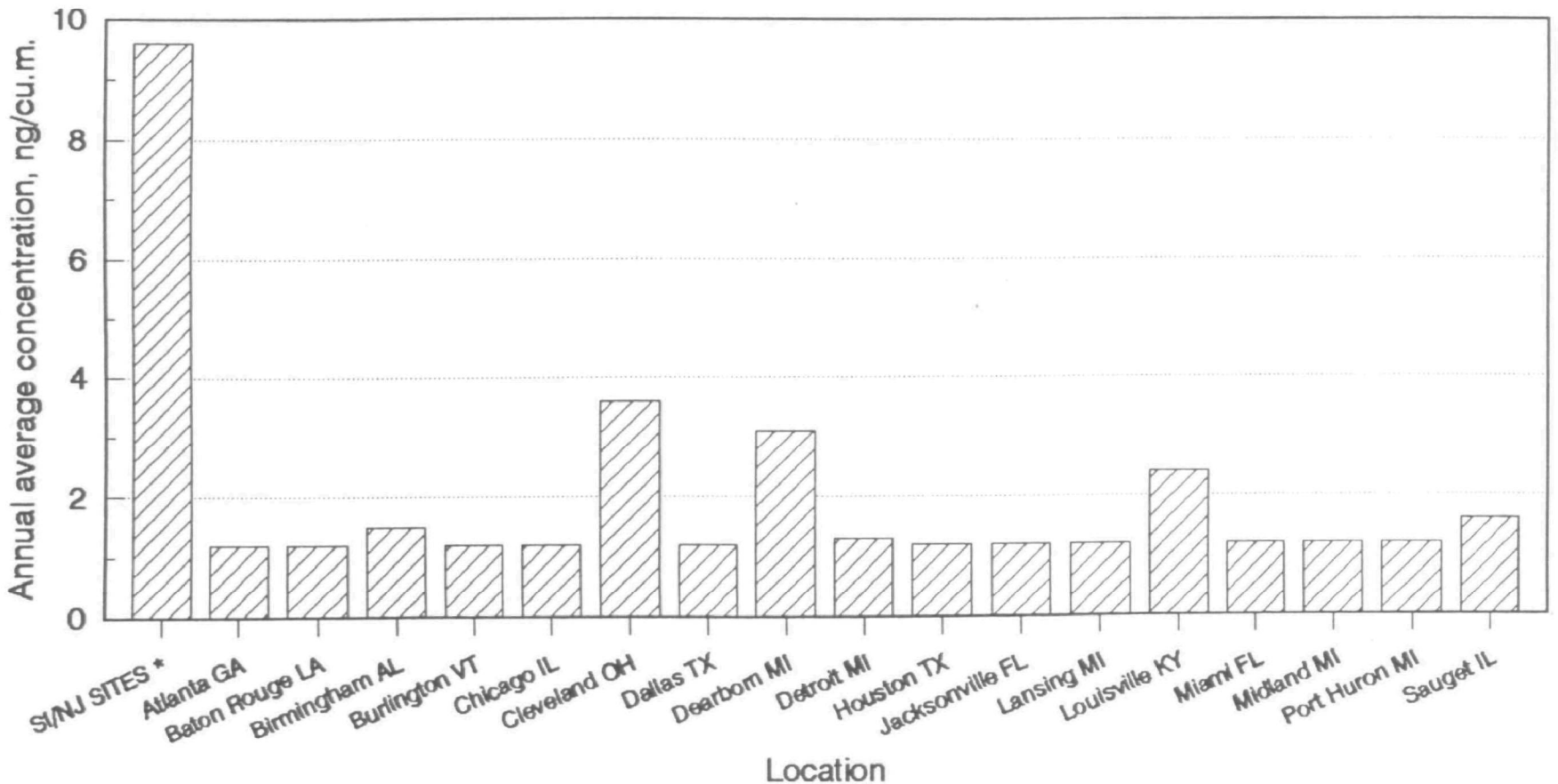
* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26, and Susan Wagner H.S.

FIGURE V-1-19

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

MOLYBDENUM

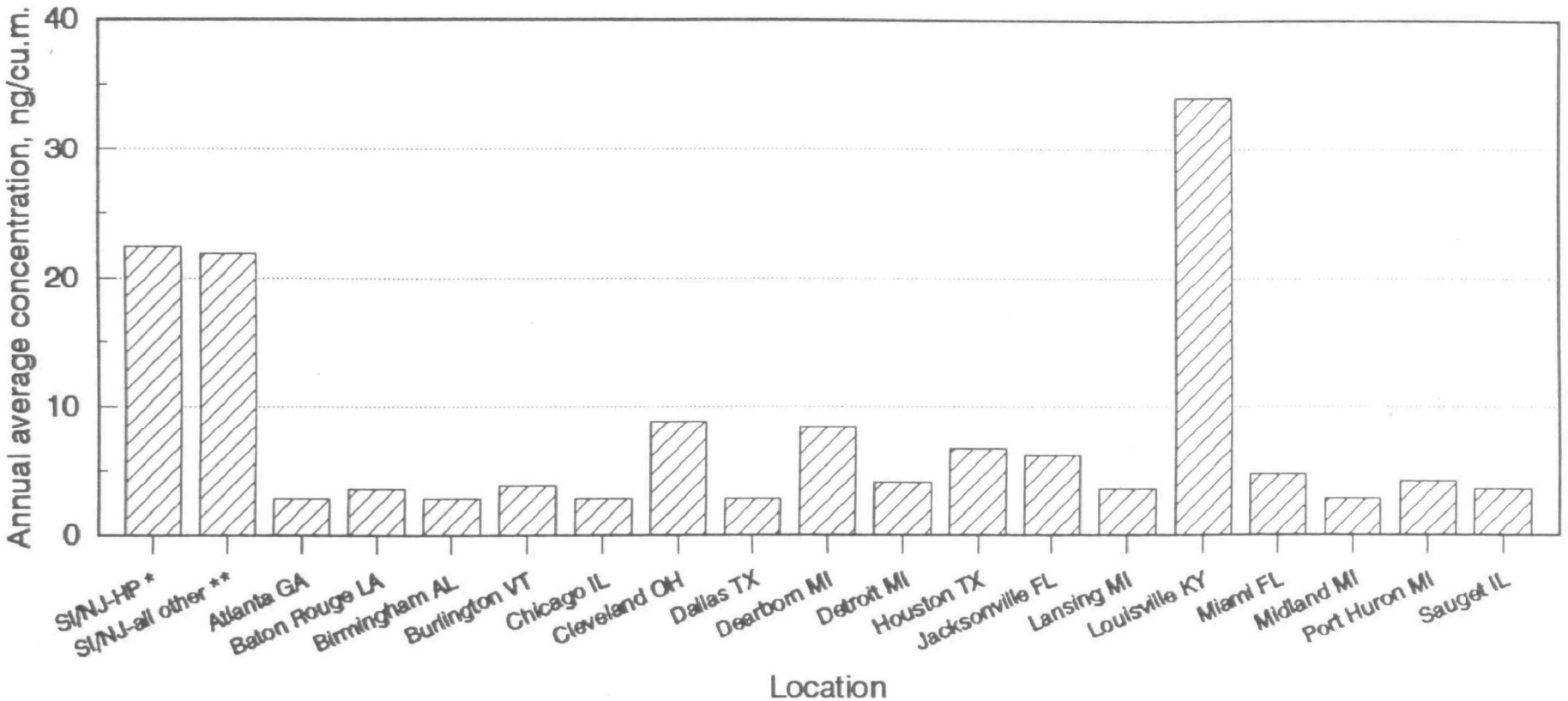


* Median for Susan Wagner H.S. and PS-26

FIGURE V-1-20

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

NICKEL



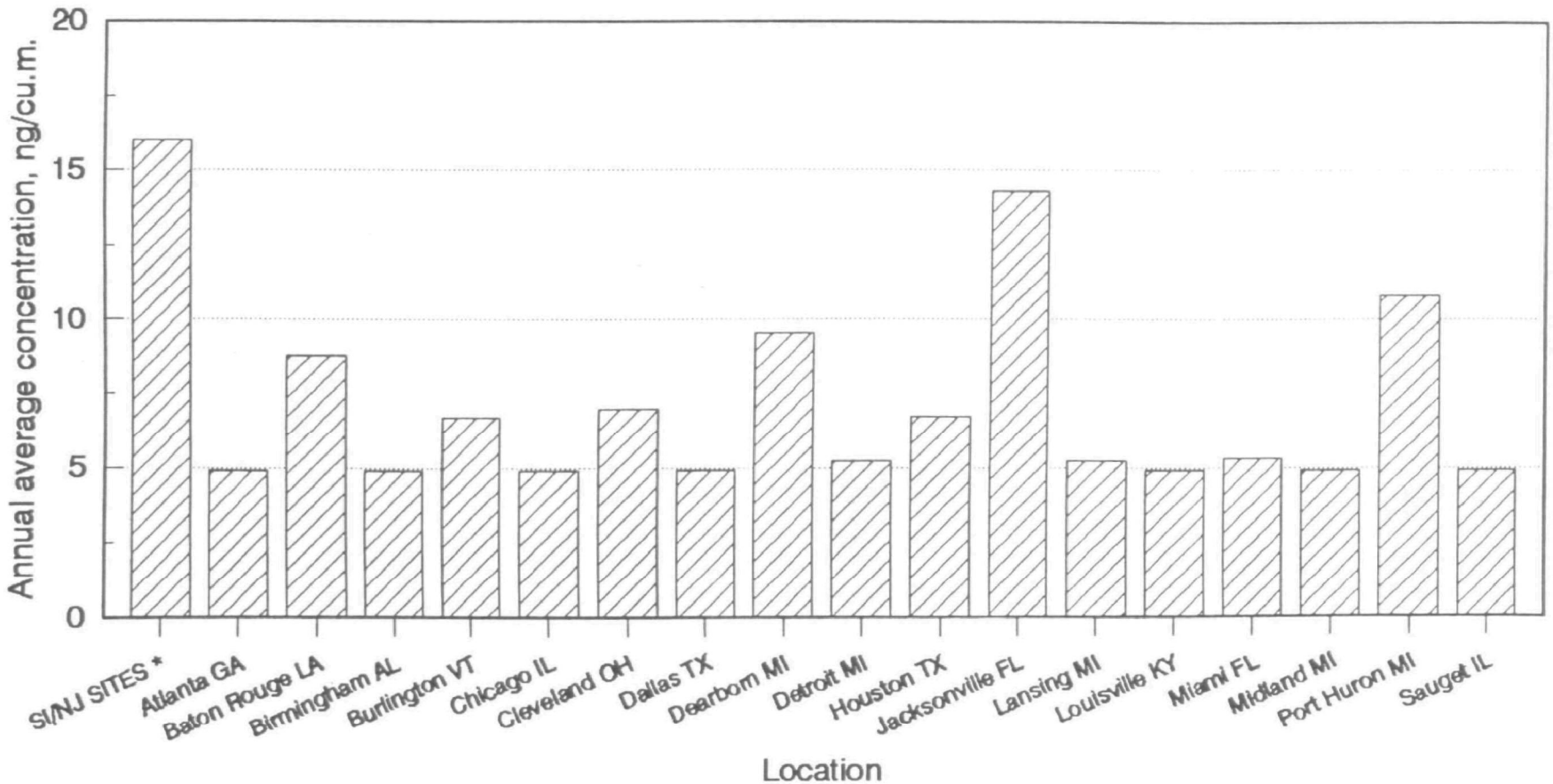
* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26, and Susan Wagner H.S.

FIGURE V-1-21

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)

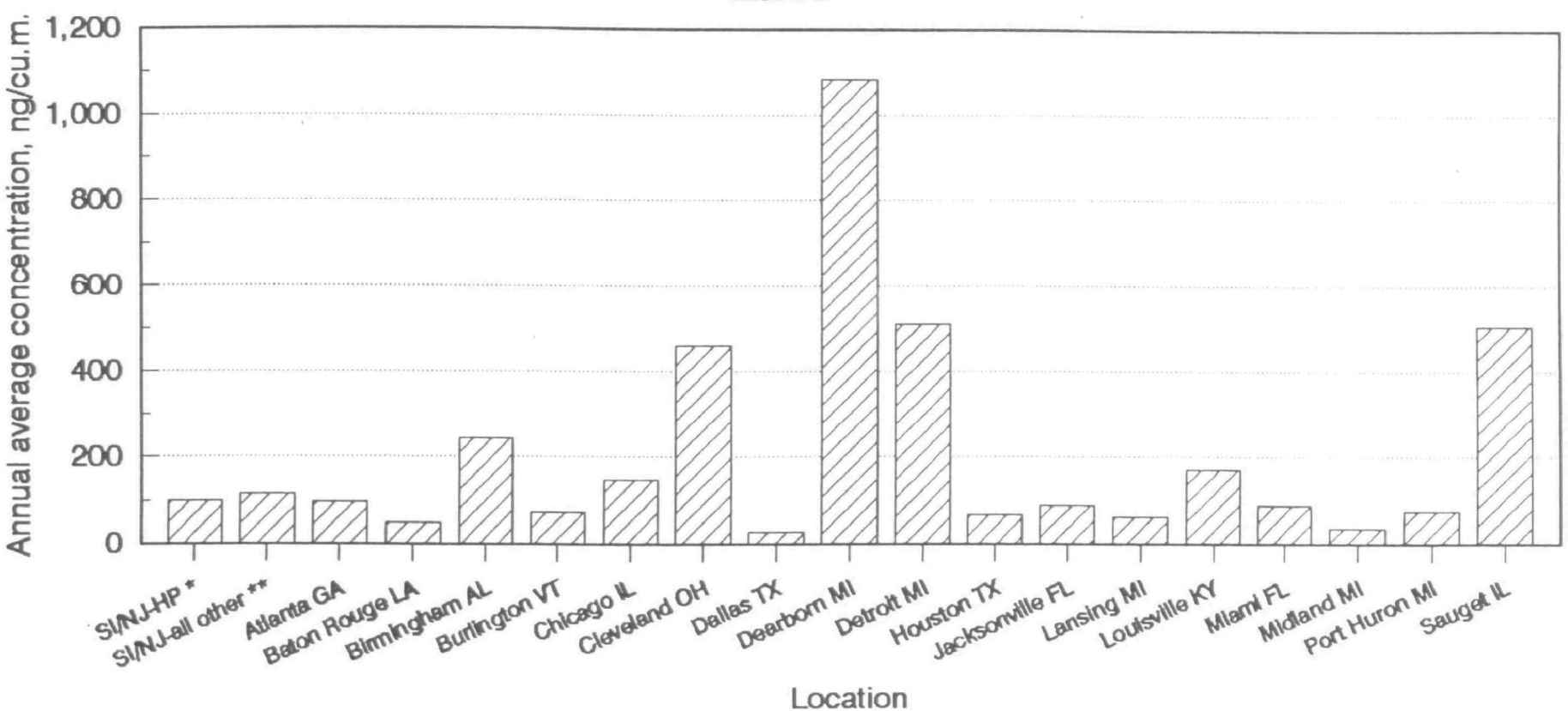
VANADIUM



* Median for Susan Wagner H.S. and PS-26

FIGURE V-1-22

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1988 UATMP Data (10/87-10/88)



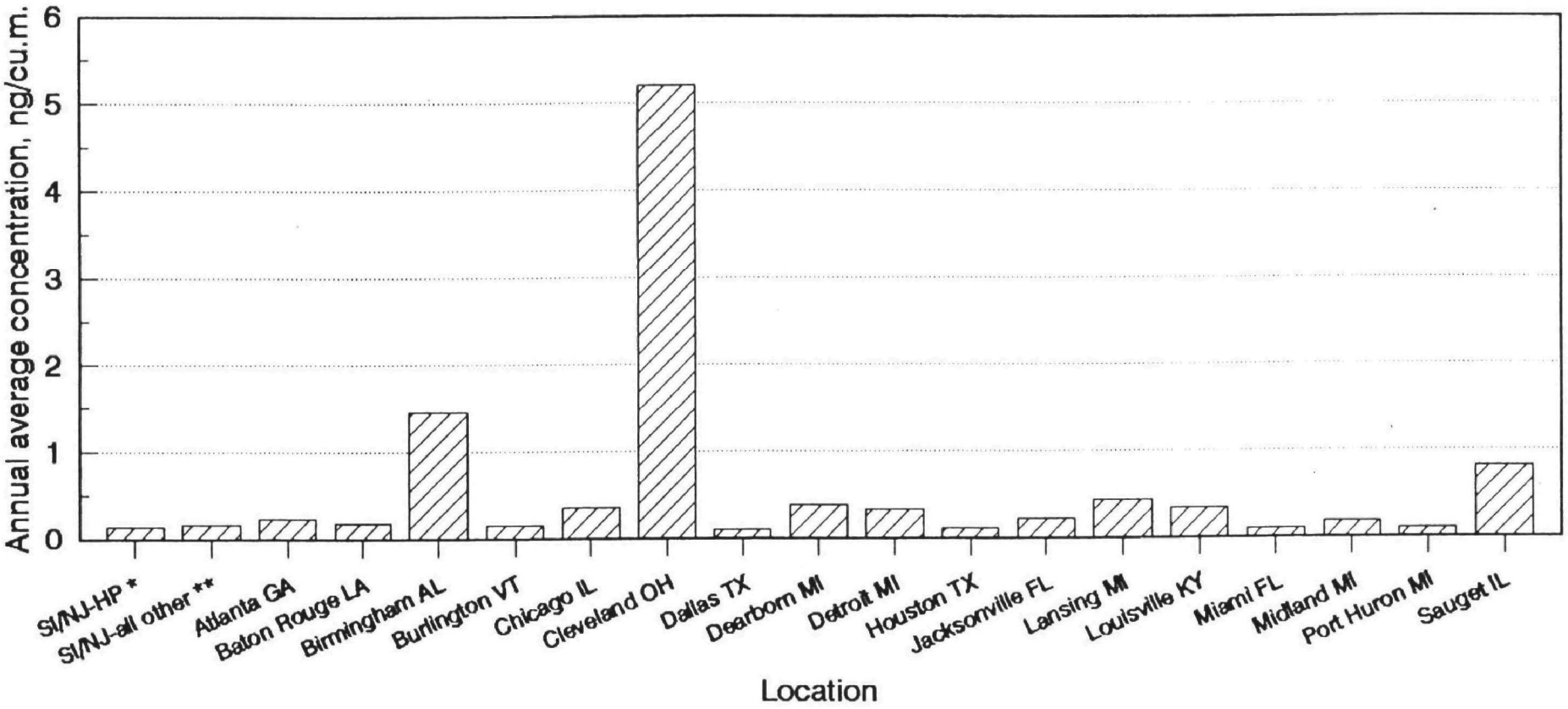
* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26, and Susan Wagner H.S.

FIGURE V-1-23

Comparison of SI/NJ UATAP Data (10/88-10/89)
with1988 UATMP Data (10/87-10/88)

BENZO(A)PYRENE

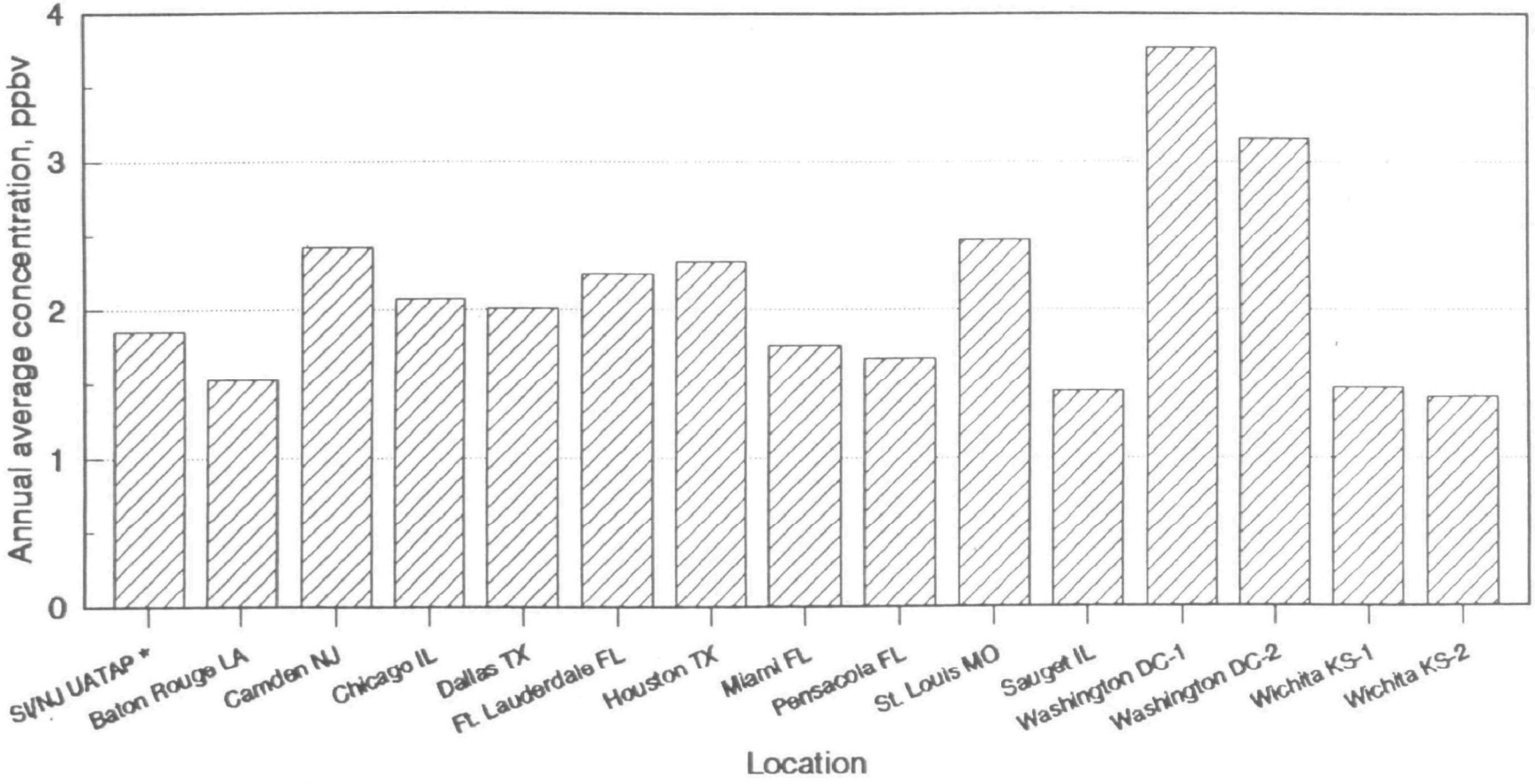


* Highland Park NJ (SI/NJ UATAP background site)

** Median for Carteret, Elizabeth, PS-26, and Susan Wagner H.S.

FIGURE V-1-24

Comparison of SI/NJ UATAP Data (10/88-10/89)
with 1989 UATMP Data for
FORMALDEHYDE



* Median for Susan Wagner H.S. and Port Richmond

TABLE V-1-6: NONCANCER INHALATION REFERENCE CONCENTRATIONS (RFC'S)

CHEMICALS	CAS NUMBER	ug/m3 per ppb at T=20 °C *	INHALATION RFC (mg/m^3)	ADJUSTED RFC (for 23 m3/d)
CHLOROMETHANE	74-87-3	2.10	0.83[1]	342 ppb
DICHLOROMETHANE	75-09-2	3.53	3.0[2]	739 ppb
TRICHLOROMETHANE	67-66-3	4.96	-	6.05[1] ppb
TETRACHLOROMETHANE	56-23-5	6.39	-	0.329[1] ppb
TRICHLOROETHENE	79-01-6	5.46	-	4.21[1] ppb
TETRACHLOROETHENE	127-18-4	6.89	-	4.35[1] ppb
HEXANE, n-	110-54-3	3.58	0.20[1]	48.6 ppb
BENZENE	71-43-2	3.26	-	0.644[1] ppb
TOLUENE	108-88-3	3.83	0.400[2]	90.8 ppb
XYLENE	1330-20-7	4.41	-[3]	-
ETHYLBENZENE	100-41-4	4.35	1.0[2]	200 ppb
FORMALDEHYDE	50-00-0	1.33	0.030[1] **	19.6 ppb, 26000 ng/m^3
LEAD	7439-92-1	-	0.0015[4]	1300 ng/m^3
CHROMIUM	7440-47-3	-	0.0001[1,5], 0.000002[3,6]	87.0[1,5], 1.7[3,6] ng/m^3
NICKEL, refinery dust	00-02-0	-	0.000020[1]	17.4 ng/m^3
BENZO(α)PYRENE	50-32-8	-	-	-
ARSENIC	7440-38-2	-	-	-
CADMIUM	7440-43-9	-	0.00002[1]	17.4 ng/m^3
MERCURY	7439-97-6	-	0.00030[2]	261 ng/m^3
MANGANESE	7439-96-5	-	0.00040[2]	348 ng/m^3
VANADIUM			0.00025[1]	217 ng/m^3
ZINC	7440-66-6	-	0.05[1,7]	43500 ng/m^3

See next page for footnotes.

TABLE V-1-6

FOOTNOTES

* For conversion from units of RfC, weight/volume, to units of reported concentrations, volume/volume) and, thus, the adjusted RfC. Based on density of ideal gas at 20 °C. Sample conversion of inhalation reference concentration to ppb for benzene:

2.1E-3 mg/m3 x (20/23) x (1 ppb/(3.26 ug/m3]) x (1000 ug/mg) = 5.6E-1 ppb

**This is a short-term guideline concentration for 1- to 4-hour exposures; a chronic RfC was not available.

- Information not available or not provided.

[1] NYSDOH

[2] January 1992 IRIS.

[3] RfC appeared in HEAST of 1991, but not in 1992 update of HEAST (Poirier, 1992).

[4] NAAQS for lead, not an RfC (U.S. EPA, 1978).

[5] For total chromium.

[6] Used for hexavalent (Cr VI) portion of total chromium.

[7] NAAQS for PM-10, not an RfC.

TABLE V-1-7: CANCER INHALATION UNIT RISK FACTORS

CHEMICALS	CAS NUMBER	WEIGHT OF EVIDENCE	ug/m3 per ppb*	CANCER SLOPE FACTOR $(mg/kg/d)^{-1}$	INHALATION UNIT RISK FACTOR**[1] (per ug/m3)	Inhalation unit risk factor at 23 m3/day
CHLOROMETHANE	74-87-3	C	2.10	6.3 E-03▲	1.8E-06▲	4.3E-06 per ppb
DICHLOROMETHANE	75-09-2	B2	3.53	7.5 E-03	4.7E-07	1.9E-06 per ppb
TRICHLOROMETHANE	67-66-3	B2	4.96	8.1 E-02	2.3E-05	1.3E-04 per ppb
TETRACHLOROMETHANE	56-23-5	B2	6.39	1.3 E-01	1.5E-05	1.1E-04 per ppb
TRICHLOROETHENE	79-01-6	B2[3]	5.46	6.0 E-03[3]	1.7E-06[2]	1.1E-05 per ppb
TETRACHLOROETHENE	127-18-4	C[3]	6.89	2.0 E-03[3]	5.8E-07[2]	4.6E-06 per ppb
HEXANE, n-	110-54-3	-	3.58	-	-	-
BENZENE	71-43-2	A	3.26	2.9 E-02	8.3E-06	3.1E-05 per ppb
TOLUENE	108-88-3	D	3.83	-	-	-
XYLENE	1330-20-7	D	4.41	-	-	-
ETHYLBENZENE	100-41-4	D	4.35	-	-	-
FORMALDEHYDE	50-00-0	B1	1.33	4.5 E-02	1.3E-05	2.0E-05 per ppb, 1.5E-08 per ng/m^3
LEAD	7439-92-1	B2	-	-	-	-
CHROMIUM, hexavalent	7440-47-3	A	-	4.1 E+01	1.2E-02	1.4E-05 per ng/m3
NICKEL, refinery dust	00-02-0	A	-	8.4 E-01	2.4E-04	2.8E-07 per ng/m3
BENZO[a]PYRENE	50-32-8	B2	-	7.3 E+00	1.7E-03[2]	2.0E-06 per ng/m3
ARSENIC	7440-38-2	A	-	-	4.3E-03	4.9E-06 per ng/m3
CADMIUM	7440-43-9	B1	-	-	1.8E-03	2.1E-06 per ng/m3
MERCURY	7439-97-6	D	-	-	-	-
MANGANESE	7439-96-5	D	-	-	-	-
VANADIUM		-	-	-	-	-
ZINC		-	-	-	-	-

See FOOTNOTES on next page.

TABLE V-1-7, continued: CANCER INHALATION UNIT RISK FACTORS

*For conversion of Inhalation Unit Risk Factor from units of per µg/m^3 to units of per ppb; assumes an ideal gas at T=20 °C, P=1 atm. See sample calculations on next page.)
**Assumes 70-kg person inhaling 20 m3 air of ambient concentration composition for 24 h each day of a 70-year lifetime.
[1]From January 1992 IRIS unless noted as otherwise.
[4]HEAST 1992.
[2]1991 HEAST
[3]In 1992 HEAST, but not IRIS; under review at EPA for reclassification as C-B2 continuum (U.S. EPA, 1992c).

Sample conversion of inhalation unit risk from cancers/(ug/m3) to cancers per ppb for benzene:

[8.3E-6 cancers/(ug/m3)] x [(3.26 ug/m3)/ 1 ppb] x (23/20) = 3.1E-5 cancers per ppb.
at T=20 C, P=1 atm

Sample conversion of inhalation unit risk from cancers/(ug/m3) to cancers per ng/m3 for chromium VI:

[1.2E-2 cancers/(ug/m3)] x (1 ug/1000ng) x (23/20) = 1.4E-5 cancers per ng/m3.

TABLE V-1-8: AVAILABILITY OF INHALATION UNIT RISK FACTORS, INHALATION REFERENCE CONCENTRATIONS, AND AMBIENT CONCENTRATIONS (OCTOBER 1988-SEPTEMBER 1989) FOR THE LEVEL 1 RISK ASSESSMENT

Chemical	Inhalation Unit Risk Factor*	Reference Concentration	Ambient conc.
chloromethane	yes	no	no
dichloromethane	yes	yes	yes
trichloromethane	yes	yes	yes
tetrachloromethane	yes	yes	yes
dichloroethane, 1,1-	no	no	no[1]
dichloroethane, 1,2-	no	no	no[2]
trichloroethene	yes	yes	yes
trichloroethane, 1,1,1-	no (D)	no	yes
trichloroethane, 1,1,2-	no (D)	no	no[3]
tetrachloroethene	yes	yes	yes
tribromomethane	no	no	no[4]
hexane	no	yes	yes
benzene	yes	yes	yes
toluene	no (D)	yes	yes
xylene, o-	no (D)	no	yes
xylene, m- and p-	no (D)	no	yes
styrene	no	no	yes[5]
ethylbenzene	no (D)	yes	yes
chlorobenzene	no	no	no[6]
dichlorobenzene, 1,2-	no	no	no[7]
dichlorobenzene, 1,3-	no	no	no[8]
dichlorobenzene, 1,4-	no	no	no[9]
formaldehyde	yes	no	yes[10,11]
arsenic	yes	no	yes[12]
barium	no	no	yes[12]
beryllium	yes	no	no*
cadmium	yes	yes	yes[10]
chromium	yes	yes	yes[13]
cobalt	no	no	yes[12]
copper	no	no	yes[10]
iron	no	no	yes[10]
lead	no	no[14]	yes[10]

TABLE V-1-8, continued

Chemical	Inhalation Unit Risk Factor*	Reference Concentration	Ambient conc.
manganese	no (D)	yes	yes[10]
mercury	no (D)	yes	yes[13]
molybdenum	no	no	yes[12]
nickel	yes	yes	yes[10]
selenium	no	no	no
vanadium	no	yes	yes[12]
zinc	no	no[15]	yes[10]
benzo[α]pyrene	yes	no	yes[10]

Footnotes

(D) Indicates that the chemical is a Group D carcinogen, a classification for which unit risk factors are not developed.
1 Low %>mdl for NYSDEC, high for CSI (No NJIT data)
2 Low %>mdl (NYSDEC and CSI; no NJIT data)
3 Almost never detected (NYSDEC and CSI; no NJIT data)
4 Almost never detected (CSI; no NYSDEC or NJIT data)
5 Almost always detected, only CSI (No NYSDC or NJIT data)
6 Low/medium %>mdl for NYSDEC, low for CSI (No NJIT data)
7 Medium/high %>mdl for NYSDEC, low for CSI (No NJIT data)
8 Low %>mdl (NYSDEC and CSI; no NJIT data)
9 Low %>mdl (NYSDEC and CSI; no NJIT data)
10 Data for NYSDEC and NJIT sites; CSI did not conduct monitoring for particulates.
11 Low number of samples for NJIT sites. Ozone interference with sampling method for all sites resulting in negative bias in reported concentrations.
12 Data for two NYSDEC sites only.
* Beryllium was never detected in ambient air.
13 Data for three NJIT sites only, including background site.
14 National Ambient Air Quality Standard (NAAQS) for lead, not a reference concentration (RfC).
15 NAAQS for PM-10, not an RfC.

TABLE V-1-9: NONCANCER RISK ESTIMATES, HAZARD QUOTIENTS* FOR VOLATILE ORGANIC COMPOUNDS BASED ON ANNUAL AVERAGE CONCENTRATIONS FROM OCT. 88 THROUGH SEPT. 89

	HAZARD QUOTIENTS													
	NEW JERSEY SITES					NEW YORK SITES								
CHEMICALS	CART	ELIZ	SEW	PSCAT	HIPRK	SW	PS-26	PRT RCH	PUMP	GT KLLS	TOTT	B-STN	ELTVL	DONGAN
DICHLOROMETHANE	--	--	--	--	-	0.0006	0.001	0.001	0.001	0.0006	0.0008	--	--	--
TRICHLOROMETHANE	0.003	0.003	0.003	0.003	-	0.01	0.02	0.01	0.03	0.01	0.01	0.005	0.007	0.005
TETRACHLOROMETHANE	0.4	0.4	0.4	0.3	-	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.4	0.4
TRICHLOROETHENE	0.01	0.01	0.01	0.01	-	0.02	0.03	0.03	0.06	0.02	0.02	0.02	0.01	0.02
TETRACHLOROETHENE	0.04	0.05	0.05	0.03	-	0.04	0.04	0.06	0.3	0.05	0.05	0.06	0.05	0.2
HEXANE, n-	0.02	0.02	0.02	0.01	-	-	-	-	-	-	-	0.02	0.02	0.02
BENZENE	3	3	2	2	-	1	2	2	2	2	2	3	3	4
TOLUENE	0.04	0.04	0.03	0.02	-	0.03	0.04	0.05	0.04	0.03	0.03	0.04	0.04	0.04
XYLENE, o-**	---	---	---	---	-	---	---	---	---	---	---	---	---	---
XYLENES, p- and m-**	---	---	---	---	-	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	-	-	-	-	-	-	-	-	-	-	-	0.002	0.003	0.003

* Hazard Quotient = Ambient conc./Reference conc.
-- Submitted data were invalid.
- Data not collected at this site.
** While an RfC for xylenes was available from the 1991 HEAST, it was absent from the 1992 update (March 1992).
--- HEAST RfC withdrawn.

Note: Apparent site-to-site differences in calculated Hazard Quotients may not be statistically significant.

TABLE V-1-10: CANCER RISK ESTIMATES, EXCESS LIFETIME (70 YEARS) CANCERS FOR VOLATILE ORGANIC COMPOUNDS- BASED ON ANNUAL AVERAGE CONCENTRATIONS FROM OCT. 88 THROUGH SEPT. 89

	CANCER RISK X 10^6													
	NEW JERSEY SITES					NEW YORK SITES								
	CART	ELIZ	SEW	PSCAT	HIPRK	SW	PS-26	PRT RCH	PUMP	GT KLLS	TOTT	B-STN	ELTVL	DONGAN
CHEMICALS														
DICHLOROMETHANE	--	--	--	--	---	0.9	1.8	1.6	1.4	1.0	1.1	--	--	--
TRICHLOROMETHANE	2.3	2.6	2.8	2.7	---	8.8	12	10	19	7.8	8.9	4.5	4.7	4.6
TETRACHLOROMETHANE	13	14	17	12	---	10	11	9.5	11	11	18	12	16	14
TRICHLOROETHENE	0.5	0.4	0.5	0.5	---	1.1	1.3	1.4	2.9	0.8	0.9	0.8	0.7	0.7
TETRACHLOROETHENE	0.8	1.0	1.0	0.6	---	0.8	0.9	1.1	5.0	0.9	0.9	1.2	1.0	3.1
HEXANE, n-	-	-	-	-	---	-	-	-	-	-	-	-	-	-
BENZENE	46	45	36	30	---	24	39	42	36	29	27	44	47	61
TOLUENE	-	-	-	-	---	-	-	-	-	-	-	-	-	-
XYLENE, o-	-	-	-	-	---	-	-	-	-	-	-	-	-	-
XYLENES, p- and m-	-	-	-	-	---	-	-	-	-	-	-	-	-	-
ETHYLBENZENE	---	---	---	---	---	---	---	---	---	---	---	-	-	-

- Unit risk factor is not available.
-- Submitted data were invalid.
--- Data not collected at this site.

Note: Apparent site-to-site differences in calculated risk may not be statistically significant.

TABLE V-1-11: NONCANCER RISK ESTIMATES, HAZARD QUOTIENTS* FOR METALS, BENZO[α]PYRENE, AND FORMALDEHYDE-BASED ON ANNUAL AVERAGE CONCENTRATIONS FOR OCT. 88 THROUGH SEPT. 89

Chemical	Hazard Quotient					
	CART	ELIZ	HIPRK	SW	PS-26	PORT RICH
ARSENIC	----	----	----	----	----	----
CADMIUM	0.2	0.1	0.1	0.1	0.1	----
CHROMIUM						
using former HEAST RfC[1]						
assuming 10% Cr VI	1.5	0.9	0.7	----	----	----
assuming 1% Cr VI	0.15	0.09	0.07	----	----	----
using NYSDOH RfC[2]	0.3	0.2	0.1	----	----	----
LEAD[3]	0.03	0.03	0.07	0.03	0.04	----
MANGANESE	0.06	0.04	0.04	0.04	0.05	----
MERCURY	0.002	0.002	0.002	----	----	----
NICKEL	2	1	1	1	1	----
VANADIUM	----	----	----	0.1	0.1	----
ZINC[4]	0.003	0.003	0.002	0.003	0.002	----
BaP	----	----	----	----	----	----
FORMALDEHYDE	----	----	----	0.1	----	0.09

* Hazard Quotient = Ambient air concentration/Reference Concentration

[1] This RfC, appearing in the 1991 HEAST but absent from the 1992 update, is 2 ng/m^3. For the purpose of the risk assessments for this project, this RfC is treated as appropriate for hexavalent chromium (Cr VI), but not for Cr III, which is treated as noncarcinogenic. Total chromium, and not Cr VI or Cr III, was quantitated; 10% or 1% of the total chromium concentration is assumed to be Cr VI. See text for further detail.

[2] The RfC from NYSDOH is 100 ng/m^3.

[3] The NAAQS for lead was used in the absence of an EPA-approved RfC. Since the NAAQS averaging period is a calendar year, the highest quarterly average concentration for each site was used instead of the annual average concentration.

[4] Based on the NAAQS for PM-10.

Note: Apparent site-to-site differences in calculated hazard quotients may not be statistically significant.

TABLE V-1-12: CANCER RISK, ESTIMATED EXCESS INDIVIDUAL LIFETIME (70 YEARS) CANCER RISK BASED ON ANNUAL AVERAGE CONCENTRATIONS FOR OCT. 88 THROUGH SEPT. 89

Chemical	Excess cancer risk x 10^6						
	CART	ELIZ	HIPRK	SW		PS-26	PORT RICH
ARSENIC	----	----	----	18	21	----	
CADMIUM	8.7	3.7	4.3	5.0		5.2	----
CHROMIUM (10%)[1]	37	22	17	----	----	----	
CHROMIUM (1%)[2]	3.7	2.2	1.7	----		----	----
LEAD	----	----	----	----		----	----
MAGANESE	----	----	----	----		----	----
MERCURY	----	----	----	----		----	----
NICKEL	7.8	6.5	6.2	5.3		5.6	----
VANADIUM	----	----	----	----		----	----
ZINC	----	----	----	----		----	----
BaP	0.39	0.37	0.27	0.29		0.41	----
FORMALDEHYDE	----	----	----	0.28		----	0.24

[1] 10% of the total chromium is assumed to be hexavalent (Cr VI).

[2] 1% of the total chromium is assumed to be hexavalent (Cr VI).

Note: Apparent site-to-site differences in calculated excess cancer risk may not be statistically significant.

TABLE V-1-13: COMPARISON OF NONCANCER RISK ESTIMATES FOR AMBIENT AIR - HAZARD QUOTIENTS FOR SI/NJ UATAP AND UATMP STUDIES

CHEMICAL	HAZARD QUOTIENT*								
	SI/NJ UATAP[1]			1988 UATMP[2] (19 Cities)			1989 UATMP[3] (12 Cities)		
	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.
DICHLOROMETHANE	0.0006	0.0011	0.0008	0.0001	0.0009	0.0005	0.0002	0.0048	0.0002
HEXANE	0.0089	0.0193	0.0154	-	-	-	-	-	-
TRICHLOROMETHANE	0.0125	0.0938	0.0250	0.0063	2.0313	0.0625	0.0025	1.6312	0.0250
TETRACHLOROMETHANE	0.3103	0.5517	0.3793	0.0138	0.1724	0.0345	0.4483	0.8276	0.6552
BENZENE	1.3750	3.5000	2.2679	0.5714	6.0893	1.5536	1.0714	7.0893	3.0714
TRICHLOROETHENE	0.0108	0.0730	0.0189	0.0027	0.4243	0.0162	0.0027	0.2405	0.0432
TOLUENE	0.02	0.041	0.033	0.016	0.15	0.026	0.012	0.15	0.034
TETRACHLOROETHENE	0.0342	0.2868	0.0553	0.0105	1.0526	0.0184	0.0184	0.1026	0.0447
ETHYLBENZENE	0.0083	0.0110	0.0088	0.0027	0.0962	0.0065	0.0020	0.0228	0.0073
XYLENE, m- and p-[4]	-	-	-	-	-	-	-	-	-
XYLENE, o-[4]	-	-	-	-	-	-	-	-	-
FORMALDEHYDE	0.0872	0.103	0.0949	-	-	-	0.0671	0.1814	0.0971
ARSENIC	0.0093	0.0108	0.0100	0.0070	0.0210	0.0083	-	-	-
CADMIUM	0.1059	0.2471	0.1235	0.0294	0.7824	0.0529	-	-	-
CHROMIUM									
using former HEAST RfC[4,5]									
assuming 10% Cr VI	0.92	1.6	1.2	0.088	1.5	0.33	-	-	-
assuming 1% Cr VI	0.092	0.16	0.12	0.0088	0.15	0.033	-	-	-
using NYSDOH RfC[6]	0.18	0.31	0.24	0.017	0.29	0.064	-	-	-
COBALT	-	-	-	-	-	-	-	-	-
COPPER	-	-	-	-	-	-	-	-	-
IRON	-	-	-	-	-	-	-	-	-
LEAD[7]	0.0111	0.0351	0.0267	0.0077	0.3385	0.0308	-	-	-
MANGANESE	0.0423	0.0617	0.0429	0.0583	1.4049	0.0823	-	-	-
MERCURY	0.0019	0.0019	0.0019	0.0000	0.0000	0.0000	-	-	-
MOLYBDENUM	-	-	-	-	-	-	-	-	-
NICKEL	1.1235	1.6588	1.2882	0.1647	2.0000	0.2235	-	-	-
VANADIUM	0.0894	0.0994	0.0941	0.0288	0.0841	0.0306	-	-	-
ZINC[8]	0.0022	0.0027	0.0026	0.0006	0.0252	0.0021	-	-	-
BENZO[a]PYRENE	-	-	-	-	-	-	-	-	-

Note: Apparent site-to-site differences in calculated hazard quotients may not be statistically significant.

SEE FOOTNOTES ON NEXT PAGE.

TABLE V-1-13, CONTINUED

FOOTNOTES

* Calculated using the minimum, maximum, and median annual average concentration data for sites in the study indicated, and adjusted reference concentrations (RfCs) from Table V-1-6.
1 Based on concentration data for the period 10/88 through 9/89; does not include the background site (Piscataway).
2 Based on concentration data for the period 9/24/87 through 10/6/88.
3 Based on concentration data for the period 1/22/89 through 1/17/90.
4 The RfC in the 1991 HEAST was withdrawn and, thus, absent from the 1992 update; no RfC is available currently.
\- Either RfC or concentration data is/are not available.
5 This RfC, appearing in the 1991 HEAST but absent from the 1992 update, is 2 ng/m^3; the RfC was withdrawn pending a public meeting scheduled for discussion of the RfC. For the purpose of the risk assessments for this project, this RfC is treated as appropriate for hexavalent chromium (Cr VI), but not for Cr III, which is treated as noncarcinogenic. Total chromium, and not Cr VI or Cr III, was quantitated; 10% or 1% of the total chromium concentration is assumed to be Cr VI. See text for further detail.
6 The RfC from NYSDOH is 100 ng/m^3.
7 The NAAQS for lead was used in the absence of an EPA-approved RfC. Since the NAAQS averaging period is a calendar year, the highest quarter concentration for each site was used instead of annual average concentration.
8 Based on the NAAQS for PM-10.

Note: Apparent site-to-site differences in calculated hazard quotients may not be statistically significant.

TABLE V-1-14: COMPARISON OF CANCER RISK ESTIMATES FOR AMBIENT AIR - ESTIMATED EXCESS INDIVIDUAL LIFETIME CANCER RISK FOR SI/NJ UATAP AND UATMP STUDIES

CHEMICAL	INCREASED LIFETIME CANCER RISK*								
	SI/NJ UATAP[1]			1988 UATMP[2] (19 Cities)			1989 UATMP[3] (12 Cities)		
	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.
DICHLOROMETHANE	8.9E-07	1.8E-06	1.3E-06	1.1E-07	1.4E-06	8.4E-07	2.5E-07	7.8E-06	4.0E-07
HEXANE	-	-	-	-	-	-	-	-	-
TRICHLOROMETHANE	2.6E-06	1.9E-05	5.2E-06	1.3E-06	4.2E-04	1.3E-05	5.2E-07	3.4E-04	5.2E-06
TETRACHLOROMETHANE	9.9E-06	1.8E-05	1.2E-05	4.4E-07	5.5E-06	1.1E-06	1.4E-05	2.6E-05	2.1E-05
BENZENE	2.4E-05	6.1E-05	3.9E-05	9.9E-06	1.1E-04	2.7E-05	1.9E-05	1.2E-04	5.3E-05
TRICHLOROETHENE	4.4E-07	3.0E-06	7.7E-07	1.1E-07	1.7E-05	6.6E-07	1.1E-07	9.8E-06	1.8E-06
TOLUENE	-	-	-	-	-	-	-	-	-
TETRACHLOROETHENE	6.0E-07	5.0E-06	9.7E-07	1.8E-07	1.8E-05	3.2E-07	3.2E-07	1.8E-06	7.8E-07
ETHYLBENZENE	-	-	-	-	-	-	-	-	-
XYLENE, m- and p-	-	-	-	-	-	-	-	-	-
XYLENE, o-	-	-	-	-	-	-	-	-	-
FORMALDEHYDE	3.5E-05	4.1E-05	3.8E-05	-	-	-	2.8E-05	7.6E-05	4.1E-05
ARSENIC	1.8E-05	2.1E-05	2.0E-05	1.4E-05	4.1E-05	1.6E-05	-	-	-
CADMIUM	3.8E-06	8.8E-06	4.4E-06	1.0E-06	2.8E-05	1.9E-06	-	-	-
CHROMIUM[4]									
assuming 10% Cr VI	2.2E-06	3.8E-05	3.0E-05	2.1E-06	3.5E-05	7.8E-06	-	-	-
assuming 1% Cr VI	2.2E-07	3.8E-06	3.0E-06	2.1E-07	3.5E-06	7.8E-07	-	-	-
COBALT	-	-	-	-	-	-	-	-	-
COPPER	-	-	-	-	-	-	-	-	-
IRON	-	-	-	-	-	-	-	-	-
LEAD[5]	-	-	-	-	-	-	-	-	-
MANGANESE	-	-	-	-	-	-	-	-	-
MERCURY	-	-	-	-	-	-	-	-	-
MOLYBDENUM	-	-	-	-	-	-	-	-	-
NICKEL	5.3E-06	7.9E-06	6.1E-06	7.8E-07	9.5E-06	1.1E-06	-	-	-
VANADIUM	-	-	-	-	-	-	-	-	-
ZINC	-	-	-	-	-	-	-	-	-
B(A)P	3.0E-07	4.2E-07	3.4E-07	6.4E-08	1.0E-05	3.7E-07	-	-	-

Note: Apparent site-to-site differences in risks may not be statistically significant.

SEE FOOTNOTES ON NEXT PAGE.

TABLE V-1-14, CONTINUED

FOOTNOTES

* Calculated using the minimum, maximum, and median annual average concentration data for sites in the study indicated, and adjusted inhalation unit risk factors (IURFs) from Table V-1-7.
1 Based on concentration data for the period 10/88 through 9/89; does not include the background site (Piscataway).
2 Based on concentration data for the period 9/24/87 through 10/6/88.
3 Based on concentration data for the period 1/22/89 through 1/17/90.
4 The available IURF is for hexavalent chromium (Cr VI). The risk assessments for this project assume that Cr VI is the only carcinogenic chromium component of the reported total chromium concentrations, and that 10% or 1% of the total reported concentrations is Cr VI. See text for further detail.
5 While lead is classified as a Group B2 carcinogen, an IURF for lead is not available.

Table V-1-15: Indoor/Outdoor Ratios and Correlation Coefficients between Indoor Air and Corresponding Outdoor Air Concentrations

Compound	Carteret, New Jersey					
	Site 0030-B1			Site 0030-B2		
	I/O	P	S	I/O	P	S
chloromethane	1.1	0.34	0.51	1.2	0.05	0.43
dichloromethane	0.4*	0.33	0.53	0.5*	0.30	0.45
hexane	0.9	0.47	0.63	1.9*	0.54	0.57
chloroform	1.8*	0.50	0.51	2.9*	0.33	0.43
1,1,1-trichloroethane	0.9	0.11	0.67	0.5*	0.07	0.07
benzene	0.9	0.65	0.65	1.6*	0.36	0.60
trichloro-ethylene	5.1*	0.33	0.37	2.3*	0.38	0.46
toluene	1.6*	0.12	0.00	2.0*	0.04	0.30
tetrachloro-ethylene	1.9*	0.09	0.37	1.7*	0.61	0.63
ethylbenzene	1.4*	0.54	0.45	2.1*	0.22	0.50
m,p-xylene	1.2	0.47	0.49	2.0*	0.36	0.74
o-xylene	1.1	0.37	0.45	2.0*	0.05	0.53

* = $p<0.05$

I/O = mean indoor air concentration divided by the corresponding mean outdoor air concentration

P = Pearson correlation coefficient

S = Spearman correlation coefficient

Table V-1-16: Indoor/Outdoor Ratios and Correlation Coefficients between Indoor Air and Corresponding Outdoor Air Concentrations

Compound	Staten Island					
	Site 7097-2A			Site 7097-2B		
	I/O	P	S	I/O	P	S
chloromethane	2.2*	0.26	0.18	2.5*	0.28	0.23
dichloromethane	0.8*	0.77	0.73	3.0*	0.20	0.11
hexane	2.1*	0.76	0.73	1.7*	0.48	0.63
chloroform	1.7*	0.19	0.34	3.4*	0.22	0.28
1,1,1-trichloroethane	0.85	0.73	0.64	1.0	0.43	0.11
benzene	1.7*	0.67	0.66	1.4*	0.58	0.35
trichloro-ethylene	0.56*	0.28	0.48	0.74	0.43	0.55
toluene	2.0*	0.09	0.21	1.7*	0.20	0.43
tetrachloro-ethylene	0.83	0.88	0.86	1.1*	0.86	0.78
ethylbenzene	1.7*	0.64	0.68	1.1*	0.74	0.51
m,p-xylene	2.0	0.51	0.51	1.1*	0.76	0.84
o-xylene	1.5	0.37	0.40	0.95	0.55	0.83

* = $p<0.05$

I/O = mean indoor air concentration divided by the corresponding mean outdoor air concentration

P = Pearson correlation coefficient

S = Spearman correlation coefficient

Table V-1-17: Comparison of Ambient Air Data for PS-26 (Travis, Staten Island)--NYSDOH* (7/90-3/91) vs. UATAP** (10/88-3/89 and 7/89-9/89)

	UATAP**		NYSDOH			
	n	mean (ppb)	n	mean (ppb)	ratio[a]	difference[b]
chloromethane	NA	NA	36	0.6	-	-
dichloromethane	41	0.93	44	1.2	1.3	+0.24
hexane	NA	NA	36	1.2	-	-
chloroform	41	0.11	44	c	-	-
1,1,1-trichloroethane	41	0.49	44	0.7	1.4	+0.20
carbon tetrachloride	41	0.11	44	c	-	-
benzene	41	1.29	44	1.7	1.4	+0.47
trichloroethylene	26	0.08	36	c	-	-
toluene	41	4.04	44	6.1	1.5	+2.19
tetrachloro-ethylene	41	0.18	44	c	-	-
ethylbenzene	NA	NA	36	0.9	-	-
m/p-xylene	41	1.47	36	3.1	2.2	+1.72
o-xylene	41	0.45	44	1.4	3.5	+1.13

* NYSDOH refers to the indoor air portion of the SI/NJ UATAP.
** UATAP refers to the ambient air portion of the SI/NJ UATAP.
NA -not available
a -ratio of NYSDOH/UATAP
b -difference equals NYSDOH minus UATAP
c -low frequency of detection prevents calculation of a valid mean

Table V-1-18: Comparison of Ambient Data for Carteret, New Jersey--
NYSDOH* (7/90-3/91) vs.
UATAP** (10/88-3/89 and 7/89-9/89)

	UATAP**		NYSDOH			
	n	mean (ppb)	n	mean (ppb)	ratio[a]	difference[b]
chloromethane	NA	NA	36	0.7	-	-
dichloromethane	NA	NA	42	2.2	-	-
hexane	25	1.09	36	0.8	0.8	-0.24
chloroform	40	0.01	42	c	-	-
1,1,1-trichloroethane	40	0.58	42	2.6	4.4	+1.98
carbon tetrachloride	40	0.11	42	c	-	-
benzene	40	1.54	42	1.4	0.9	-0.14
trichloroethylene	40	0.04	36	c	-	-
toluene	40	4.11	42	6.0	1.4	+1.76
ethylbenzene	NA	NA	36	0.9	-	-
m/p-xylene	40	1.29	36	3.1	2.2	+1.72
o-xylene	40	0.43	44	1.4	3.5	+1.13

* NYSDOH refers to the indoor air portion of the SI/NJ UATAP.
** UATAP refers to the ambient air portion of the SI/NJ UATAP.
NA -not available
a -ratio of NYSDOH/UATAP
b - difference equals NYSDOH minus UATAP
c - low frequency of detection prevents calculation of a valid mean.

Table V-1-19: Level 2 Exposure Assessment Scenarios and Sample Calculation

General equations and explanation

The general equation used to calculate lifetime average daily dose is as follows:

$$D=\Sigma[(t_i/70)D_{Ai}],$$

where D_{Ai} = average daily dose for a given age interval, and
t_i = number of years covered by that age interval.

The general equation used to calculate average daily dose for each age interval is as follows, where C_I and C_O are variables; and V_I and V_O are selected constants that vary with age and level of activity, and B is a constant that varies with age:

$$D_A= (V_{AI}C_I + V_{AO}C_O))/W_A,$$

where D_A = average daily dose, μg/(kg-d), for a given age interval;
V_{AI} = volume of indoor air inhaled per day, m^3/d;
V_{AO} = volume of outdoor air inhaled per day, m^3/d;
C_{AI} = average concentration of pollutant in indoor air, $\mu g/m^3$;
C_{AO} = average concentration of pollutant in outdoor air, $\mu g/m^3$; and
W_A = average body weight, kg, for given age interval.

Of the numerous options for the constants V_I, V_O, and B, several sets were chosen and presented as exposure scenarios. Inhalation rate varies with age and activity level (e.g., resting, light exercise, or moderate exercise). The number of hours spent indoors and outdoors varies with age and occupation/lifestyle. The tables below present the body weights and information used to derive the inhaled volumes of air.

Table V-1-19, continued

Table V-1-19a: Body Weight and Inhalation Rate for Three Age Intervals and Three Activity Levels

Age, years	Body Wt, kg	Inhalation Rate, m^3/d		
		Resting	Light exercise	Moderate exercise
0-2	10	0.125	-----	0.125
3-18	40	0.4	1	3.2
19-70	70	0.5	0.6	2.1

Table V-1-19b: Hours Per Day Spent Indoors and Outdoors by Age Interval

Age, years	Hours per day			
	Scenario 1		Scenario 2	
	Indoors	Outdoors	Indoors	Outdoors
0-2	23.5	0.5	23.5	0.5
3-18	20.4	3.6	20.4	3.6
19-70	22.5	1.5	17	7

Table V-1-19c: Volume of Inhaled Air by Age Interval (based on information in Tables V-1-19a and 19b)

Age, years	Volume of air inhaled, m^3/d					
	Scenario 1			Scenario 2		
	Indoors	Outdoors	Daily Total	Indoors	Outdoors	Daily Total
0-2	2.9375	0.0625	3.00	2.9375	0.0625	3.00
3-18	14.28	11.52	25.80	14.28	11.52	25.80
19-70	12.375	3.15	15.52	9.35	14.7	24.05

Sample Calculation

Sample Level 2 exposure calculation of lifetime average daily dose for tetrachloroethene:

Scenario 1 for Home 0030-81 (Table V-1-20)

	0 thru 2 yrs	3 thru 18 yrs	19 thru 70 yrs
V_I, m^3/d	2.9375	14.28	12.375
C_I, mg/m^3	3.5	3.5	3.5
V_O, m^3/d	0.0625	11.52	3.15
C_O, mg/m^3	1.8	1.8	1.8
W, kg	10	40	70

$$D = (2/70)[(2.9375)(3.5)+(0.0625)(1.8)]/10 + (16/70)[(14.28)(3.5)+(11.52)(1.8)]/40 + (52/70)[(12.375)(3.5)+(3.15)(1.8)]/70$$

$$= 0.02970 + 0.4041 + 0.5198$$

$D = 0.9536$ µg/kg-d

TABLE V-1-20: ESTIMATED EXCESS INDIVIDUAL LIFETIME CANCER RISKS AND HAZARD QUOTIENTS, BASED ON MEASURED AIR QUALITY JULY 1990 - MARCH 1991 for Home 0030-81, Ambient monitor 0030-83

POLLUTANT	Conc.($\mu g/m^3$)[1] in	Conc.($\mu g/m^3$)[1] out	Life.Avg.Expos.[2] (ug/kg- day) Scen.1	Life.Avg.Expos.[2] (ug/kg- day) Scen.2	Cancer Slope Factor ($\mu g/kg\text{-}d)^{-1}$	Est.Lifetime Cancer Risk[3] Scen. 1	Est.Lifetime Cancer Risk[3] Scen. 2	Ref. Conc.[4] (ug/m3)	Composite Air Concentration[5] (ug/m3) Scen. 1	Composite Air Concentration[5] (ug/m3) Scen. 2	Hazard Quotient[6] Scen. 1	Hazard Quotient[6] Scen. 2
chloromethane	1.5	1.4	0.47	0.59	6.30E-06	3.0E-06	3.7E-06	826	1.65	2.06	0.002	0.002
dichloromethane	3.1	7.9	1.47	2.34	1.60E-06	2.4E-06	3.7E-06	3000	5.15	8.20	0.002	0.003
hexane	2.7	3.0	0.89	1.17	-	-	-	200	3.12	4.10	0.016	0.020
tricholoromethane	1.7	1.0	0.47	0.54	8.10E-05	3.8E-05	4.3E-05	30.4	1.66	1.88	0.055	0.062
tetrachloromethane*	1.3	1.3	0.43	0.54	1.30E-04	5.5E-05*	7.0E-05*	2.10	1.49	1.89	0.71*	0.90*
benzene	4.2	4.5	1.38	1.79	2.90E-05	4.0E-05	5.2E-05	2.10	4.83	6.27	2.3	3.0
trichloroethene	5.5	1.1	1.33	1.28	1.70E-05	2.3E-05	2.2E-05	23.00	4.64	4.48	0.20	0.195
toluene	35.2	22.2	10.01	11.59	-	-	-	400	35.03	40.55	0.088	0.10
tetrachloroethene	3.5	1.8	0.95	1.06	1.80E-06	1.7E-06	1.9E-06	30.0	3.32	3.72	0.11	0.12
ethylbenzene	3.9	2.8	1.15	1.36	-	-	-	1000	4.01	4.77	0.004	0.005
m,p-xylene	12.6	10.6	3.85	4.75	-	-	-	300	13.48	16.62	-	-
o-xylene	5.4	5.0	1.69	2.14	-	-	-	700	5.92	7.47	-	-

[1] Indoor and outdoor concentrations

[2] Lifetime Average Exposure. See Table V-1-19 for sample calculation of lifetime average daily dose, and for meaning of "Scen.1" and "Scen.2" (scenarios 1 and 2).

[3] Estimated Excess Individual Lifetime Cancer Risk. Sample calculation for benzene, scenario 1:
Estimated Excess Individual Lifetime Cancer Risk = (Life.Avg.Expos.) x (Cancer Slope Factor)
= 1.38 $\mu g/kg\text{-}d$) x [2.9E-05/ ($\mu g/kg\text{-}d$)]
= 4.0 x 10-5

[4] Reference Concentration

[5] Sample calculation for benzene, scenario 1: Composite Air Concentration = (Life.Avg. Expos.)x (1/Volume inhaled daily) x (Weight of Individual).
= (1.38 $\mu g/kg\text{-}d$) x (1/20m3/d) x (70 kg)
= 4.83 $\mu g/m3$

[6] For this risk assessment, Hazard Quotient = Composite Air Concentration/Reference Concentration.

* Tetrachloromethane was never detected in the indoor air portion of the SI/NJ UATAP. 1.3 $\mu g/m^3$ is half the weighted average mdl. The detection limit was 5.4 $\mu g/m^3$ from 7/10/90 to 10/2/90, and 1.2 $\mu g/m^3$ from 10/14/90 to 3/19/91.

TABLE V-1-21: ESTIMATED EXCESS INDIVIDUAL LIFETIME CANCER RISKS AND HAZARD QUOTIENTS, BASED ON MEASURED AIR QUALITY JULY 1990 - MARCH 1991 for Home 0030-B2, Ambient monitor 0030-B3

POLLUTANT	Conc.($\mu g/m^3$)[1] in	Conc.($\mu g/m^3$)[1] out	Life.Avg.Expos.[2] (ug/kg- day) Scen.1	Life.Avg.Expos.[2] (ug/kg- day) Scen.2	Cancer Slope Factor ($\mu g/kg\text{-}d)^{-1}$	Est.Lifetime Cancer Risk[3] Scen. 1	Est.Lifetime Cancer Risk[3] Scen. 2	Ref. Conc.[4] (ug/m3)	Composite Air Concentration[5] (ug/m3) Scen. 1	Composite Air Concentration[5] (ug/m3) Scen. 2	Hazard Quotient[6] Scen. 1	Hazard Quotient[6] Scen. 2
chloromethane	1.6	1.4	0.48	0.60	6.30E-06	3.0E-06	3.8E-06	826	1.69	2.10	0.002	0.003
dichloromethane	3.6	7.9	1.58	2.43	1.60E-06	2.5E-06	3.9E-06	3000	5.52	8.51	0.002	0.003
hexane	5.7	3.0	1.56	1.74	-	-	-	200	5.45	6.09	0.027	0.030
trichloromethane	2.8	1.0	0.72	0.75	8.10E-05	5.9E-05	6.1E-05	30.4	2.53	2.62	0.083	0.086
tetrachloromethane	1.4*	1.3*	0.45	0.56	1.30E-04	5.8E-05*	7.3E-05*	2.10	1.56	1.96	0.748	0.93*
benzene	7.0	4.5	2.00	2.33	2.90E-05	5.8E-05	6.7E-05	2.10	7.02	8.14	3.3	3.9
trichloroethene	2.5	1.1	0.65	0.70	1.70E-05	1.1E-05	1.2E-05	23.0	2.29	2.46	0.099	0.11
toluene	45.0	22.2	12.19	13.44	-	-	-	400	42.65	47.05	0.11	0.12
tetrachloroethene	3.1	1.8	0.87	0.99	1.80E-06	1.6E-06	1.8E-06	30.0	3.03	3.47	0.10	0.12
ethylbenzene	5.8	2.8	1.57	1.72	-	-	-	1000	5.48	6.03	0.005	0.006
m,p-xylene	21.4	10.6	5.80	6.41	-	-	-	300	20.29	22.44	0.068	0.075
o-xylene	10.3	5.0	2.78	3.07	-	-	-	700	9.73	10.73	0.014	0.015

Footnotes: See Table V-1-20.

TABLE V-1-22: ESTIMATED EXCESS INDIVIDUAL LIFETIME CANCER RISKS AND HAZARD QUOTIENTS, BASED ON MEASURED AIR QUALITY JULY 1990 - MARCH 1991 for Home 7097-2A, Ambient monitor 7097-2C

POLLUTANT	Conc.(µg/m³)[1] in	Conc.(µg/m³)[1] out	Life.Avg.Expos.[2] (ug/kg- day) Scen.1	Life.Avg.Expos.[2] (ug/kg- day) Scen.2	Cancer Slope Factor (µg/kg-d)-[1]	Est.Lifetime Cancer Risk[3] Scen. 1	Est.Lifetime Cancer Risk[3] Scen. 2	Ref. Conc.[4] (ug/m3)	Composite Air Concentration[5] (ug/m3) Scen. 1	Composite Air Concentration[5] (ug/m3) Scen. 2	Hazard Quotient[6] Scen. 1	Hazard Quotient[6] Scen. 2
chloromethane	2.8	1.3	0.74	0.80	6.30E-06	4.7E-06	5.1E-06	826	2.59	2.81	0.003	0.003
dichloromethane	3.3	4.1	1.13	1.53	1.60E-06	1.8E-06	2.4E-06	3000	3.97	5.35	0.001	0.002
hexane	8.6	4.2	2.33	2.56	-	-	-	200	8.16	8.98	0.041	0.045
trichloromethane	1.7	1.1	0.49	0.56	8.10E-05	4.0E-05	4.6E-05	30.4	1.72	1.97	0.057	0.065
tetrachloromethane*	1.3*	1.4*	0.43	0.56	1.30E-04	5.6E-05*	7.2E-05*	2.10	1.51	1.94	0.72*	0.93*
benzene	9.8	5.6	2.73	3.10	2.90E-05	7.9E-05	9.0E-05	2.10	9.56	10.86	4.6	5.2
trichloroethene	1.0	1.7	0.39	0.57	1.70E-05	6.6E-06	9.6E-06	23.0	1.36	1.99	0.059	0.086
toluene	46.8	23.5	12.71	14.07	-	-	-	400	44.47	49.25	0.11	0.12
tetrachloroethene	2.1	2.6	0.73	0.98	1.80E-06	1.3E-06	1.8E-06	30	2.55	3.42	0.085	0.11
ethylbenzene	7.1	4.1	1.97	2.25	-	-	-	1000	6.91	7.87	0.007	0.008
m,p-xylene	28.1	13.9	7.61	8.41	-	-	-	300	26.65	29.42	0.089	0.098
o-xylene	10.4	6.8	2.98	3.48	-	-	-	700	10.42	12.18	0.015	0.017

Footnotes: See Table V-1-20.

TABLE V-1-23: ESTIMATED EXCESS INDIVIDUAL LIFETIME CANCER RISKS AND HAZARD QUOTIENTS, BASED ON MEASURED AIR QUALITY JULY 1990 - MARCH 1991 for Home 7097-2B, Ambient monitor 7097-2C

POLLUTANT	Conc.(µg/m³)[1] in	Conc.(µg/m³)[1] out	Life.Avg.Expos.[2] (ug/kg- day) Scen.1	Life.Avg.Expos.[2] (ug/kg- day) Scen.2	Cancer Slope Factor (µg/kg-d)-[1]	Est.Lifetime Cancer Risk[3] Scen. 1	Est.Lifetime Cancer Risk[3] Scen. 2	Ref. Conc.[4] (ug/m3)	Composite Air Concentration[5] (ug/m3) Scen. 1	Composite Air Concentration[5] (ug/m3) Scen. 2	Hazard Quotient[6] Scen. 1	Hazard Quotient[6] Scen. 2
chloromethane	3.1	1.3	0.82	0.87	6.30E-06	5.1E-06	5.5E-06	826	2.85	3.04	0.0035	0.0037
dichloromethane	12.4	4.1	3.16	3.26	1.60E-06	5.1E-06	5.2E-06	3000	11.06	11.41	0.0037	0.0038
hexane	7.3	4.2	2.03	2.31	-	-	-	200	7.10	8.07	0.036	0.040
trichloromethane	3.6	1.1	0.90	0.91	8.10E-05	7.3E-05	7.4E-05	30.4	3.15	3.20	0.10	0.11
tetrachloromethane*	1.3*	1.4*	0.42	0.55	1.30E-04	5.5E-05*	7.1E-05*	2.10	1.48	1.92	0.71*	0.91*
benzene	8.0	5.6	2.32	2.75	2.90E-05	6.7E-05	8.0E-05	2.10	8.13	9.64	3.9	4.6
trichloroethene	1.3	1.7	0.46	0.63	1.70E-05	7.8E-06	1.1E-05	23.0	1.60	2.19	0.069	0.095
toluene	38.8	23.5	10.94	12.56	-	-	-	400	38.29	43.97	0.096	0.011
tetrachloroethene	2.9	2.6	0.89	1.12	1.80E-06	1.6E-06	2.0E-06	30	3.12	3.90	0.10	0.13
ethylbenzene	4.5	4.1	1.40	1.76	-			1000	4.88	6.14	0.0049	0.0061
m,p-xylene	14.9	13.9	4.67	5.90	-	-		300	16.36	20.64	0.055	0.069
o-xylene	6.5	6.8	2.13	2.76	-	-		700	7.46	9.65	0.11	0.014

Footnotes: See Table V-1-20.

Table V-1-24: Summary of Risk (Cancer and Noncancer) from Median Annual Average Concentrations of Pollutants Addressed in the Level 1 Risk Assessment

Chemical	Median Cancer Risk (per million)[a]	Median Hazard Quotient[a]	Number of Sites[b]
Arsenic	20	-[c]	2
Benzene	40	2	12
Benzo[α]pyrene	0.38	-	4
Cadmium	5.1	0.1	4
Chromium	30[d], 3[e]	1.2[f], 0.12[g], 0.2[h]	2
Dichloromethane	1.2	0.0008	6
Ethylbenzene	-	0.03	3
Formaldehyde	0.26	0.1	2
Hexane, n-	-	0.2	6
Lead	-	0.03[i]	4
Manganese	-	0.04	4
Mercury	-	0.002	2
Nickel	6.0	1	4
Tetrachloroethene	1.0	0.05	12
Tetrachloromethane	12	0.4	12
Toluene	-	0.04	12
Trichloroethene	0.8	0.02	12
Trichloromethane	6.2	0.009	12
Vanadium	-	0.1	2
Xylene, o-	-	-	12
Xylenes, p- and m-	-	-	12
Zinc	-	0.003	4
TOTAL	123[d], 96[e]	5.3[f], 4.2[g], 4.3[h]	

Footnotes

a The background sites were excluded when determining the median annual average concentrations.

b Number of sites contributing annual average concentrations to the medians.

c Dash indicates that the Inhalation Unit Risk Factor or the Reference Concentration was not available so that the cancer risk or Hazard Quotient could not be calculated.

(Footnotes continued on next page.)

Table V-1-24, continued

[d] Assuming 10% chromium VI. The cancer risks associated with chromium exposure were calculated assuming that 10% or 1% of the total reported chromium concentration is in the hexavalent oxidation state (Cr VI). In the ambient environment, chromium is found in the Cr VI and Cr III forms. Only Cr VI has been shown to be carcinogenic; the cancer unit risk factor is based on exposure to Cr VI. See text for further detail.

[e] Assuming 1% Cr VI. See footnote d above.

[f] Using the former HEAST RfC and assuming that 10% of the total reported chromium concentration is Cr VI. See text for further detail.

[g] Using the former HEAST RfC and assuming that 1% of the total reported chromium concentration is Cr VI. See text for further detail.

[h] Using the NYSDOH RfC for total chromium. The NYSDOH RfC is based on different toxicological studies from those used to develop the former HEAST RfC. See text for further detail.

[i] In the absence of either an Inhalation Unit Risk Factor or a Reference Concentration, the current National Ambient Air Quality Standard (NAAQS) for lead was used in place of an RfC in the Hazard Quotient calculation. EPA, currently reevaluating the standard, plans to publish a notice in the Federal Register concerning a proposed new NAAQS for lead.

Table V-1-25: Noncancer Additive Risk Analysis by Target Organ

Effect Associated with Chemical Exposure	Hazard Quotient from Table V-1-24
Respiratory Tract (Irritation)	
Chromium	1.2[a], 0.12[b], 0.2[c]
Formaldehyde	0.1
Manganese*	0.04
Nickel	1.0
Vanadium	0.1
Zinc	0.003
TOTAL HI, Respiratory	2[a], 1[b], 1[c]
Liver Effects	
Ethylbenzene**	0.03
Trichloromethane	0.009
Tetrachloromethane	0.4
Trichloroethene	0.02
Tetrachloroethene	0.05
Xylenes (m-)	-[d]
TOTAL HI, Liver	0.5
Hematopoietic System	
Benzene	2.0
TOTAL HI, Hematopoietic	2
Kidney	
Cadmium	0.1
TOTAL HI, Kidney	0.1
Central Nervous System	
Lead	0.03
Mercury***	0.002
Dichloromethane	0.0008
Hexane n-	0.02
Toluene	0.04
Xylene, o-	-[d]
TOTAL HI, CNS	0.1

Footnotes

* Developmental toxicity and effects on the kidney are also associated with exposure to manganese.
** Effects on the central nervous system have been associated with exposure to ethylbenzene.
*** Effects on the kidney have been associated with exposure to mercury.
a Assumes the former HEAST RfC and 10% Cr VI in the total reported chromium concentration.
b Assumes the former HEAST RfC and 1% Cr VI in the total reported chromium concentration.
c Assumes the NYSDOH RfC for total chromium.
d The RfC in the 1991 HEAST does not appear in 1992 update; no RfC is available currently.

2. STATISTICAL ANALYSES

2.1 INTRODUCTION

The Staten Island/New Jersey Urban Air Toxics Assessment Project included ambient air monitoring for a set of target organic compounds at 13 sites in the area. The compounds examined in this report include: benzene (BENZ), toluene (TOLU), o-xylene (OXYL), hexane (HEXA), 1,1,1-trichloroethane (T11E), carbon tetrachloride (CARB), trichloroethene (TRIC), tetrachloroethene (TECH), styrene (S), and m,p-xylene (MPXY). The physical monitoring covered a two-year period beginning in October 1987 and was conducted by three independent organizations: the College of Staten Island (CSI), the New Jersey Institute of Technology (NJIT) and the New York State Department of Environmental Conservation (NYSDEC). Each organization had complete responsibility for its sampling sites and employed different sampling and analytical methodologies.

The purpose of this section is to present the results of a statistical analysis of the project's volatile organic compound (VOC) ambient monitoring data, to assess the site-to-site differences for each compound, and to determine the concentration levels that should be included in the risk assessment for the project. This statistical assessment was performed by Research Triangle Institute, under contract to EPA. It followed similar work performed by the University of Medicine and Dentistry of New Jersey (UMDNJ), and utilized the data files prepared by UMDNJ.

Sections 2 and 3 focus on the assessment of site-to-site differences using "adjusted" data derived from collocated measuring instruments which were made by PEI using a canister technique. Section 4 examines the potential transformation of the CSI data set by utilizing the logarithm of the concentrations to assess differences among the sites it operated. Unadjusted data are used since all measurements were made by a single organization.

2.2 ADJUSTING FOR METHOD BIAS

The initial step in assessing organization bias was to plot the data from collocated instruments by compound and organization. For sites operated by NYSDEC, the data were plotted by year to correspond to the two methods employed--sorbent and ATD. After examining the plots, some data points were deleted as outliers. These are listed in Table V-2-1. In

addition, an assessment of bias was considered inappropriate for TECH in NJIT sites because of the small number of collocated samples and for HEXA in CSI sites in year 1 because of apparent problems with the PEI canister.

After excluding the data points identified above, three models were fitted to the collocated data. This was done by compound for CSI and NJIT and by compound and method for NYSDEC. The models were

$$\text{Model A:} \quad E(\sqrt{PEI}) = (\alpha + \beta X_r)^{1/2}$$

$$\text{Model B:} \quad E(\ln(PEI)) = \ln(\alpha + \beta X_r)$$

$$\text{Model C:} \quad E(PEI) = \alpha + \beta X_r$$

where

$E(\sqrt{PEI})$ = expected value of the square root of the PEI measurement corresponding to a given value of X_r,

$E(\ln(PEI))$ = expected value of the logarithm of the PEI measurement corresponding to a given value of X_r,

Table V-2-1

VALUES DELETED IN ASSESSING BIAS

Compound	Organization	Year	Values*
MPXY	NYSDEC	2	(6.6, 0.9), (0.9, 2.9)
	CSI	1	(5.8, 0.9)
OXYL	CSI	1	(1.0, 0.1)
	NYSDEC	2	(8.6, 0.8)
T11E	NYSDEC	2	(0.3, 2.3)
	CSI	2	(2.7, 0.2)
TECH	NYSDEC	2	(6.7, 0.3)
TOLU	CSI	1	(6.4, 1.6)
	CSI	2	(13.4, 3.6)
BENZ	NYSDEC	2	(0.3, 2.6)

* The first value within the parenthesis is the PEI measurement.

E(PEI) = expected value of the PEI measurement corresponding to a given value of X_r,

X_r = reported measurement, and

α, β = parameters to be estimated.

Note that the parameters α and β have the same interpretation for all three models: $\alpha = 0$ implies an additive bias (of one method relative to PEI) and $\beta = 1$ implies a multiplicative bias relative to PEI. The models differ in the error structure--in Model A the error is additive on the square root scale, in Model B the error is additive on the logarithmic scale and in Model C the error is additive on the original measurement scale. In each case the variances of the errors are assumed stable on their respective scales.

Estimates of α and β (i.e., a and b, respectively) for the three models are given in Table 2 by compound, organization and method. In all cases, the intercept, a, is positive and in most cases it is statistically different from zero. In general, the slope parameter estimate, b, is statistically less than one (some exceptions are NYSDEC measurements of OXYL, T11E and TECH). For a given compound/organization/method combination, the relationship between PEI measurements and an organization's reported measurements is basically the same for all three models. For instance, the first line of Table V-2-2 shows the following relationships between PEI and CSI in the measurement of BENZ

Model A: $\widehat{PEI} = 0.61 + 0.51\ (CSI)$

Model B: $\widehat{PEI} = 0.57 + 0.52\ (CSI)$

Model C: $\widehat{PEI} = 0.64 + 0.51\ (CSI)$

Le V-2-2

ITER ESTIMATES FOR MODELS A, B, C
D TO COLLOCATED DATA

Compound	Org.	Meth	Model A a Intercept	Model A b Slope	Model B a Intercept	Model B b Slope	Model C a Intercept	Model C b Slope
BENZ	CSI		(.08)*	.51(.07)	.57(.08)	.52(.08)	.64(.09)	.51(.06)
	NYSDEC	A	(.04)	.76(.04)	.29(.04)	.72(.05)	.25(.05)	.80(.04)
	NYSDEC	S	(.10)	.39(.10)	.47(.09)	.39(.11)	.52(.10)	.40(.10)
	NJIT		5(.09)	.50(.08)	.39(.08)	.54(.10)	.54(.10)	.46(.06)
HEXA	CSI		6(.07)	.54(.09)	.37(.06)	.51(.09)	.36(.09)	.56(.09)
	NJIT		1(.09)	.51(.10)	.33(.07)	.59(.12)	.52(.11)	.42(.10)
MPXY	CSI		3(.08)	.49(.05)	.43(.08)	.47(.06)	.44(.09)	.50(.05)
	NYSDEC		1(.08)	.81(.06)	.14(.06)	.82(.07)	.36(.10)	.74(.06)
	NYSDEC		7(.14)	.81(.13)	.23(.13)	.82(.14)	.35(.17)	.79(.13)
	NJIT		53(.12)	.58(.13)	.41(.08)	.72(.15)	.70(.15)	.46(.13)
OXYL	CSI		21(.04)	.97(.11)	.21(.04)	.92(.12)	.21(.04)	.98(.09)
	NYSDEC		.17(.08)	1.06(.18)	.14(.05)	1.02(.14)	.33(.12)	.89(.21)
	NYSDEC		.25(.10)	.92(.26)	.23(.08)	.89(.25)	.29(.11)	.90(.27)
	NJIT		.25(.06)	.51(.15)	.22(.05)	.53(.16)	.29(.07)	.46(.15)
T11E	CSI		.31(.06)	.87(.15)	.33(.06)	.75(.16)	.27(.08)	1.01(.14)
	NYSDEC		.22(.04)	.95(.09)	.22(.04)	.89(.10)	.24(.05)	.96(.08)
	NJIT		.33(.07)	.66(.14)	.30(.07)	.69(.17)	.37(.08)	.64(.12)
TECH	CSI		.12(.06)	.73(.09)	.17(.06)	.61(.13)	.09(.06)	.80(.05)
	NYSDEC		.08(.05)	1.29(.13)	.10(.03)	1.17(.13)	.16(.11)	1.21(.12)
TOLU	CSI		.57(.18)	.66(.05)	.54(.14)	.66(.06)	.62(.23)	.66(.06)
	NYSDEC		.40(.13)	.70(.04)	.40(.10)	.68(.04)	.34(.18)	.74(.04)
	NYSDEC		.39(.23)	.77(.10)	.44(.20)	.70(.11)	.39(.28)	.80(.10)
	NJIT		1.16(.27)	.49(.09)	.82(.20)	.60(.10)	1.50(.33)	.42(.08)

* Standard error of estiven in parenthesis.

Other examples can be formed by the estimates given on <u>any</u> line in Table V-2-2.

The choice of which model to use to make adjustments to data reported by an organization was based, in part, on correlations between the observed and predicted values of PEI measurements. For a given compound/organization/method combination, these correlations correspond to

Model A: $\text{corr}(\sqrt{PEI}, (a + bX_r)^{1/2})$

Model B: $\text{corr}(\ln(PEI), \ln(a + bX_r))$

Model C: $\text{corr}(PEI, a + bX_r)$

The sets of correlations calculated for the three models are shown in Table V-2-3. Ideally, the model with the highest correlations is the best selection; however, there was not a particular model that exhibited this characteristic across all compounds and organizations. We selected Model B for two reasons. First, in cases in which all three correlations were relatively low, this model tended to have the highest correlations (e.g., OXYL measurements by NYSDEC's ATD method). Second, and more importantly, it was felt that standard deviations of measurement errors are likely to increase proportionately with concentration level. Having selected Model B, adjustments were then made for all reported measurements of compounds for which the organization's correlation shown in Table V-2-3 was ≥ 0.60*. Adjustments based on correlations below 0.60 were not considered reliable. For a given compound/organization/method combination, an adjusted measurement, adjusted X_r, was calculated for each reported measurement, X_r, using the following relationship:

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* Adjustments based on correlations below 0.60 would account for less than 36% of the variation in the data. While this is an arbitrary cut-off, it is logical approach for dealing with a difficult situation.

Table V-2-3

CORRELATION BETWEEN THE OBSERVED AND PREDICTED VALUES OF PEI BY MODEL, COMPOUND AND ORGANIZATION

Compound	Organization	Method	Model A	Model B	Model C
BENZ	CSI	-	0.72	0.70	0.74
	NYSDEC	ATD	0.87	0.84	0.88
	NYSDEC	SOR	0.52	0.51	0.54
	NJIT	-	0.78	0.77	0.78
HEXA	CSI	-	0.80	0.79	0.80
	NJIT	-	0.73	0.78	0.66
MPXY	CSI	-	0.81	0.77	0.82
	NYSDEC	ATD	0.78	0.78	0.76
	NYSDEC	SOR	0.71	0.71	0.68
	NJIT	-	0.61	0.69	0.53
OXYL	CSI	-	0.82	0.77	0.85
	NYSDEC	ATD	0.52	0.62	0.38
	NYSDEC	SOR	0.50	0.51	0.47
	NJIT	-	0.52	0.55	0.48
T11E	CSI	-	0.71	0.67	0.75
	NYSDEC	ATD	0.74	0.70	0.75
	NJIT	-	0.67	0.64	0.68
TECH	CSI	-	0.90	0.82	0.95
	NYSDEC	ATD	0.88	0.89	0.82
TOLU	CSI	-	0.84	0.85	0.83
	NYSDEC	ATD	0.85	0.84	0.85
	NYSDEC	SOR	0.75	0.71	0.76
	NJIT	-	0.72	0.76	0.68

$$\text{adjusted } X_r = a + bX_r$$

where a and b are the values shown in Table V-2-2 for Model B. Table V-2-4 shows the number of observations contained in the adjusted database.

2.3 ANALYSIS OF VARIANCE RESULTS USING ADJUSTED DATA

Differences among sites operated by all three organizations were assessed through the use of the two-way analysis of variance (ANOVA) procedure applied to logarithms of adjusted measurements. For a given compound, this procedure requires adjusted measurement data from s sites on each of d days. The sites are coded as follows:

Susan Wagner	1	Pumping Station	7
Travis (PS-26)	2	Bayley Seton Hospital	8
Eltingville	3	Tottenville	9
Great Kills	4	Elizabeth	A
Port Richmond	5	Carteret	B
Dongan Hills	6	Sewaren	C
		Piscataway	D

The sites included in a particular analysis of a compound are shown in Table V-2-5. These sites were determined after examining the availability of adjusted data (as reflected in Table V-2-4) and the data collection periods for the various sites. For example, Sites 2, 4, 7, C and D began operations in January 1989 and Sites 3, 6 and 8 ceased operations in April 1989. Because of this short overlapping time period, the number of days common to all 13 study sites with usable data is very small. Therefore, Sites 2, 4, 7, C and D were never included with Sites 3, 6 and 8 in any of the ANOVAs (see Table V-2-5). For some compounds (e.g., BENZ), multiple ANOVAs were made by dropping selected sites in order to increase the number of days with usable data.

The ANOVA results (specifically the Student-Newman-Keuls (SNK) test results) are given in Appendix A and are summarized in Table V-2-6.

2.4 INTERPRETATION OF ANOVA RESULTS

The ANOVA results presented in Table V-2-6 and in Appendix A depict the relative differences in the mean concentrations measured at the various sites for each contaminant. For each SNK Analysis, the sites are arranged in descending order of mean concentration, with each underlined group of sites having mean concentrations

measured at the various sites for each contaminant. For each SNK Analysis, the sites are arranged in descending order of mean concentration, with each underlined group of sites having mean concentrations statistically indistinguishable from each other (at the 0.05 level). Thus, for Analysis 7 toluene (TOLU), for example, the first seven sites are not statistically different from each other, but site 1 is different from all of the rest. In this case, the concentration reported for the seven indistinguishable sites would be the average of seven means.

More than one SNK Analysis was performed for every parameter except o-xylene (OXYL). This was done as an effort to include as many sites as possible. As can be seen for benzene (BENZ), the largest possible data set, with 69 sets of simultaneous samples, only included four sites. In order to add a fifth site to the analysis, only 32 samples sets were available, while only 15 sets could be used to analyze all eight sites. There are obvious advantages and disadvantages to each approach.

It is also clear for Table V-2-6 that Analysis 7 is the exception rather than the rule, presenting a single, obvious partitioning of the data into mutually exclusive groupings. Analysis 9 for m-, p-xylene (MPXY) is more typical, with three overlapping groupings.

When several analyses for the same compound are made the results should be used as follows: The comparison using the largest number of sites should be used as a first cut, in order to determine the breakdown of differences. The second comparison, with the greater sample size and fewer sites, should be used to make further comparisons, but only among those groups which were compared. For example, analysis 1 indicates that site 6 was significantly different from sites 5 and 9 and site 1. However, site 6 was indistinguishable from sites B, 8, and 3. Using analysis 2 shows that site 6 was indeed different from sites B, 8 and 3, but was indistinguishable from site A. Analysis 3 shows that site B is different from sites 3 and 8.

Table V-2-4

NUMBER OF OBSERVATIONS IN ADJUSTED DATABASE

Organization	Site	Method	Compound						
			BENZ	HEXA	MPXY	OXYL	T11E	TECH	TOLU
NJIT	A	-	76	74	74		76		76
	B	-	110	110	108		108		109
	C	-	36	36	36		37		36
	D	-	42	42	42		42		42
CSI	3	-	441	445		434	439	432	440
	6	-	443	447		438	434	432	443
	8	-	501	504		488	485	484	496
NYSDEC	1	SOR			49				50
	1	ATD	50		49	49	50	49	49
	2	SOR							
	2	ATD	41		41	41	41	41	41
	4	SOR							
	4	ATD	39		39	39	39	39	39
	5	SOR			41				42
	5	ATD	53		53	53	53	53	53
	7	SOR							
	7	ATD	41		41	41	41	41	41
	9	SOR			39				40
	9	ATD	54		53	53	54	53	53

Table V-2-5

SUBGROUPS OF ADJUSTED DATA ANALYZED
BY ANALYSIS OF VARIANCE

Analysis	Compound	Sites	Organizations
1	BENZ	3, 6, 8, A, B, 1, 5, 9	CSI, NJIT, NYSDEC
2	BENZ	3, 6, 8, A, B	CSI, NJIT
3	BENZ	3, 6, 8, B	CSI, NJIT
4	T11E	3, 6, 8, A, B, 1, 5, 9	CSI, NJIT, NYSDEC
5	T11E	3, 6, 8, A, B	CSI, NJIT
6	T11E	3, 6, 8, B	CSI, NJIT
7	TOLU	3, 6, 8, A, B, 1, 5, 9	CSI, NJIT, NYSDEC
8	TOLU	3, 6, 8, B, 1, 5, 9	CSI, NJIT, NYSDEC
9	MPXY	A, B, C, D, 1, 5, 9, 2, 4, 7	NJIT, NYSDEC
10	MPXY	B, 1, 5, 9	NJIT, NYSDEC
11	OXYL	3, 6, 8, 1, 5, 9	CSI, NYSDEC
12	HEXA	3, 6, 8, A, B	CSI, NJIT
13	HEXA	3, 6, 8, B	CSI, NJIT
14	TECH	3, 6, 8, 1, 5, 9	CSI, NYSDEC

Table V-2-6

SUMMARY OF STUDENT-NEWMAN-KEULS TEST RESULTS
FOR FOURTEEN ANALYSES INVOLVING SELECTED SITES
FROM TWO OR MORE ORGANIZATIONS

Analysis No.	Compound	Sample Size	Site*
1	BENZ	15	6 A B 3 8 5 9 1
2	BENZ	32	6 A B 8 3
3	BENZ	69	6 3 8 B
4	T11E	13	A 8 B 3 5 6 9 1
5	T11E	31	A 8 B 3 6
6	T11E	63	8 B 3 6
7	TOLU	21	A B 6 5 3 8 9 1
8	TOLU	46	3 6 5 8 B 9 1

Table V-2-6 Cont'd

Analysis No.	Compound	Sample Size	Site*
9	MPXY	24	5 B 7 C A 9 D 4 2 1
10	MPXY	73	B 5 9 1
11	OXYL	17	6 5 3 8 9 1
12	HEXA	33	A B 3 6 8
13	HEXA	70	B 3 6 8
14	TECH	17	6 8 5 3 9 1

* Sites are arranged from left to right in descending order based on mean concentration (site means on the log scale are given in Appendix A). Sites underlined are not significantly different at the 0.05 level.

2.5 ANALYZING DAILY CONCENTRATIONS AT SITES 3, 6 AND 8

2.5.1 Choice of Time Unit

Let X_{ij} denote the concentration of a given compound at site i (i=1,2,...,I) on day j (j=1,2,...,J). Let $Y_{ij} = \ln(X_{ij})$. The underlying model structure for the analysis, using a day as the time unit of analysis, is:

$$Y_{ij} = \mu + \gamma_i + \delta_j + (\gamma\delta)_{ij} + \epsilon_{ij},$$

where

μ = overall long-term mean over all I sites,

γ_i = deviation due to effect of i^{th} site,

δ_j = deviation due to effect of j^{th} day,

$(\gamma\delta)_{ij}$ = deviation for site i and day j (interaction effect), and

ϵ_{ij} = random deviation for observation at site i on day j (due to uncontrollable errors associated with all aspects of measurement and analysis).

The goal of the analysis is to determine if sites differ in terms of compound concentrations (more specifically, in terms of average ln(concentrations)). This objective can expressed as testing the null hypothesis $j(\gamma) = 0$, where

$$\theta(\gamma) = \sum_i^2 \gamma / (I-1). \qquad \text{(summation over i)}$$

Also define

$$\theta(\gamma\delta) = \sum_{ij}^2 (\gamma\delta) / (I-1)(J-1). \qquad \text{(summation over i and j)}$$

We consider two scenarios. For both, the set of sites is assumed to be fixed--i.e., we do not regard the sites to be representative of some larger population of sites. This assumption is dictated by the analysis objective, since the hypothesis test of site differences would not be of interest otherwise. For scenario 1, we consider the days to be a random component (e.g., a random sample from a large population of days). Under scenario 2, we consider them to be a fixed component. The analysis of variance for the two cases is carried

out in the same manner, and results in three sums of squares and associated mean squares, as shown below:

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
Days	J-1	SSD	MSD=SSD/(J-1)
Sites	I-1	SSS	MSS=SSS/(I-1)
Error	(J-1)(I-1)	SSE	MSE=SSE/(J-1)(I-1)
Total	IJ-1		

Expected values of the pertinent mean squares under the two scenarios are different, however, and are as follows:

	Expected Value of Mean Squares for:	
Source	Scenario 1 (days random)	Scenario 2 (days fixed)
Sites	$V_\epsilon + V_{\gamma\delta} + J\theta(\gamma)$	$V\epsilon + J\theta(\gamma)$
Error	$V_\epsilon + V_{\gamma\delta}$	$V\epsilon + \theta\gamma\delta)$

In the above, the V_ϵ and $V_{\gamma\delta}$ represent the error and interaction variance components, respectively.

The test for site differences is formed by computing F = MSS/MSE; as can be seen by the above table, this will be a valid test under scenario 1 since the numerator and denominator mean squares have the same expectation when the null hypothesis is true. If days are considered fixed, however, the test will be valid only if there are no site-by-day interaction effects (i.e., $j(\gamma d) = 0$). If such interactions are present but are ignored in the analysis, then the denominator mean square will be an overestimate of the V_ϵ and hence real differences will be less likely to be detected than they should be.

In contrast with the other two organizations, the three CSI sites furnished concentration data essentially on a daily basis. While some argument can be made that the days for the other organizations are representative of some larger set of days, the use of all days for the CSI sites implies that days should be considered a fixed component. Thus it is important to consider whether it is reasonable to assume that there are no interaction effects, and if not, whether there is another time unit (e.g., a week) where the assumption of no site-by-time interaction might be more tenable. The model indicates, in the absence of measurement errors and interaction effects, that one site's set of LN(concentrations) differs from those of another site by a

constant--i.e., that one site has daily concentrations that consistently differ from those of another by a constant percentage. Assuming that measurement errors of different days' samples are independent, then, in the absence of interactions, the differences in LN(concentrations) for two sites should not exhibit autocorrelations. Conversely, if autocorrelations in such differences do exist, then interactions are indicated. (It should be pointed out that lack of autocorrelations does not preclude the existence of interactions, since the interaction effects may not occur in a systematic temporal fashion.)

Autocorrelations of the differences in daily LN(concentrations) for each pair of CSI sites are shown in Table V-2-7. The correlations are given for lags 1 through 9, where the lag-k correlation is defined as the correlation between D_j and D_{j+k}, where D_j denotes the difference in LN(concentrations) for a given pair of sites on day j. Since sample sizes are large for these series, even relatively small correlations are statistically significant. Correlations significant at the 0.01 level (generally any correlation above about 0.13) are shown in boldface type in Table V-2-7.

With the exception of carbon tetrachloride, all compounds showed significant lag-1 correlations for at least one pair of sites. The presence of a weekly cycle was also indicated for a number of cases as evidenced by the significant correlations at lags 6, 7, and 8. Toluene exhibited persistently high lag correlations for differences involving site 8; this indicates that these series of differences are nonstationary. A similar pattern occurred for 1,1,1-trichloroethane for site 3 vs. site 8.

The results suggest that there are some compounds for which the assumed lack of interaction is not a reasonable assumption. Weekly concentrations were thus computed by averaging concentrations over days; at least 5 days within a week were required to form the weekly value. Autocorrelations among the weekly data (log scale) were then calculated. These are given in Table V-2-8. Many of the weekly correlations are larger than those for the daily data, though because of smaller sample sizes substantially fewer are statistically significant at the 0.01 level. Very few large autocorrelations were found after four lags. The first four lag correlations for the site 6 vs. 8 difference were found significant for benzene, hexane, o-xylene, and toluene.

Table V-2-7

AUTOCORRELATIONS OF SITE DIFFERENCES IN LN(DAILY CONCENTRATIONS)

Compound	Sites	Autocorrelations x 100, for Lag: 1	2	3	4	5	6	7	8	9
1,1,1-trichloroethane	3,6	03	06	-05	03	07	-03	09	09	03
	3,8	**19**	**21**	**24**	11	**20**	11	**14**	**15**	**18**
	6,8	09	-11	-02	-04	08	09	05	10	10
Benzene	3,6	**23**	**16**	10	02	-02	03	-09	-05	02
	3,8	**22**	**27**	10	10	13	**14**	**14**	10	04
	6,8	**21**	14	13	13	**14**	**20**	**14**	**16**	02
Carbon Tetrachloride	3,6	-03	10	-09	-04	-01	12	07	07	08
	3,8	09	08	11	06	10	**16**	**20**	10	03
	6,8	10	-07	03	11	09	02	08	06	13
Hexane	3,6	**15**	03	04	04	-05	-03	-06	02	00
	3,8	**15**	13	09	09	06	08	03	**16**	12
	6,8	**20**	09	13	**16**	11	**16**	**15**	11	06
o-Xylene	3,6	**19**	10	**17**	08	00	09	01	03	13
	3,8	**19**	**14**	**17**	10	08	**22**	11	05	**19**
	6,8	**32**	**16**	05	**16**	14	**28**	**27**	**14**	10
Styrene	3,6	**17**	00	10	04	10	**18**	04	06	-05
	3,8	**21**	11	10	08	09	05	02	09	11
	6,8	**25**	15	08	13	07	05	**22**	10	06
Toluene	3,6	**22**	11	12	10	03	09	03	09	06
	3,8	**28**	**20**	**20**	**20**	**23**	**23**	**19**	**23**	**17**
	6,8	**32**	**23**	**15**	**19**	**23**	**29**	**30**	**21**	**20**
Tetrachloroethene	3,6	**23**	10	11	02	05	10	00	05	08
	3,8	**14**	02	02	08	08	08	**20**	00	01
	6,8	**19**	04	11	04	11	**15**	02	-01	04
Trichloroethene	3,6	15	12	**15**	03	-06	07	-06	07	-02
	3,8	**20**	11	**14**	10	06	09	**14**	04	02
	6,8	09	09	02	07	-09	02	-01	-02	-07

Autocorrelations shown in bold are statistically significant (0.01 level).

Table V-2-8

AUTOCORRELATIONS OF SITE DIFFERENCES IN LN(WEEKLY CONCENTRATIONS)

Compound	Sites	Autocorrelations x 100, for Lag: 1	2	3	4	5	6	7	8	9
1,1,1-trichloroethane	3,6	23	14	09	-01	-08	-03	03	17	14
	3,8	24	36	17	40	**43**	40	34	22	43
	6,8	-12	11	-01	09	10	04	-15	21	14
Benzene	3,6	08	24	15	34	-21	08	24	-04	-10
	3,8	35	**43**	**47**	**38**	05	21	**42**	10	-02
	6,8	**47**	**44**	**52**	**40**	-06	27	22	-12	16
Carbon Tetrachloride	3,6	22	26	-12	14	21	17	13	-20	-22
	3,8	25	29	-07	04	33	30	24	-23	-05
	6,8	**44**	35	**41**	31	22	26	33	-14	05
Hexane	3,6	06	-02	-04	31	-04	08	05	-01	-07
	3,8	14	29	18	26	03	10	07	-05	-31
	6,8	**58**	**48**	**43**	**50**	34	**45**	33	24	21
o-Xylene	3,6	28	16	11	24	-03	17	15	04	12
	3,8	**39**	30	10	28	18	12	10	26	03
	6,8	**45**	**53**	**42**	**49**	23	28	10	09	22
Styrene	3,6	06	-08	03	23	04	06	30	01	-04
	3,8	19	-19	-40	-11	16	06	04	03	16
	6,8	21	27	22	37	17	07	30	24	32
Toluene	3,6	20	26	16	15	-05	-05	26	01	13
	3,8	36	**51**	32	**44**	32	32	**40**	22	22
	6,8	**56**	**63**	**54**	**61**	38	**45**	29	28	23
Tetrachloroethene	3,6	06	32	28	04	41	-14	28	-04	27
	3,8	30	28	17	00	17	-05	18	23	24
	6,8	12	04	12	03	05	-18	15	-13	17
Trichloroethene	3,6	34	35	16	12	24	-11	07	20	03
	3,8	**49**	**49**	**38**	21	20	08	03	12	34
	6,8	09	**39**	23	18	15	-02	35	-13	00

Autocorrelations shown in bold are statistically significant (0.01 level).

These results, together with those for the daily data, suggest that a still longer averaging time (e.g., 4-wk average) might be appropriate for some compounds and sites. Nonstationarity for two of the toluene series was again indicated. This is illustrated in Figure V-2-1, which gives a plot of the weekly toluene
data for the site 6 minus site 8 differences. Similar, though less pronounced, patterns were evident for several of the other compounds. One implication of such nonstationarity is that general conclusions regarding site differences are not possible, since the differences depend on the particular time frame that is examined (e.g., one site's levels may be higher in one season and lower in another relative to another site). Also, if long-term site means (or differences between them) are to be reported, then the preferred time frame consists of whole years (i.e., 52 or 104 weeks rather than 75 weeks, say).

2.5.2 Comparisons of Sites 3 and 6

The daily results for sites 3 and 6 (Table V-2-7) generally showed significant autocorrelations only for the first few lags. The weekly results for these same sites (Table V-2-8) showed no significant lag correlations at the 0.01 level of significance. For this pair of sites, the use of a weekly unit of analysis would thus appear to be preferable to the daily unit. Consequently, for these two sites, paired t-tests were calculated using the weekly unit. In the case of only two sites, this procedure is equivalent to the two-way ANOVA and negates the need for using the SNK procedure for comparing specific sites. The results are summarized in Table V-2-9. Benzene, o-xylene, styrene, toluene, and tetrachloroethene exhibited significantly higher levels at site 6 than at site 3, while carbon tetrachloride levels were significantly smaller for site 6 relative to site 3.

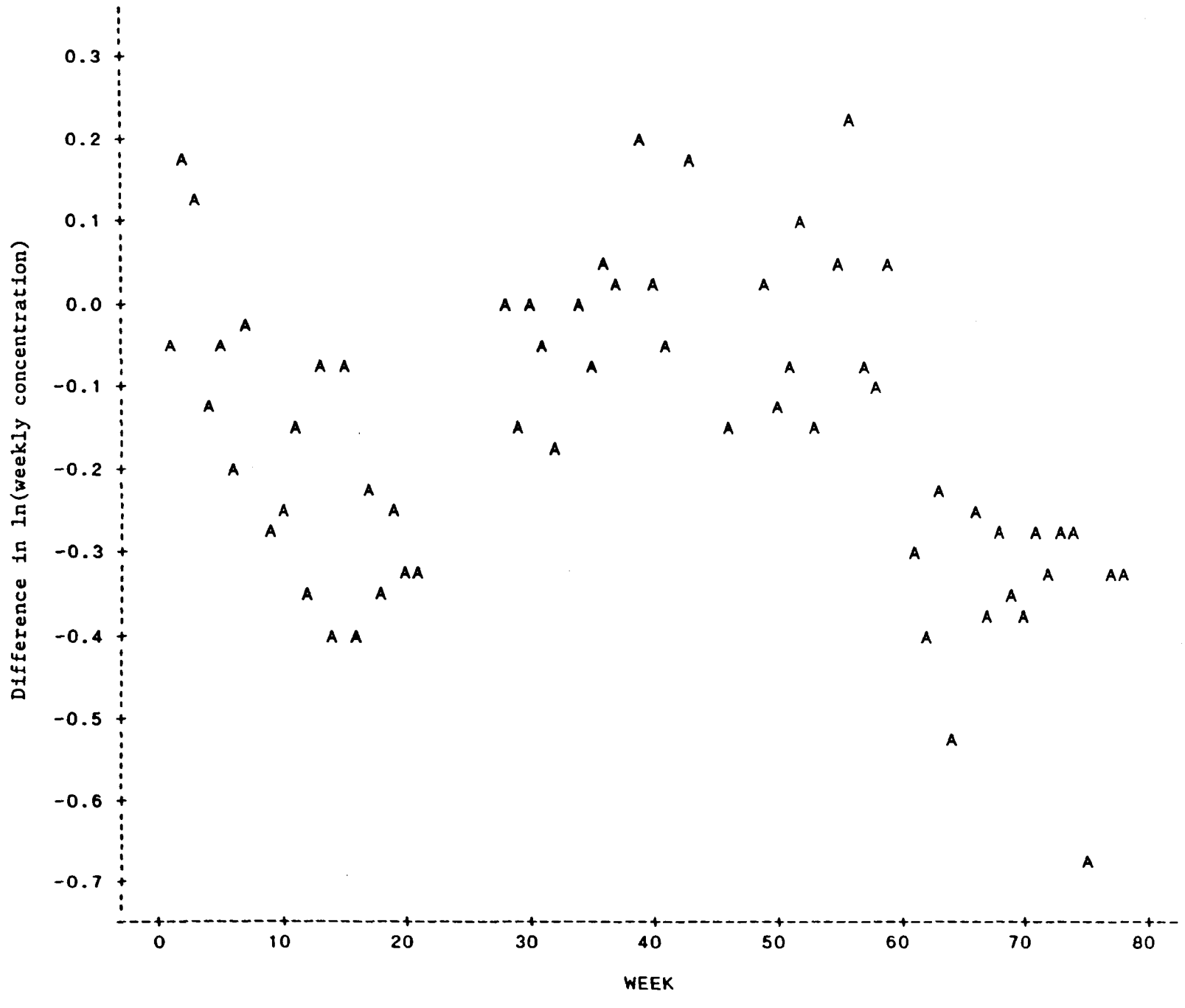
PLOT OF WEEKLY DIFFERENCES (SITE6-SITE8) AS A FUNCTION OF TIME - TOLUENE
Difference in ln(weekly concentration)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
0
10
20
30
40
50
60
70
80
WEEK

Figure V-2-1

Table V-2-9

TEST OF DIFFERENCES IN AVERAGE
LN(WEEKLY CONCENTRATIONS) FOR TWO CSI SITES

Compound	No. of Weeks	Difference (Site 6-Site 3)
1,1,1-trichloroethane	56	-0.0528
Benzene	54	0.1984**
Carbon Tetrachloride	56	-0.1567**
Hexane	57	-0.0614
o-Xylene	56	0.2152**
Styrene	44	0.2031**
Toluene	56	0.1070**
Tetrachloroethene	55	0.9044**
Trichloroethene	57	-0.0001

** Differences are statistically significant (0.01 level).

2.6 CONCLUSIONS

The statistical analysis presented here is necessarily quite complex. It is an attempt to determine, after the fact, whether site-to-site differences in VOC concentrations measured by different organizations are statistically significant; the design of the original study was not entirely suitable for that analysis. The PEI reference samples which are used as the basis for the site-to-site comparisons, were intended to be used for a different purpose. They were to be used as a quality assurance check on the assumption that the two-tube Tenax sampling scheme would prove satisfactory and that the various organizations could produce valid data. The reference samples did satisfy this purpose and show that the two-tube adsorbent methods would be effective and that the individual organizations could and did produce valid data. However, neither the PEI reference samples nor the specific collocated sampling events (so-called shootouts) provided enough data to confirm, in every case, whether the concentrations of VOCs produced by the different organizations are directly comparable. This was because of the great variability between organizations discovered during the shootouts. It was not feasible to perform additional shootouts, making it necessary to use the PEI data for this purpose as well.

The results of the analysis do indicate that, for certain VOCs, the differences between certain sites were significant during the times that the reference samples from PEI were available. However, since those data sets were limited when compared to the overall data set, all possible comparisons between sites could not be performed.

When the analysis showed no statistically significant differences, the results should be considered the same. Any risk assessments or other uses for the data should use the actual measured annual means but should consider the effects from those VOCs to be indistinguishable across those monitoring sites.

When the analysis shows a significant difference between sites for the limited data set for which the reference samples are available, the overall results may be considered different. Any risk assessment or other data use may utilize the actual annual mean concentrations.

An additional benefit of this statistical analysis is the confirmation that annual averaging is the most appropriate means for utilizing the VOC monitoring data from this project. As shown in the analysis of the daily PEI results, the autocorrelations between consecutive samples could strongly affect any short-term averaging of the data. Thus, the presence of more frequent data, while serving to improve the precision of the calculated means does not necessarily enhance the ability to

look at shorter averaging times. The conclusion, then, is that the use of annual averages for all of the VOC results, for all organizations, is appropriate.

ANOVA Results

SAS

---------- COMP=BENZ ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 98 MSE= 0.038236

Number of Means	2	3	4	5
Critical Range	0.1416934	0.1699247	0.1866214	0.1984399

Number of Means	6	7	8
Critical Range	0.207552	0.2149506	0.2211598

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	0.3416	15	6
A			
A	0.2568	15	A
A			
A	0.2328	15	B
A			
A	0.2138	15	3
A			
A	0.1777	15	8
B	0.0054	15	5
B			
B	-0.0077	15	9
C	-0.3412	15	1

SAS

---------- COMP=BENZ ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 124 MSE= 0.032802

Number of Means	2	3	4	5
Critical Range	0.0896179	0.1074091	0.117917	0.1253449

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	0.2981	32	6
A			
B A	0.2172	32	A
B			
B	0.1698	32	B
B			
B	0.1552	32	8
B			
B	0.1366	32	3

SAS

---------- COMP=BENZ ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 204 MSE= 0.043343

Number of Means	2	3	4
Critical Range	0.0698846	0.0836842	0.0918135

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	0.2562	69	6
B	0.1678	69	3
B			
B	0.1372	69	8
C	0.0070	69	B

SAS

---------- COMP=T11E ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 84 MSE= 0.056285

Number of Means	2	3	4	5
Critical Range	0.1850504	0.2220264	0.2439191	0.2594301

Number of Means	6	7	8
Critical Range	0.2713976	0.2811157	0.2892762

Means with the same letter are not significantly different.

SNK Grouping			Mean	N	SITE
	A		-0.2370	13	A
	A				
B	A		-0.3231	13	8
B	A				
B	A	C	-0.4319	13	B
B		C			
B		C	-0.5217	13	3
B		C			
B		C	-0.5253	13	5
B		C			
B		C	-0.5619	13	6
B		C			
B		C	-0.5711	13	9
		C			
		C	-0.6915	13	1

SAS

---------- COMP=T11E ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 120 MSE= 0.054839

Number of Means	2	3	4	5
Critical Range	0.117768	0.1411583	0.1549755	0.1647444

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	-0.2651	31	A
A			
B A	-0.3002	31	8
B			
B	-0.4130	31	B
C	-0.5326	31	3
C			
C	-0.5718	31	6

SAS

---------- COMP=T11E ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 186 MSE= 0.050702

Number of Means	2	3	4
Critical Range	0.079148	0.0947893	0.1040068

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	-0.3908	63	8
B	-0.4746	63	B
B			
C B	-0.4989	63	3
C			
C	-0.5724	63	6

SAS

---------- COMP=TOLU ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 140 MSE= 0.079053

Number of Means	2	3	4	5
Critical Range	0.1715467	0.2055495	0.2256215	0.2398003

Number of Means	6	7	8
Critical Range	0.250727	0.2595813	0.2670143

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	1.1374	21	A
A			
A	1.1238	21	B
A			
A	1.0061	21	6
A			
A	0.9678	21	5
A			
A	0.9279	21	3
A			
A	0.9192	21	8
A			
A	0.9126	21	9
B	0.4798	21	1

SAS

---------- COMP=TOLU ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 270 MSE= 0.092197

Number of Means	2	3	4	5	6	7
Critical Range	0.1246497	0.1492132	0.163671	0.1738793	0.1817284	0.1880855

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	0.9941	46	3
A			
A	0.9870	46	6
A			
A	0.9504	46	5
A			
A	0.9470	46	8
A			
A	0.8499	46	B
A			
A	0.8173	46	9
B	0.5059	46	1

SAS

---------- COMP=MPXY ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 207 MSE= 0.140176

Number of Means	2	3	4	5	6
Critical Range	0.2130788	0.2551486	0.2799308	0.2974369	0.3109054

Number of Means	7	8	9	10
Critical Range	0.321817	0.3309595	0.3388223	0.3457033

Means with the same letter are not significantly different.

SNK Grouping		Mean	N	SITE
	A	0.157	24	5
	A			
B	A	0.021	24	B
B	A			
B	A	0.012	24	7
B	A			
B	A	0.001	24	C
B	A			
B	A	-0.012	24	A
B	A			
B	A	-0.051	24	9
B				
B	C	-0.200	24	D
B	C			
B	C	-0.200	24	4
B	C			
B	C	-0.281	24	2
	C			
	C	-0.392	24	1

SAS

---------- COMP=MPXY ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 216 MSE= 0.17216

Number of Means	2	3	4
Critical Range	0.1353651	0.1620823	0.1778182

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	0.0122	73	B
A			
A	-0.0992	73	5
B	-0.3072	73	9
C	-0.5752	73	1

SAS

---------- COMP=OXYL ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 80 MSE= 0.042746

Number of Means	2	3	4	5	6
Critical Range	0.1411255	0.1693531	0.1860725	0.1979139	0.2070663

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	-0.4792	17	6
A			
B A	-0.6180	17	5
B			
B	-0.6770	17	3
B			
B	-0.6880	17	8
B			
B	-0.7686	17	9
C	-1.0965	17	1

SAS

---------- COMP=HEXA ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 128 MSE= 0.072304

Number of Means	2	3	4	5
Critical Range	0.1309819	0.1569737	0.1723229	0.1831709

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	0.0047	33	A
A			
A	-0.0953	33	B
B	-0.2730	33	3
B			
B	-0.3039	33	6
B			
B	-0.3317	33	8

SAS

---------- COMP=HEXA ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 207 MSE= 0.060907

Number of Means	2	3	4
Critical Range	0.0822421	0.0984798	0.108045

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	-0.2541	70	8
A			
A	-0.2892	70	3
A			
A	-0.3245	70	6
A			
A	-0.3319	70	8

SAS

---------- COMP=TECH ----------

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: LCONC

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 80 MSE= 0.075218

Number of Means	2	3	4	5	6
Critical Range	0.1872045	0.2246486	0.246827	0.2625349	0.2746756

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	SITE
A	-0.6319	17	6
B	-1.2228	17	8
B			
C B	-1.3039	17	5
C B			
C B	-1.3209	17	3
C B			
C B	-1.3882	17	9
C			
C	-1.5179	17	1

APPENDIX A

BRIEF COMPARISON OF THE SI/NJ UATAP AND THE 1988 AND 1989 UATMP STUDIES

(from Section 3.5.1 of Volume III, Part A, of the SI/NJ UATAP report).

1. SI/NJ UATAP (Staten Island/New Jersey Urban Air Toxics Assessment Project)

Sites: 13 ambient air sites for VOCs, 5 sites for metals and B[α]P, and 2 sites for formaldehyde for the outdoor air portion of the study. (Piscataway served as an upwind site for VOCs and formaldehyde; and Highland Park, as an upwind site for metals and B[α]P. Upwind refers to the W to SW wind direction, the predominant wind direction for the project area.) Four indoor and two outdoor sites were used for the 8-month indoor air portion of the study.

Chemicals: 41 chemicals--23 VOCs[31], 16 metals, benzo[α]pyrene, and formaldehyde.

Sampling frequency: 24-h samples every 6th day; October '87 through September '89. (Only data for the period 10/88 through 9/89 have been included in this comparison). CSI sampled daily during certain quarters. Annual averages are arithmetic averages of all samples; for CSI sites, many more samples were collected during some quarters than others.

Collection: For VOCs, NJIT and CSI used Tenax as the sole adsorbent, and NYSDEC used a series of Tenax/Amersorb/carbon in a single tube as the adsorbent. A combination of canisters and periodic simultaneous sampling by the three organizations was used as an indication of accuracy of the sorbent methods, and as a basis for integration of the inter-organizational set of data. For particulate matter and B[α])P, high-volume samplers were used. For formaldehyde, 2,4-dinitrophenylhydrazine-coated (DNPH-coated) silica cartridges were used.

Analysis: For VOCs, NYSDEC and CSI used GC/MS; NJIT used GC/FID/ECD with confirmation by GC/MS. For metals, all organizations used atomic absorption spectrophotometry.

In this tally, m- and p-xylene were counted separately, although they were not distinguished by the analytical methods used.

Organization: Sites were run by three organizations--6 by NYSDEC, 5 by NJDEP, 3 by CSI; each organization had a different lab analyze samples collected at its sites.

Site selection: Residential neighborhood complaints, availability, accessibility, security, absence of known point sources nearby, geographic distribution, proximity to breathing zone, in general conforming to the USEPA air monitoring siting requirements.

Objectives: Characterization of ambient air quality, risk assessment, and source identification. Further detail may be found in the nine objectives stated in Volume II of the SI/NJ UATAP project report.

2. 1988 and 1989 UATMP (Urban Air Toxics Monitoring Program, USEPA)

Sites: 19 sites operated in the 1988 study (9/24/87 through 10/6/88). 14 sites operated in 1989 study (1/22/89 through 1/17/90)--6 sites were the same as in the 1988 study, and 8 sites were new. See tables for site locations.

Chemicals: 38 gaseous organic compounds; and metals, B[α]P, and carbonyl compounds.

Sampling frequency: 24-h samples every 12 days. Annual arithmetic averages are listed in the tables.

Collection: For VOCs, stainless steel canisters. For particulate matter, high-volume filters. For carbonyl compounds, DNPH-coated silica cartridges.

Analysis: GC/MD, with 3 detectors for identification (ECD, PID, FID)[32]; FID for most quantitation, ECD for most halogenated compounds. GC/MS for identification confirmation of GC/MD results.

Organization: A contractor set up the sites. State or local personnel collected samples and sent them to the EPA contractor. The contractor analyzed all samples.

Site selection: OAQPS (Office of Air Quality Planning and Standards) guidelines, with site selection by Regional EPA offices and State offices together.

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[32] GC = gas chromatograph. MD = multi-detector. ECD = electron capture detector. PID = photoionization detector. FID = flame ionization detector. MS = mass spectrometer.

Objective: Screening to help state and local agencies determine if an air toxics problem existed, assess air quality, provide focus for follow-up studies and risk reduction activities.

APPENDIX B
DESCRIPTION OF THE 1988 UATMP SITES

From "Calculation of Cancer Risks from 1988 UATMP Data, " (Lahre, 1990).

Atlanta, Georgia (AT GA)

-- site close to downtown
-- 1/2 mile or so from two freeways
-- adjacent to junk yard that occasionally burns insulated wire and auto engines, etc.
-- adjacent to slightly used parking lot
-- mixed commercial and residential E and N of site, commercial in other directions

Birmingham, Alabama (BH AL)

-- residential site location, across from police and fire department
-- closest major point source is U. S. Steel, within 1/2 mile
-- Koppers coking facility about 4 or 5 miles distant from site

Baton Rouge, Louisiana (BR LA)

-- located near State Capital
-- also site of Louisiana hourly monitoring station
-- several miles south of major petrochemical complex
    ... 2 synthetic organic chemical manufacturers
    ... 1 petroleum refinery
    ... 1 power plant
-- smaller petroleum refinery to NW
-- petroleum product tank farm to west of site
-- major highway within 1/2 mile

Burlington, Vermont (BR VT)

-- site generally commercial in nature
-- site within Burlington city limits
-- site located in municipal parking lot
-- 2 service stations across street
-- several parking decks within one block

Chicago Illinois (CH IL)

-- in Southeast Chicago
-- mixed residential/industrial area with many traffic arterials
-- major steel mill/coke oven within 1/2 mile
-- hazardous waste incinerator nearby
-- garbage landfill within 1/2 mile
-- site location changed during '88 from Carver to Washington High School, but still in same general area of Chicago

Cleveland, Ohio (CL OH)

-- site located within industrial/warehouse area
-- major steel mill/coke oven within 1 mile
-- major traffic arterials nearby
-- some residential areas nearby

Dearborn, Michigan (DB MI)

-- Dearborn is a western suburb of Detroit
-- site located at school
-- primary land use is industrial, changing within 2 miles to residential to the north, east and south
-- Ford Motor assembly, steel and glass plant located 1/2 mile W of monitor
-- the Asphalt Products Co., a slag processing company and Detroit Lime are within 1 mile SW
-- significant railroad activity adjacent to site

Dallas, Texas (DL TX)

-- commercial downtown area, not residential or industrial
-- no major point sources within 1 mile
-- mostly parking lots, minor arterials, commercial buildings immediately adjacent to site

Detroit, Michigan (DT MI)

-- site located in mixed residential, industrial and commercial area
-- dominant influence is area sources
-- site located immediately adjacent to freeway
-- General Motors plant located 3/4 mile N
-- Detroit incinerator located 1/2 mile SW
-- freeway immediately adjacent to site

Houston, Texas (HI TX)

-- site located at a school
-- near heavily industrialized East Houston
-- several miles from Houston Ship Channel
-- heavily automotive traffic in area

Hammond, Indiana (HA IN)

-- site located in industrial park
-- major petroleum tank farm within 1/2 mile to W
-- little immediate traffic, no residences nearby
-- major freeway 1/2 to 3/4 miles away

Jacksonville, Florida (JA FL)

-- site immediately surrounded by residences and city park
-- nearest major traffic artery about 500 feet away
-- Kraft pulp mill within 1 mile to NE
-- oil storage tanks and phosphate storage/loading facilities within 1 mile to N

Louisville, Kentucky (L2 KY)

-- downtown site
-- site at 3-way street intersection below elevated freeway
-- service station 1 block W
-- multi-story parking garage 1 block SW

Lansing, Michigan (LA MI)

-- site located at school
-- primary land use is commercial
-- land use to N and E changes in 2 miles to residential
-- land use in SE, SW and NW is a mixture of residential, commercial and industrial
-- dominant immediate influence at site is area sources
-- within 1/2 mile of site is a heat treating company, 3 GM plants, and a GMC assembly/powerhouse plant
-- a wastewater treatment plant and a steel company are within 1 mile

Midland, Michigan (MD MI)

-- primary immediate land use is commercial
-- adjacent major traffic arterial
-- land use changes to residential within 2 miles to N, NE and NW
-- Dow Chemical is largest source nearby, occupying all of land to SW, S and SE of plant within 1 mile
-- about 1 mile E of site is a metal coating company and a municipal sewage treatment plant

Miami,Florida (MI FL)

-- residential/commercial site
-- site located on rooftop of several story commercial building
-- site across street from baseball stadium and parking lot
-- residential to NW, N and W
-- mixture of warehouses and small shops to NE and S, including bakery, auto repair shops
-- jail for criminally insane to E
-- no major point sources in proximity

Portland, Oregon (P2 OR)

-- site located in Portland's NW industrial area
-- immediate proximity of extensive gasoline storage and transfer facilities
-- nearby railroad switching yard with diesel engines
-- various other sources in general proximity (involving plastics, paints, roofing materials, and "tall oil" combustion)

Port Huron, Michigan (PH MI)

-- site in parking lot of National Guard armory
-- primary immediate land use is residential
-- dominant local source influencing site is area sources
-- land use changes within 1-2 miles to the E, W and NE to industrial
-- small industrial park with 30 small sources about 1/2 mile to E with at least one formaldehyde emitter
-- hospital is 1 mile E of site
-- Canadian refineries and chemical companies 1.5 miles E of site

Sauget, Illinois (SA IL)

-- heavily industrialized area, in East St. Louis
-- Monsanto chemical plant within 500 meters
-- also in proximity are metal processors and a rubber recycler

APPENDIX C

SUMMARY OF POPULATION ANALYSIS

The following is a summary of the population analysis prepared by Marian Olsen for the SI/NJ UATAP.

Summary of the Population Analysis for the SI/NJ UATAP

Anecdotal data suggested that many residents had been so-called Islanders for their entire lifetimes. While it is difficult to verify this, analysis of the 1980 census data indicated the following:

With few exceptions, the population in the communities studied showed a steady increase from 1930 through projections for 2010. (Union County showed a slight decrease in 1980 and 1990, with projected increased in 2000 and 2010.)

In 1980, the data showed that owner- and renter-occupied units occupied 20 or more years by the same person(s) in Richmond, Union, and Middlesex Counties were, respectively, 17.2%, 21.6%, and 24.2%.

The percentage of employees living in the same county as they work ranged from 42% for Richmond County to 72% for Highland Park.

The majority of New Jersey workers in Union and Middlesex Counties spends 21.1 to 23.4 minutes traveling from home to work. In Richmond County, the average time spent commuting one way is 42.9 minutes.

These preliminary data qualitatively suggest that many residents in the study area spend a good part of their time either living in the community or working there. However, it was not possible to determine the percentage of the community that would match the assumptions used in this report.

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